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AVIATION MAINTENANCE MANAGEMENT

SECOND EDITION



HARRY A. KINNISON

TARIQ SIDDIQUI

Aviation Maintenance Management

ABOUT THE AUTHORS

Harry A. Kinnison, Ph.D., worked for the Boeing Company for 20 years, 10 years as a specialist in the Maintenance and Ground Operations Systems Group of the Customer Services Organization. Specifically, he represented Boeing to airlines on the ETOPS (extended range twin-engine operations) program, participated in airline maintenance evaluations, and helped airlines develop reliability programs. He has taught aviation maintenance management courses at Embry-Riddle Aeronautical University in Daytona Beach, Florida. He developed this book because no suitable text for courses such as his existed.

Tariq "Terry" Siddiqui received his degree, Master of Aeronautical Science with specialization in Aviation/Aerospace Safety Systems and Management Specialization, from Embry Riddle Aeronautical University (ERAU). Currently, he is employed as manager of aircraft maintenance at a commercial airline. Terry is also teaching on an adjunct basis at ERAU.

Terry started his aviation career with Pan Am Airlines. He has over 20 years of experience in aviation maintenance, management, project management, environmental regulations, and investigation of incidents and accidents.

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Harry A. Kinnison

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In memory of Najma Begum Siddiqui

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Preface

I started teaching at Embry Riddle approximately 5 years ago. One of the classes that I have taught all these years is Aircraft Maintenance Management. I started using this book for my class. This is the best textbook for the class. It provides the best insights and knowledge about airline management that are available. However, since the publication of the first edition, the airline industry has gone through drastic changes, reorganizations, and adjustments in fleet size and management. There were various changes in the FAA's advisory circulars and methods of compliance. Due to these changes, I humbly presented to the publishers the idea of revamping the book and creating an even better textbook for the aviation student and faculty.

The result is a combination of the original textbook by Harry A. Kinnison, Ph.D., and my amendments. The purpose of this textbook is to provide insight and perspective to the aviation student on the aviation industry, airline management, aircraft maintenance fundamentals, maintenance planning, FAA regulations, development of maintenance programs, aviation safety, and the steps needed to help improve them.

I would like to thank my professors at Embry Riddle Aeronautical University for their encouragement and support; especially former director of academic support (DAS), Leo Haigley, of the Miami campus. The Pan Am airline family taught me that the airline industry is both beautiful and heartbreaking. I also thank my family for their love and support.

TARIQ SIDDIQUI
Miami Lakes, Florida

Preface to the First Edition

I never read the "begat chapters" in the front of books until I became a writer myself. I wanted to see just what it took to write a book and was quite surprised to say the least. Although only one name appears on the book as "author" it takes many, many people (as well as numerous books, articles, and experiences) to produce the final, usable manuscript. This textbook is no exception.

The project began many years ago when the author was in Electronics School at Keesler Air Force Base, Mississippi, where instructors have long since become nameless and faceless, but their efforts were not in vain. They planted the seeds for my future harvest. Next, I spent several years as an Airborne Navigation Equipment Repairman in Wiesbaden, Germany. Line, hangar, and shop maintenance activities were drilled into me by a Sergeant Gottlieb R. Schneider, who taught me the art and science of troubleshooting as well. My coworkers—Ron Wright, Tom Cummins, and Gene Hackett—helped immensely in my training. They taught me radar systems and I taught them navigation systems. We all gained from that.

After receiving a Bachelor of Science degree in Electrical Engineering, I spent several years on an Air Force Radar Site as a maintenance officer. Then it was on to civilian employment with the FAA and The Boeing Company. It was the latter experience—about 20 years worth—where I encountered the regulatory, management, and administrative aspects of the maintenance field. The people I worked with, and there were many, all contributed something to my knowledge and understanding of the maintenance field, which I have set forth in this book. Those most directly involved with my education at that level were Isaac Zere, Lloyd Wilson, and Lee McEachron, team leaders on many of my visits to airlines. Others who contributed in various ways were

Peter Ansdell	Naseem Mahmood
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Special thanks should go to those at Embry-Riddle Aeronautical University (ERAU) Extended Campus. They not only hired me to teach the subject of this book, they allowed me to use my own materials. This book is an outgrowth of that original series of lectures. In addition, the staff at the Seattle Center of ERAU not only provided assistance on contacts and information when needed, several of them read and critiqued the manuscript. These people include Dr. Richard Glover, Center Director of Operations; Tom Glover, Center Faculty Chair and Safety Professor; and Dr. Ernie Damier, National Faculty Advisor, ERAU who read the manuscript not once but twice. And last but not least, Terry Cobb, Course Monitor for the Aviation Maintenance Management course for the entire Extended Campus. Their comments and suggestions were quite helpful.

Several airline people have also assisted in this endeavor. First are the employees of foreign and domestic airlines—too numerous to mention by name—who were the key figures of my airline technical visits which addressed various maintenance management topics. Special recognition goes to Dr. Karl Pape, Maintenance Supervisor at United Airlines, retired, now Associate Regional Academic Dean, ERAU Western Region, who read the first draft of the manuscript and provided much information and guidance. Thanks, also, to Les Ross, Aircraft Maintenance Supervisor, United Parcel Service, Ontario, California, for taking the time to discuss his organization's operation with me and for allowing me to measure the inside of one of his package freighters.

Additional information and discussion came from the Air Transport Association (ATA) of America: Victoria Day, Director, Publications and Technical Communications, and Rick Anderson, Director of Maintenance and Material. At the FAA, Northwest Region, Tom Newcomb, Aircraft Evaluation Group (AEG) and Kevin Mullin, Manufacturing Inspection District Office (MIDO), provided copies of FAA certificates to use as illustrations. The Boeing Company's Renton library allowed me to use their facilities for some basic literature research.

As with all such efforts with acknowledgments, this one has probably missed a good many names, and I sincerely want to apologize to those people. It should be understood that their efforts and contributions were just as important and just as appreciated as any of those mentioned.

Although many people have contributed and assisted in the production of this book, it is appropriate that the person whose name appears on the byline should take full credit for any errors or omissions within the text. For those inaccuracies, I humbly apologize.

Harry A. Kinnison, Ph.D.
Kent, Washington

Introduction

Aviation in the Beginning

The 24th International Air Transportation Conference was held in Louisville, Kentucky, June 5–7, 1996. One of the many evening activities available to the attendees was a tour of the main facilities of United Parcel Service (UPS) at the Louisville International Airport. About 15 people signed up for the tour. After watching the young college students hustle around unloading, sorting, and loading the packages and listening to the tour guide's explanation of this unique distribution system, we were escorted out to the flight line parking ramp to look at airplanes. Our tour guide led us up the portable air stairs into the huge chasm that was the Boeing 747 freighter. She stood there for a moment, silently looking around at the huge, empty airframe. Her tour guests did the same. Finally she spoke.

"The cargo area inside this 747 freighter is longer than the Wright brothers' first flight," she said with some pride. "And the deck we are standing on is higher off the ground than that first flight was."[1]

Certainly aviation has come a long way since that windy December day in 1903 when Wilbur and Orville Wright made history at Kill Devil Hills near Kitty Hawk, North Carolina. Likewise, the field of aviation maintenance has made great strides. The early days of aviation were filled with experimenters, daredevils, and showoffs called barnstormers for obvious reasons. With their stunt flying and other antics, they were trying to prove to the public the safety and utility of this newfangled machine, the airplane. Selling "rides" to the curious became a side business. At first, aviation was more entertainment than transportation, but that soon changed. Just as modern jet liners boast dimensions greater than those of the first flight itself, the technological advances in aviation over the ensuing 100 years are equally impressive. And the approach to the maintenance of these complex vehicles has kept pace. Today, aviation is

[1]The Wright Brothers' first flight went 120 ft in about 12 seconds and reached an altitude of less than 10 ft. The Boeing 747 freighter is approximately 150 ft inside and the deck is 16 ft off the ground (unloaded).

the safest mode of transport in the world.[2] A considerable part of that safety record can be attributed to the efforts of mechanics, technicians, engineers, and managers who work in the field of aviation maintenance.

A Brief History of Aviation[3]

Aviation began as a pastime, a sport, a whimsy. Like so many new and "past-the-edge-of-reason" inventions, flying was considered a fanatic's sport. It would not last, people said. It is unnatural. "If God had meant for man to fly He would have given us wings." Well, in a sense He has given us wings.

Through the efforts of people like the Joseph and Jacques Montgofier, Octave Chanute, Otto Lilienthal, Samuel P. Langley, Glenn Curtis, Orville and Wilbur Wright, and many others, we have "earned our wings." We can fly.

All these men devoted time, thought, and fortunes to resolving the problems of manned flight. Even men famous for other great works—Leonardo da Vinci, George Cayley, Hiram Maxim, Thomas Edison, et al.—made contributions. But it was two inquisitive bicycle makers and repairers in Dayton, Ohio, who brought man's longtime longings to "fly like the birds" to fruition. Much work was done by many people, but it was Orville and Wilbur Wright who are credited with the first controlled, manned flight.[4] Although they covered a distance of only 120 feet and got no higher than 10 feet off the ground, their first flight was the result of a concentrated effort to master that which others had only courted.[5] Many experimenters in aviation—some of them with more academic or engineering credentials than the Wrights—had failed to meet the challenge. And some of them, unfortunately, lost their lives in the attempt.

The Wright Brothers were early systems engineers. They insisted that certain obstacles be surmounted, certain ideas be proven regarding manned flight before they would opt to get into their "airplane." An idea other experimenters should have heeded. Although Otto Lilienthal had done considerable work in aerodynamics and had published lift tables for others to use, the Wright Brothers found these tables to be in error and proceeded to make their own corrections. They built a small wind tunnel, made a few tests, and developed their own tables.

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[2]In 1999, there were 17 commercial aviation deaths for 569 million miles flown. Or 0.003 deaths per 100 million miles. Contrast that with other transportation modes for that same year. Automobile: 20,763 deaths or 0.83 per 100 million miles; railroad: 14 deaths or 0.10 per 100 million miles; transit bus: 1 death or 0.005 per 100 million miles.

[3]Ray Bradbury probably wrote the shortest history of aviation in his short story "Icarus Montgofier Wright." It is recommended reading for aviation students. See Ray Bradbury, "S is for Space," Bantam Books, NY, 1970. Also available in other anthologies.

[4]There were disputes as to who was actually first, but the credit is generally awarded to the Wright Brothers.

[5]The Wright Brothers made four flights in all that first day (December 17, 1903). The fourth one was up for 59 seconds and covered a distance of 852 ft.

Some of the first attempts to fly by the Wright Brothers involved essentially flying a kite.[6] They tied ropes to their craft, released it into the high winds of Kitty Hawk Beach and, by tugging on these ropes and thereby twisting the wing surfaces, they assured themselves that this rig, this airplane, could not only fly with the wind strategically directed over and under its wings, but its direction of flight could be altered and controlled by a human operator. Then and only then would they climb into the contraption themselves. Satisfied that they could control their glider, Orville and Wilbur Wright set out to find an engine with the right power-to-weight ratio to successfully power their invention. They soon found that there was no such engine available, so they designed their own with optimum specifications for flight.[7]

Next, the brothers needed a propeller. They thought the ship-building industry would be the most likely place to solve this problem, but they were disappointed. The shipbuilders told them that, for the most part, props were designed on a trial and error basis—there was no exact science. Undaunted by this, the Wrights designed and built their own propeller. They did not have time to use the trial and error method to develop a suitable propeller, so the Wrights used their newly developed aerodynamic tables to design the ideal device. And they were successful.

Although many others over the next few years after 1903 would make great advances in aviation and improve the performance, safety, and convenience of manned flight, it was the Wright Brothers' systematic process, their effort to design the whole system as a usable device (usable by people), that made the airplane a viable and important invention. The next step would be to convince the public of its value.

Promotion of Flying

Flying was for daredevils, at first. Numerous pilots showed off their skills and their new toys by performing for crowds—acrobatic stunts and other daring maneuvers—and often by selling joy rides to brave onlookers at three to five dollars apiece. But this showmanship soon gave way to those who wanted to see a more practical use for the airplane, and delivery of the U.S. Mail was considered the first down-to-earth application.

The first airline in the United States to carry passengers on a regular schedule was the St. Petersburg to Tampa Airboat Line, which started operations in January 1914 between the two cities, but they carried only one passenger at a time. Service ended after 3 months, however, due to the end of the tourist season and the onset of World War I.

[6]To this day, old-timers in the Seattle area refer to The Boeing Company as "The Kite Factory."

[7]The Wrights had already designed and built a gasoline engine to run the drill press and lathe in their shop.

After World War I, airmail service began and dominated the aviation industry (such as it was). Entrepreneurs set up airline operations for that specific purpose. Occasionally, a passenger would ride along, sitting atop the mailbags if there was room. But later, additional seats were added to airplanes and passengers became more frequent sources of revenue. The U.S. government encouraged operators to use bigger planes and carry more passengers so they wouldn't have to rely solely on government mail contracts to stay in business.

Navigational aids were nonexistent in the early days of flying, and flyers used railroads, highways, and common automobile road maps to find their way. Nor could the first flyers fly at night until someone decided to light bonfires along the desired route to show the way. Weather conditions were received by observation and by telephone until air-to-ground radio came into use in the late 1920s. By the end of 1929, however, there were over 10,000 miles of lighted airways, 275 lighted airports, and 1352 rotating beacons.

While development of air travel in the United States lagged behind that of Europe after World War I, the opposite was true after World War II. Airplanes got bigger and flew "higher, faster, farther," and in 1958, we were introduced to the "jet age" with the Boeing 707, followed by the Douglas DC-8, and the Lockheed L1011. Navigational aids both on the ground and in the aircraft (later in earth-orbiting satellites) revolutionized the industry along with drastic improvements in aircraft and engine technology. Today, 100 years after the Wright Brothers' historic first flight, aviation has come of age. People can fly—and in immense comfort and safety.

Early Aviation Maintenance

In those early days of aviation, maintenance was performed "as necessary" and the machines often required several hours of maintenance time for every hour of flying time. Major maintenance activities consisted of overhauling nearly everything on the aircraft on a periodic basis. Even though the airplanes and their systems were quite simple at first, maintenance carried out in this manner became quite expensive. With the increasing complexity of the aircraft and their onboard systems over the following years, that expense rose accordingly.

The modern approach to maintenance is more sophisticated. The aircraft are designed for safety, airworthiness, and maintainability, and a detailed maintenance program is developed along with every new model aircraft or derivative of an existing model. This initial maintenance program can then be tailored by each airline to accommodate the nature of their individual operations. This ensures continued airworthy operation under any circumstances. Backing up that individual undertaking are the ongoing efforts by manufacturers, airlines, and regulators to improve design and maintenance techniques and to keep the aviation industry on the leading edge.

Of course, such a sophisticated approach to maintenance requires sophisticated management, both in development of the initial maintenance program

and at the airlines to accomplish all that is necessary to maintain that superior record of safety mentioned earlier.

Technical Management

It takes several disciplines to properly conduct the maintenance activities at an airline: (*a*) Maintenance: the hands-on, "nuts and bolts" labor required to accomplish the physical work; (*b*) Engineering: the design, analysis, and technical assistance required to support maintenance work; (*c*) Management: the organization, control, and administration of the many facets of the maintenance operation; (*d*) Production Planning: the planning concepts and organization activity to support maintenance effectively to plan all required work; (*e*) Logistics: understanding the aircraft inventory scope, realistic, futuristic, to meet the continuous demand for parts required for a successful maintenance operation; (*f*) Technical Training: to meet the demands of all required maintenance training effectively.

This book will be somewhat unique: it will cover all of these topics—maintenance, engineering, management—but in a more cursory manner than the individual courses would address them. We will be looking at the "big picture." We will be looking at maintenance, engineering, and management as an integrated whole. We will examine how all these disciplines combine and coordinate to accomplish the goals and objectives of airline maintenance. While some of the details of these three topics may be left out of the discussion, this text will emphasize the coordination of these three disciplines required to achieve the desired results.

The book is written for those who have background and experience in aviation maintenance and who wish to move into lower and middle level management positions within the airline's maintenance and engineering section. Those managers without a technical background, of course, can still benefit from the book by expanding their horizons to the technical realm. Mechanics and technicians who desire to move into the management of maintenance will gain valuable information about the overall operation of the maintenance and engineering unit.

Aviation Industry Interaction

The aviation industry is unlike any other transportation mode. In aviation, we cannot pull off the road and wait for a tow truck whenever we a have problem. We are required by the Federal Aviation Administration (FAA) regulations to meet all maintenance requirements before releasing a vehicle into service. This is often not the case with other commercial transport modes. In aviation we have a relationship with gravity that differs considerably from that of any other transportation mode. We have problems with extremes of temperature (e.g., very hot engines and very cold air at high altitude).

In aviation we have an interactive group of people determined to make aviation a safe, efficient, and pleasurable activity. Aircraft manufacturers, makers of onboard equipment and systems, airline operators, industry trade associations, regulatory authorities, flight crews, and maintenance personnel all work together to ensure aviation safety from the design of the aircraft and its systems, through the development of maintenance programs and modifications, and continuing throughout the lifetime of the aircraft.

Working together and providing feedback at all levels and in all directions between and among these factions allows the aviation industry to provide continually improved systems and services to the public. The aviation industry was one of the first to employ this "continuous quality improvement" concept even before that catch phrase became popular.

Layout of the Book

This book has five parts. Part I contains information related to the basic philosophy of maintenance, as well as fundamental requirements for an effective maintenance and engineering operation. Part I ends with the discussion of the organizational structure of a typical midsized airline. Parts II through IV give the particulars of each functional unit within that structure. Part V, Appendixes, provides information essential to various aspects of maintenance and engineering activities. These should be read and understood as background or support material for the rest of the book.

Part I: Fundamentals of Maintenance

Chapter 1, Why We Have to Do Maintenance, discusses some basic theory about designing and building complex equipment and why we cannot build perfect systems. This chapter also covers common failure patterns and failure rates of components and systems as well as methods for minimizing service interruptions such as line replaceable units (LRUs), redundant systems, and minimum dispatch requirements (MEL). It establishes the basic reasons why maintenance has to be planned, organized, and systematic.

Chapter 2, Development of Maintenance Programs, discusses the process of creating a maintenance program for a given model aircraft and how that program can be changed by an operator, as necessary, after entry into service. The chapter also defines basic maintenance intervals.

Chapter 3, Definitions, Goals, and Objectives, defines maintenance and a few other selected terms including goals and objectives. The chapter then establishes specific goals and objectives for maintenance. The text discusses how these were developed and what they mean to airline maintenance management.

Chapter 4, Aviation Industry Certification Requirements, addresses the Federal Aviation Administrations requirements for aircraft design and manufacture and the federal requirements with which a transportation company must comply to become an airline and operate the aircraft in commercial service.

Chapter 5, Documentation for Maintenance, discusses the manuals supplied by the manufacturers and vendors with the aircraft, the documentation required to be written by the airline for defining maintenance activities, and the regulations and advisories issued by the Federal Aviation Administration and other regulatory authorities relative to that maintenance.

Chapter 6, Requirements for a Maintenance Program, covers the regulatory requirements for a maintenance program outlined in FAA Advisory Circular, AC-120-16E and other FAA requirements: scheduled and unscheduled maintenance, inspection, overhaul, and recordkeeping. The chapter also discusses additional management requirements deemed necessary by airline managers: requirements for engineering, reliability, quality assurance, computer support, and training, for example.

Chapter 7, The Maintenance and Engineering Organization, covers the organizational structure of the maintenance and engineering function of a typical, midsized airline based on the requirements identified in Chap. 6. Variations of this structure for large and small airlines as well as operators with multiple maintenance bases and those who outsource some or all of the major maintenance work are also discussed.

Part II: Technical Services

Chapter 8, Engineering, covers the duties and responsibilities of the technical experts of the maintenance organization. This includes development of the airline's maintenance program from the airframe manufacturer's data and creation of the policies and procedures that govern the execution of that program. Engineering also provides assistance to maintenance for the solution of difficult problems and performs investigation of maintenance problems noted by the reliability program, as well as problems brought up by mechanics or by personnel from the quality control and quality assurance organization.

Chapter 9, Production Planning and Control, discusses the organization and workings of the department that is at the center of all maintenance activity. Production planning and control (PP&C) is responsible for all maintenance activities performed on the unit's aircraft. Duties and responsibilities of PP&C include forecasting future maintenance requirements and activities, planning and scheduling major checks for the current operational situation, and exercising control of the maintenance in progress. They are responsible for ensuring that personnel, parts, facilities, and special tools and test equipment are available for each planned maintenance event and that the activity is accomplished successfully and on time.

Chapter 10, Technical Publications, discusses the publication and distribution of all documentation required by the various maintenance and engineering departments. This includes documents provided by manufacturers, vendors, and regulatory authorities as well as those documents produced by the airline.

Chapter 11, Technical Training, covers the training requirements of mechanics, technicians, quality control (QC) inspectors, and quality assurance (QA) auditors.

The chapter also discusses training conducted by the airline as well as that done by outside sources. The technical training organization is also required by the FAA to keep records of all training accomplished by each employee.

Part III: Aircraft Management, Maintenance, and Material Support

Chapter 12 will show the aircraft maintenance management, structure, role of management in aviation, coordinated activities, front line management their responsibilities, upkeep of industry trends, new development in aviation management, and management concerns in aircraft maintenance.

Chapter 13, Line Maintenance (on-Aircraft), discusses the activities of the line maintenance units that are responsible for maintenance and servicing on all aircraft in service. This includes maintenance activities at the home base, at outstations where the airline performs regular stops, and the organization and operation of a maintenance control center, the unit responsible for coordinating maintenance for all in-service aircraft.

Chapter 14, Hangar Maintenance (on-Aircraft), discusses the unit that is involved with maintenance activity on out-of-service aircraft (i.e., aircraft not currently on the flight schedule). The hangar group handles all major maintenance activities including major modifications. Both line and hangar maintenance are supported by the ground support equipment (GSE) unit that provides power units, work stands, and various other equipment and facilities for the efficient production of maintenance and servicing. Maintenance Overhaul Shops (off-Aircraft) discusses the organizations that perform maintenance on systems and components that have been removed from the aircraft during line or hangar maintenance activities. These shops are sometimes called back shops, and include avionics, mechanical, and hydraulic systems and various other specialty shops. They may also include third-party maintenance activities. The organizations of these shops as well as their work and data collection efforts are discussed.

Chapter 15, Material Support, discusses the functions and processes of purchasing, issuing, inventory control, loaner and bogus parts, and storing parts and supplies needed for the maintenance operation. Material establishes usage rates and reorder points to ensure adequate stock is on hand at all times. Material is also responsible for processing defective units through maintenance and for handling warranty claims on equipment.

Part IV: Oversight Functions

Chapter 16, Quality Assurance, covers one of the primary oversight functions an airline needs to ensure top operation. Quality assurance (QA) is responsible for setting maintenance standards at the airline and also serves as M&E's point of contact with the regulatory authority. QA also performs yearly audits of all maintenance and engineering functions, including outside suppliers and contractors, to ensure compliance with airline and regulatory requirements.

Chapter 17, Quality Control, discusses the duties and responsibilities of those inspectors who provide direct oversight of the performance of maintenance actions. While QA looks at the overall compliance to rules and regulations, QC looks at the day-to-day work activities for compliance with good maintenance practices and procedures. The QC organization is also responsible for conducting nondestructive test and inspection activities and for the calibration of tools and test equipment.

Chapter 18, Reliability, discusses types of reliability and the concept of a reliability program to monitor the effectiveness of the airline's maintenance activity. Data collection on maintenance actions, such as failures, removals, etc., is monitored for trends. Investigation is made into possible problem areas so that corrective action can be implemented. Follow-up activities of reliability determine the effectiveness of that corrective action and the need (if any) for further action.

Chapter 19, Maintenance Safety, discusses the safety programs of the airline as they relate to maintenance and engineering. This includes smoking regulations, fire detection and prevention, fall protection, handling of hazardous material, etc. The chapter also discusses the material safety data sheets (MSDS) and the "right to know" program to alert workers to hazards.

Part V: Appendixes

Appendix A, Systems Engineering, discusses the concept of systems engineering and how it applies to maintenance and engineering in aviation. The text includes discussion of various system engineering terms, such as internal and external components, inputs and outputs, system boundaries, and the changing of system boundaries for the sake of analysis. It also discusses the difference between the systems approach and the systematic approach.

Appendix B, Human Factors in Maintenance, discusses the application of human factors in the maintenance field. Since human beings constantly interface with the complex aviation equipment, those humans should be considered as part of the system when it is designed. This appendix discusses human factors in general and then discusses human factors as they relate to systems engineering. The appendix ends with a discussion of human factors activities at the manufacturer and airline levels.

Appendix C, The Art and Science of Troubleshooting, discusses one of the fundamentals of a maintenance activity that is difficult and elusive. Troubleshooting requires a certain amount of experience for one to blossom fully in the art, but there are some basic concepts one should understand first. This appendix provides the fundamentals of the troubleshooting process, which can be used by maintenance mechanics and technicians, by engineering personnel, and by management to locate and pinpoint problems.

Appendix D, Investigation of Reliability Alerts, provides detailed information on how engineering would go about investigating maintenance problems identified by the reliability program. It is an extension of the troubleshooting process.

While mechanics look at a specific system and its interfacing equipment, the engineer must look beyond the particular electrical, electronic, or mechanical system and include the entire aviation environment, if necessary, in his or her analysis of a problem. This appendix consists of a cross-functional chart showing the interaction of M&E organizations during the process of these investigations and a series of flow charts to guide the investigator through the process of determining the specific problem area.

Appendix E, Extended Range Operations (ETOPS), discusses the 60-minute rule for two-engine airplanes (FAR 121.161) and provides some historical background on the development of ETOPS. Requirements a carrier must meet to obtain FAA permission to deviate from the 60-minute rule (i.e., to fly ETOPS) are also covered.

Appendix F, Glossary, is a list of terms and abbreviations used throughout the book.

Part

I

Fundamentals of Maintenance

"... maintenance is a science since its execution relies, sooner or later, on most or all of the sciences. It is an art because seemingly identical problems regularly demand and receive varying approaches and actions and because some managers, foremen, and mechanics display greater aptitude for it than others show or even attain. It is above all a philosophy because it is a discipline that can be applied intensively, modestly, or not at all, depending upon a wide range of variables that frequently transcend more immediate and obvious solutions."

LINDLEY R. HIGGINS
Maintenance Engineering Handbook;
McGraw-Hill, NY, 1990.

These opening chapters contain basic information related to the aviation maintenance field and should be considered background for the maintenance management effort. Chapter 1 begins with a discussion of the fundamental reasons why we have to do maintenance in the first place. After all, our skills and techniques have improved immensely over the 100-year history of flight, but we haven't quite reached total perfection. And, considering the number of components on a modern aircraft, we realize early on that maintenance is a complex, ongoing process. For that reason, we need to approach it systematically.

We need a well-thought-out program to address the diverse activities we will encounter in this endeavor, so in Chap. 2 we will study the industry procedures for developing an initial maintenance program. We will discuss the various maintenance check packages (the 48-hour and transit check, the monthly "A" check, the yearly "C" check, etc.)

used to implement the maintenance tasks. We then address the ongoing process of adjusting that program during the lifetime of the equipment. In Chap. 3, we establish the goals and objectives for an airline maintenance program that will serve the real-life operation.

Chapter 4 discusses the extensive certification requirements levied on the aviation industry from the original design of the vehicle to the establishment of commercial operators and the people who run them. The documentation for the aircraft, its operation, and its maintenance, is discussed in Chap. 5 and includes the documents produced by the equipment manufacturers, by the regulatory authorities, and by the airline itself.

Chapter 6 will identify those activities required by the FAA to accomplish maintenance as well as those additional requirements deemed necessary by operators to coordinate and implement an effective maintenance and engineering program. Chapter 7 defines a maintenance and engineering (M&E) organization for a typical midsized airline. Variations for larger and smaller airlines will also be discussed. Part I, then, can serve as background to the remainder of the book and can, if desired, be used as the basis for a first or introductory course on the subject of aviation maintenance management.

Chapter

1

Why We Have to Do Maintenance

Introduction

Why do we have to do maintenance? It is simple: "The maintenance of an aircraft provides assurance of flight safety, reliability, and airworthiness." The aircraft maintenance department is responsible for accomplishing all maintenance tasks as per the aircraft manufacturer and the company's requirements. The goal is a safe, reliable, and airworthy aircraft.

The aircraft maintenance department provides maintenance and preventive maintenance to ensure reliability, which translates into aircraft availability. These functions do not preclude a random failure or degradation of any part or system, but routine maintenance and checks will keep these from happening and keep the aircraft in good flying condition.

Thermodynamics Revisited

Nearly all engineering students have to take a course in thermodynamics in their undergraduate years. To some students, aerodynamicists and power plant engineers for example, thermodynamics is a major requirement for graduation. Others, such as electrical engineers for instance, take the course as a necessary requirement for graduation. Of course, thermodynamics and numerous other courses are "required" for all engineers because these courses apply to the various theories of science and engineering that must be understood to effectively apply the "college learning" to the real world. After all, that is what engineering is all about—bridging the gap between theory and reality.

There is one concept in thermodynamics that often puzzles students. That concept is labeled *entropy*. The academic experts in the thermodynamics field got together one day (as one thermo professor explained) to create a classical thermodynamic equation describing all the energy of a system—any system. When they finished, they had an equation of more than several terms; and all

but one of these terms were easily explainable. They identified the terms for heat energy, potential energy, kinetic energy, etc., but one term remained. They were puzzled about the meaning of this term. They knew they had done the work correctly; the term had to represent energy. So, after considerable pondering by these experts, the mysterious term was dubbed "unavailable energy"—energy that is unavailable for use. This explanation satisfied the basic law of thermodynamics that energy can neither be created nor destroyed; it can only be transformed. And it helped to validate their equation.

Let us shed a little more light on this. Energy is applied to create a system by manipulating, processing, and organizing various elements of the universe. More energy is applied to make the system do its prescribed job. And whenever the system is operated, the sum total of its output energy is less than the total energy input. While some of this can be attributed to heat loss through friction and other similar, traceable actions, there is still an imbalance of energy. Defining entropy as the "unavailable energy" of a system rectifies that imbalance.

The late Dr. Isaac Asimov, biophysicist and prolific writer of science fact and science fiction,[1] had the unique ability to explain the most difficult science to the layperson in simple, understandable terms. Dr. Asimov says that if you want to understand the concept of entropy in practical terms, think of it as the difference between the theoretically perfect system you have on the drawing board and the actual, physical system you have in hand. In other words, we can design perfect systems on paper, but we cannot build perfect systems in the real world. The difference between that which we design and that which we can build constitutes the natural entropy of the system.

A Saw Blade Has Width

This concept of entropy, or unavailable energy, can be illustrated by a simple example. Mathematically, it is possible to take a half of a number repeatedly forever. That is, half of one is 1/2; half of that is 1/4, half of that is 1/8, and so on to infinity. Although the resulting number is smaller and smaller each time you divide, you can continue the process as long as you can stand to do so, and you will never reach the end.

Now, take a piece of wood about 2 feet long (a 2 × 4 will do) and a crosscut saw. Cut the board in half (on the short dimension). Then take one of the pieces and cut that in half. You can continue this until you reach a point where you can no longer hold the board to saw it. But, even if you could find some way to hold it while you sawed, you would soon reach a point where the piece you have left to cut is thinner than the saw blade itself. When (if) you saw it one more time, there will be nothing left at all—nothing but the pile of sawdust on the floor. The number of cuts made will be far less than the infinite number of times that you divided the number by two in theory.

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[1]Dr. Asimov wrote over 400 books during his lifetime.

The fact that the saw blade has width and that the act of sawing creates a kerf in the wood wider than the saw blade itself, constitutes the entropy of this system. And no matter how thin you make the saw blade, the fact that it has width will limit the number of cuts that can be made. Even a laser beam has width. This is a rather simple example, but you can see that the real world is not the same as the theoretical one that scientists and some engineers live in. Nothing is perfect.

The Role of the Engineer

The design of systems or components is not only limited by the imperfections of the physical world (i.e., the "natural entropy" of the system), it is also limited by a number of other constraints which we could refer to as "man-made entropy." A design engineer may be limited from making the perfect design by the technology or the state of the art within any facet of the design effort. He or she may be limited by ability or technique; or, more often than not, the designer may be limited by economics; i.e., there just is not enough money to build that nearly perfect system that is on the drawing board or in the designer's mind. Although the designer is limited by many factors, in the tradition of good engineering practice, the designer is obliged to build the best system possible within the constraints given.

Another common situation in design occurs when the designer has produced what he or she believes is the optimum system when the boss, who is responsible for budget asks, "How much will it cost to build this?" The designer has meticulously calculated that these widgets can be mass produced for $1200 each. "Great," says the boss. "Now redesign it so we can build it for under a thousand dollars." That means redesign, usually with reduced tolerances, cheaper materials, and, unfortunately, more entropy. More entropy sometimes translates into more maintenance required. The design engineer's primary concern, then, is to minimize (not eliminate) the entropy of the system he or she is designing while staying within the required constraints.

The Role of the Mechanic

The mechanic [aircraft maintenance technician (AMT), repairer, or maintainer], on the other hand, has a different problem. Let us, once again, refer to the field of thermodynamics. One important point to understand is that entropy not only exists in every system, but that the entropy of a system is always increasing. That means that the designed-in level of perfection (imperfection?) will not be permanent. Some components or systems will deteriorate from use, and some will deteriorate from lack of use (time or environment related). Misuse by an operator or user may also cause some premature deterioration or degradation of the system or even outright damage. This deterioration or degradation of the system represents an increase in the total entropy of the system. Therefore, while the engineer's job is to minimize the

entropy of a system during design, the mechanic's job is to combat the natural, continual increase in the entropy of the system during its operational lifetime.

To summarize, it is the engineer's responsibility to design the system with as high degree of perfection (low entropy) as possible within reasonable limits. The mechanic's responsibility is to remove and replace parts, troubleshoot systems, isolate faults in systems by following the fault isolation manual (FIM, discussed in Chap. 5), and restore systems for their intended use.

Two Types of Maintenance

Figure 1-1 is a graph showing the level of perfection of a typical system. One hundred percent perfection is at the very top of the y-axis. The x-axis depicts time. There are no numbers on the scales on either axis since actual values have no meaning in this theoretical discussion. The left end of the curve shows the level of perfection attained by the designers of our real world system. Note that the curve begins to turn downward with time. This is a representation of the natural increase in entropy of the system—the natural

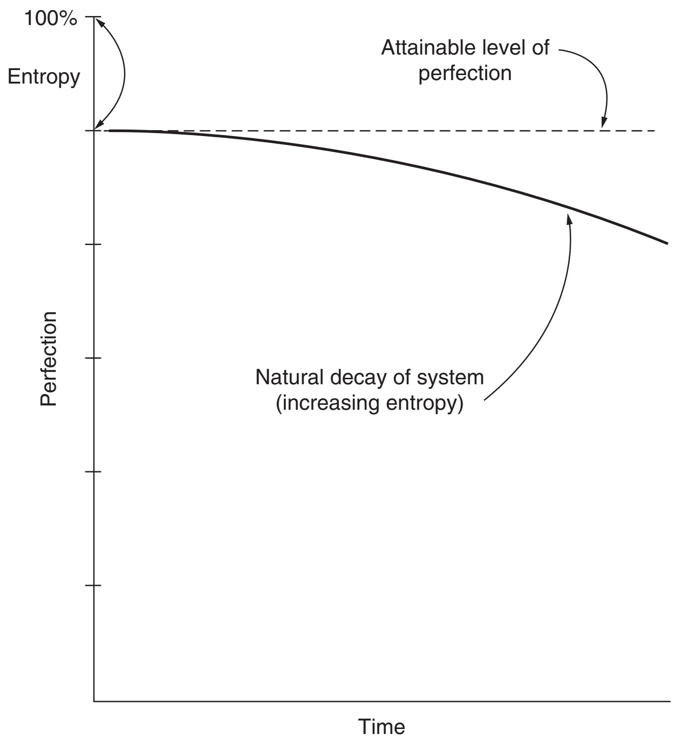


Figure 1-1 The difference between theory and practice.

deterioration of the system—over time. When the system deteriorates to some lower (arbitrarily set) level of perfection, we perform some corrective action: adjusting, tweaking, servicing, or some other form of maintenance to restore the system to its designed-in level of perfection. That is, we reduce the entropy to its original level. This is called *preventive maintenance* and is usually performed at regular intervals. This is done to prevent deterioration of the system to an unusable level and to keep it in operational condition. It is sometimes referred to as *scheduled maintenance*. This schedule could be daily, every flight, every 200 flight hours, or every 100 cycles (a cycle is a takeoff and a landing).

Figure 1-2 shows the system restored to its normal level (curves a and b). There are times, of course, when the system deteriorates rather rapidly in service to a low level of perfection (curve c). At other times the system breaks down completely (curve d). In these cases, the maintenance actions necessary to restore the system are more definitive, often requiring extensive testing, troubleshooting, adjusting, and, very often, the replacement, restoration, or complete overhaul of parts or subsystems. Since these breakdowns occur at various, unpredictable intervals, the maintenance actions employed to correct the problem are referred to as *unscheduled maintenance*.

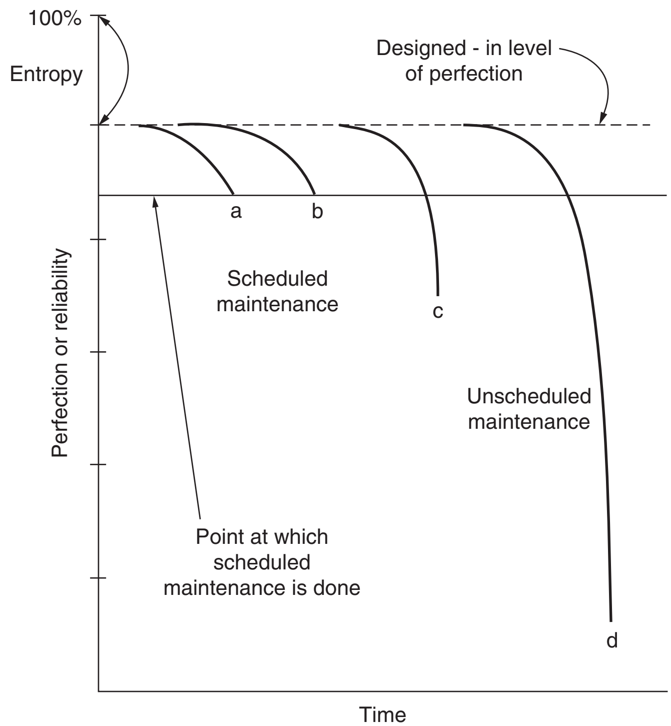


Figure 1-2 Restoration of system perfection.

Reliability

The level of perfection we have been talking about can also be referred to as the reliability of the system. The designed-in level of perfection is known as the inherent reliability of that system. This is as good as the system gets during real world operation. No amount of maintenance can increase system reliability any higher than this inherent level. However, it is desirable for the operator to maintain this level of reliability (or this level of perfection) at all times. We will discuss reliability and maintenance in more detail in Chaps. 13, 14, and 18. But there is one more important point to cover—redesign of the equipment.

Redesign

Figure 1-3 shows the original curve of our theoretical system, curve A. The dashed line shows the system's original level of perfection. Our system, however, has now been redesigned to a higher level of perfection; that is, a higher level of reliability with a corresponding decrease in total entropy. During this redesign, new components, new materials, or new techniques may have been used to reduce the natural entropy of the system. In some cases, a reduction in man-

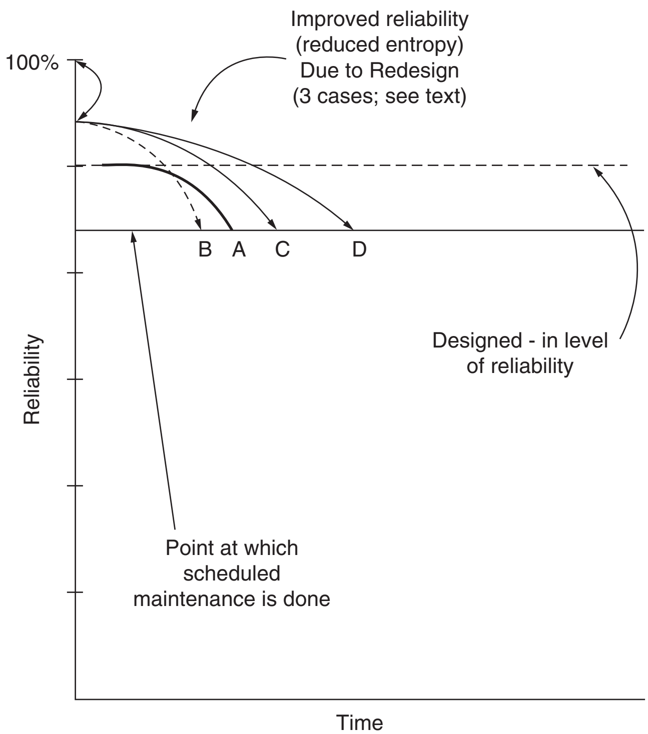


Figure 1-3 Effects of redesign on system reliability.

made entropy may result because the designer applied tighter tolerances, attained improved design skills, or changed the design philosophy.

Although the designers have reduced the entropy of the system, the system will still deteriorate. It is quite possible that the rate of deterioration will change from the original design depending upon numerous factors; thus, the slope of the curve may increase, decrease, or stay the same. Whichever is the case, the maintenance requirements of the system could be affected in some way.

If the decay is steeper, as in (B) in Fig. 1-3, the point at which preventive maintenance needs to be performed might occur sooner, and the interval between subsequent actions would be shorter. The result is that maintenance will be needed more often. In this case, the inherent reliability is increased, but more maintenance is required to maintain that level of reliability (level of perfection). Unless the performance characteristics of the system have been improved, this redesign may not be acceptable. A decision must be made to determine if the performance improvement justifies more maintenance and thus an increase in maintenance costs.

Conversely, if the decay rate is the same as before, as shown in curve C of Fig. 1-3, or less steep, as shown in curve D, then the maintenance interval would be increased and the overall amount of preventive maintenance might be reduced. The question to be considered, then, is this: Does the reduction of maintenance justify the cost of the redesign? This question, of course, is a matter for the designers to ponder, not the maintenance people.

One of the major factors in redesign is cost. Figure 1-4 shows the graphs of two familiar and opposing relationships. The upper curve is logarithmic. It represents the increasing perfection attained with more sophisticated design efforts.

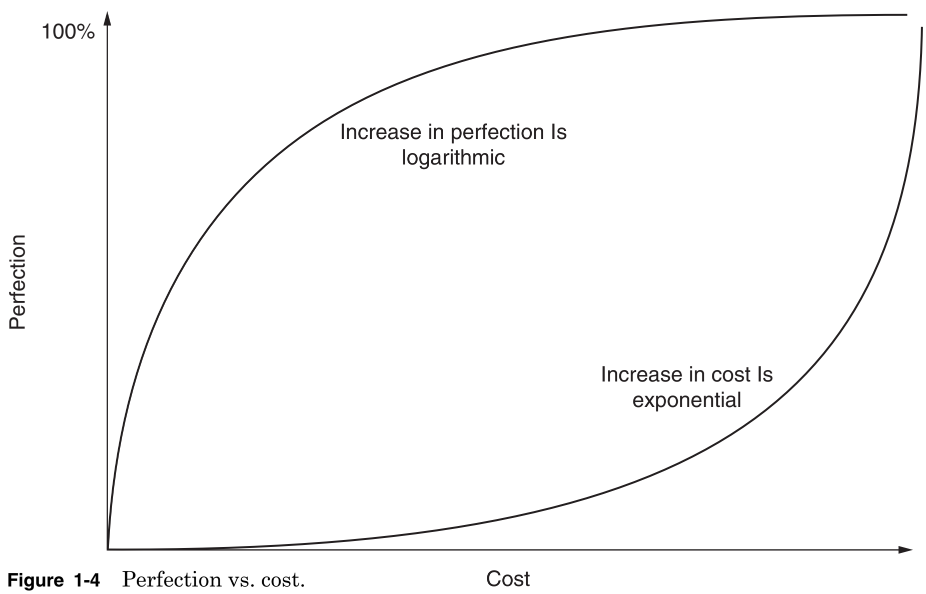
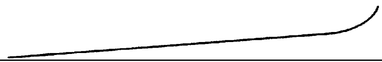
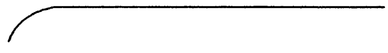
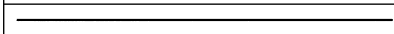


Figure 1-4 Perfection vs. cost.

TABLE 1-1 Failure Rate Patterns

	A. Infant mortality; constant or slightly rising failure rate; definite wear-out period (4%)
	B. No infant mortality; slightly rising failure rate; definite wear-out period (2%)
	C. No infant mortality; slightly rising rate; no definite wear-out period (5%)
	D. Increasing failure rate at outset; constant or slightly rising rate; no definite wear-out period (7%)
	E. No infant mortality; constant failure rate throughout life; no definite wear-out period (14%)
	F. Infant mortality; constant failure rate throughout life; no definite wear-out period (68%)

Source: F. Stanley Nowlan and Howard F. Heap: *Reliability-Centered Maintenance*; U.S. Department of Commerce, National Technical Information Service, Washington, DC, 1978.

The closer we get to perfection (top of the illustration) the harder it is to make a substantial increase. (We will never get to 100 percent.) The lower curve depicts the cost of those ongoing efforts to improve the system. This, unfortunately, is an exponential curve. The more we try to approach perfection, the more it is going to cost us. It is obvious, then, that the designers are limited in their goal of perfection, not just by entropy but also by costs. The combination of these two limitations is basically responsible for our profession of maintenance.

Failure Rate Patterns

Maintenance, of course, is not as simple as one might conclude from the above discussion of entropy. There is one important fact that must be acknowledged: not all systems or components fail at the same rate nor do they all exhibit the same pattern of wear out and failure. As you might expect, the nature of the maintenance performed on these components and systems is related to those failure rates and failure patterns.

United Airlines did some studies on lifetime failure rates and found six basic patterns.[2] These are shown in Table 1-1. The vertical axes show failure rates and the horizontal axes indicate time. No values are shown on the scales since these are not really important to the discussion.

Curve A shows what is commonly referred to as the "bathtub" curve, for obvious reasons. This failure rate pattern exhibits a high rate of failure during the early portion of the component's life, known as infant mortality. This is one of the bugaboos of engineering. Some components exhibit early failures for several

[2] Nowlan, F. Stanley and Howard F. Heap, *Reliability-Centered Maintenance*. National Technical Information Service, Washington, DC, 1978.

reasons: poor design, improper parts, or incorrect usage. Once the bugs are worked out and the equipment settles into its pattern, the failure rate levels off or rises only slightly over time. That is, until the later stages of the component's life. The rapid rise shown in curve A near the end of its life is an indication of wear out. The physical limit of the component's materials has been reached.

Curve B exhibits no infant mortality but shows a level, or slightly rising failure rate characteristic throughout the component's life until a definite wear-out period is exhibited toward the end.

Curve C depicts components with a slightly increasing failure rate with no infant mortality and no discernible wear-out period, but at some point, it becomes unusable.

Curve D shows a low failure rate when new (or just out of the shop), which rises to some steady level and holds throughout most of the component's life.

Curve E is an ideal component: no infant mortality and no wear-out period, just steady (or slightly rising) failure rate throughout its life.

Curve F shows components with an infant mortality followed by a level or slightly rising failure rate and no wear-out period.

The United Airlines study showed that only about 11 percent of the items included in the experiment (those shown in curves A, B, and C of Table 1-1) would benefit from setting operating limits or from applying a repeated check of wear conditions. The other 89 percent would not. Thus, time of failure or deterioration beyond useful levels could be predicted on only 11 percent of the items (curves A, B, and C of Table 1-1). The other 89 percent (depicted by curves D, E, and F of Table 1-1) would require some other approach. The implication of this variation is that the components with definite life limits and/or wear-out periods will benefit from scheduled maintenance. They will not all come due for maintenance or replacement at the same time, however, but they can be scheduled; and the required maintenance activity can be spread out over the available time, thus avoiding peaks and valleys in the workload. The other 89 percent, unfortunately, will have to be operated to failure before replacement or repair is done. This, being unpredictable, would result in the need for maintenance at odd times and at various intervals; i.e., unscheduled maintenance.

These characteristics of failure make it necessary to approach maintenance in a systematic manner, to reduce peak periods of unscheduled maintenance. The industry has taken this into consideration and has employed several techniques in the design and manufacturing of aircraft and systems to accommodate the problem. These are discussed in the next section.

Other Maintenance Considerations

The aviation industry has developed three management techniques for addressing the in-service interruptions created by the items that must be operated to failure before maintenance can be done. These are equipment redundancy, line replaceable units, and minimum aircraft dispatch requirements.

The concept of redundancy of certain components or systems is quite common in engineering design of systems where a high reliability is desirable. In the case of redundant units—usually called primary and backup units—if one unit fails, the other is available to take over the function. For example, in aviation most commercial jets have two high-frequency (HF) radios. Only one is needed for communications, but the second one is there for backup in case the first one fails.

A unique feature of redundant units also affects the maintenance requirements. If both primary and backup units are instrumented such that the flight crew is aware of any malfunction, no prior maintenance check is required to indicate that incapability. On the other hand, if neither system is so instrumented, maintenance personnel would need to perform some check on both primary and backup systems (at the transit or other check) to determine serviceability.

Very often, however, one system (usually the backup) is instrumented to show serviceability to the crew. If a maintenance check is performed on the other (i.e., the primary) the crew can be assured that it is serviceable. In the case of failure, then, they already have a positive indication, through the instrumentation, that the backup system is available and useable. The purpose for this arrangement is to strike a balance between how much instrumentation is used and how much maintenance is required to ensure system serviceability. In some cases, the backup system is automatically switched into service when the primary system fails. Flight crew needs during the flight are primary concerns in making such decisions.

Another common concept used in aviation is the *line replaceable unit* (LRU). An LRU is a component or system that has been designed in such a manner that the parts that most commonly fail can be quickly removed and replaced on the vehicle. This allows the vehicle to be returned to scheduled service without undue delay for maintenance. The failed part, then, can either be discarded or repaired in the shop as necessary without further delaying the flight.

The third concept for minimizing delays for maintenance in aviation is known as the *minimum equipment list* (MEL). This list allows a vehicle to be dispatched into service with certain items inoperative provided that the loss of function does not affect the safety and operation of the flight. These items are carefully determined by the manufacturer and sanctioned by the regulatory authority during the early stages of vehicle design and test. The manufacturer issues a *master minimum equipment list* (MMEL) which includes all equipment and accessories available for the aircraft model. The airline then tailors the document to its own configuration to produce the MEL (more on this in Chap. 5). Many of these MEL items are associated with redundant systems. The concept of the MEL allows deferral of maintenance without upsetting the mission requirements. The maintenance, however, must be performed within certain prescribed periods, commonly 1, 3, 10, or 30 days, depending on the operational requirements for the system.

The items are identified in the MMEL by flight crew personnel during the latter stages of new aircraft development. Thus, flight personnel determine what systems they can safely fly the mission without or in a degraded condition.

These flight crew personnel also determine how long (1, 3, 10, or 30 days) they can tolerate this condition. Although this is determined in general terms prior to delivering the airplane, the flight crew on board makes the final decision based on actual conditions at the time of dispatch. The pilot in command (PIC) can, based on existing circumstances, decide not to dispatch until repairs are made or can elect to defer maintenance per the airline's MEL. Maintenance must abide by that decision.

Associated with the MEL is a *dispatch deviation guide* (DDG) that contains instructions for the line maintenance crew when the deviation requires some maintenance action that is not necessarily obvious to the mechanic. A dispatch deviation guide is published by the airplane manufacturer to instruct the mechanic on these deviations. The DDG contains such information as tying up cables and capping connectors from removed units, opening and placarding circuit breakers to prevent inadvertent power-up of certain equipment during flight, and any other maintenance action that needs to be taken for precautionary reasons. Similar to the MEL is a *configuration deviation list* (CDL). This list provides information on dispatch of the airplane in the event that certain panels are missing or when other configuration differences not affecting safety are noted. The nonessential equipment and furnishing (NEF) items list contains the most commonly deferred items that do not affect airworthiness or safety of the flight of the aircraft. This is also a part of the MEL system.

Although failures on these complex aircraft can occur at random and can come at inopportune times, these three management actions—redundancy of design, line replaceable units, and minimum dispatch requirements—can help to smooth out the workload and reduce service interruptions.

Establishing a Maintenance Program

Although there has been a considerable amount of improvement in the quality and reliability of components and systems, as well as in materials and procedures, over the 100-year life of aviation, we still have not reached total perfection. Aviation equipment, no matter how good or how reliable, still needs attention from time to time.

Scheduled maintenance and servicing are needed to ensure the designed-in level of perfection (reliability). Due to the nature of the real world, some of these components and systems will, sooner or later, deteriorate beyond a tolerable level or will fail completely. In other instances, users, operators, or even maintenance people who interface with these components and systems can misuse or even abuse the equipment to the extent of damage or deterioration that will require the need for some sort of maintenance action.

We have seen that components and systems fail in different ways and at different rates. This results in a requirement for unscheduled maintenance that is somewhat erratic and uncertain. There are often waves of work and no-work periods that need to be managed to smooth out the workload and stabilize the manpower requirements.

Those components exhibiting life limits or measurable wear-out characteristics can be part of a systematic, scheduled maintenance program. Design redundancy, line replaceable units, and minimum dispatch requirements have been established as management efforts to smooth out maintenance workload. But there are numerous components and systems on an aircraft that do not lend themselves to such adjustment for convenience. Occasionally, inspections and/or modifications of equipment are dictated—within specified time limits—by aviation regulators as well as by manufacturers. It is necessary, then, that the maintenance and engineering organization of an airline be prepared to address the maintenance of aircraft and aircraft systems with a well-thought-out and well-executed program. The remainder of this textbook will address the multi-faceted process known as aircraft maintenance and engineering.

The program discussed herein has been created over the years by concentrated and integrated efforts by pilots, airlines, maintenance people, manufacturers, component and system suppliers, regulatory authorities, and professional and business organizations within the aviation industry. Not every airline will need to be organized and operated in the same manner or style, but the programs and activities discussed in this text will apply to all operators.

Chapter

2

Development of Maintenance Programs

Introduction

The maintenance programs currently in use in commercial aviation were developed by the industry using two basic approaches: the process-oriented approach and the task-oriented approach. The differences in these two methods are twofold: (*a*) the attitude toward maintenance actions and (*b*) the manner in which maintenance actions are determined and assigned to components and systems. Although the commercial aviation industry has recently gone to the task-oriented approach for the most recent airplane models, there are many older airplanes still in service whose maintenance programs were developed by the process-oriented approach. In recent years, McDonnell-Douglas (now part of Boeing) and Boeing have developed new task-oriented maintenance programs for some of these older model aircraft. The operators can purchase these new programs from the manufacturer.

The process-oriented approach to maintenance uses three primary maintenance processes to accomplish the scheduled maintenance actions. These processes are called hard time (HT), on-condition (OC), and condition monitoring (CM). The *hard time* and *on-condition processes* are used for components or systems that, respectively, have definite life limits or detectable wear-out periods. These are the items in categories A, B, and C discussed in Chap. 1 and illustrated in Table 1-1. The *condition monitoring process* is used to monitor systems and components that cannot utilize either the HT or OC processes. These CM items are operated to failure, and failure rates are tracked to aid in failure prediction or failure prevention efforts. These are the "operate to failure" items in categories D, E, and F of Table 1-1.

The task-oriented approach to maintenance uses predetermined maintenance tasks to avoid in-service failures. Equipment redundancies are sometimes

used to allow in-service failures to occur without adversely affecting safety and operation. A reliability program is usually employed (similar to, but more elaborate than, the CM process) for those components or systems whose failure rates are not predictable and for those that have no scheduled maintenance tasks. Reliability is discussed in Chap. 18.

Both of these maintenance philosophies—the process oriented and the task oriented—are discussed in general below along with the basic method of generating the program. How the maintenance tasks and task intervals are determined will be discussed in detail in later sections.

The Maintenance Steering Group (MSG) Approach

The Boeing Company started the modern approach to maintenance program development in 1968 with the Boeing 747 airplane, then the largest commercial airplane. It was the start of a new era in aviation, the era of the jumbo jets, and the company felt that this new era should begin with a more sophisticated approach to maintenance program development. They organized teams of representatives from the Boeing Company's design and maintenance program groups along with representatives from the suppliers and the airlines who were interested in buying the airplane. The FAA was also included to ensure that regulatory requirements were properly addressed.

The process used involved six industry working groups (IWGs): (*a*) structures; (*b*) mechanical systems; (*c*) engine and auxiliary power plant (APU); (*d*) electrical and avionics systems; (*e*) flight controls and hydraulics; and (*f*) zonal. Each group addressed their specific systems in the same way to develop an adequate initial maintenance program. Armed with information on system operation, maintenance significant items (MSIs) and their associated functions, failure modes, failure effects, and failure causes, the group analyzed each item using a logic tree to determine requirements.

This approach to maintenance program development was called a "bottom-up" approach because it looked at the components as the most likely causes of equipment malfunction. The purpose of the analysis was to determine which of three processes would be required to repair the item and return it to service. The three processes were identified as HT, OC, and CM as defined above.

This maintenance steering group (MSG) approach to maintenance program development was so successful on the 747 that it was modified slightly for use with other aircraft. The specific references to the 747 airplane were removed, and the new generalized process could be used on all aircraft. It was renamed MSG-2 and applied to the development of maintenance programs for the Lockheed L-1011 and the McDonnell-Douglas DC-10 airplanes. Other slight modifications were made to the process in 1972 by European manufacturers, and the resulting procedure used in Europe became known as EMSG.

The MSG-2 process was slightly different for the three maintenance areas studied: (*a*) systems and components; (*b*) structures; and (*c*) engines. Table 2-1 summarizes the steps for each:

TABLE 2-1 MSG-2 Process Steps

Step number for			
System/comp	Structure	Engine	Analysis activity
1		1	Identify the systems and their significant items
	1		Identify significant structural items
2			Identify their functions, failure modes, and failure reliability
	2		Identify failure modes and failure effects
		2	Identify their functions, failure modes, and failure effects
3		3	Define scheduled maintenance tasks having potential effectiveness relative to the control of operational reliability
	3		Assess the potential effectiveness of scheduled inspections of structure
4		4	Assess the desirability of scheduling those tasks having potential effectiveness
	4		Assess the desirability of those inspections of structure which do have potential effectiveness
	5		Determine that initial sampling thresholds were appropriate

Source: Airline/Manufacturer Maintenance Program Document-MSG-2: R&M Subcommittee, Air Transport Association; March 25, 1970.

Step 1, identify the maintenance or structure items requiring analysis.

Step 2, identify the functions and failure modes associated with the item and the effect of a failure.

Step 3, identify those tasks which may have potential effectiveness.

Step 4, assess the applicability of those tasks and select those deemed necessary.

Step 5, for structures only, evaluate initial sampling thresholds.

The process flow diagram in the MSG-2 document is too complex to repeat here, especially since the MSG-2 process is no longer used. It is important, however, to understand how the maintenance processes were assigned to the tasks selected. Figure 2-1 is a simplified diagram of that process. Briefly, if failure of the unit is safety related (block 1) and there is a maintenance check available to detect a reduction in failure resistance (block 4), then the item in question is identified as on-condition. If no such check is available, then the item is classified as hard time. The student can follow the logic of Fig. 2-1 for the other conditions.

Once the maintenance action was determined, it was necessary to define how often such maintenance should be done. Available data on failure rates, removal rates, etc. of the item were then used to determine how often the maintenance should be performed.

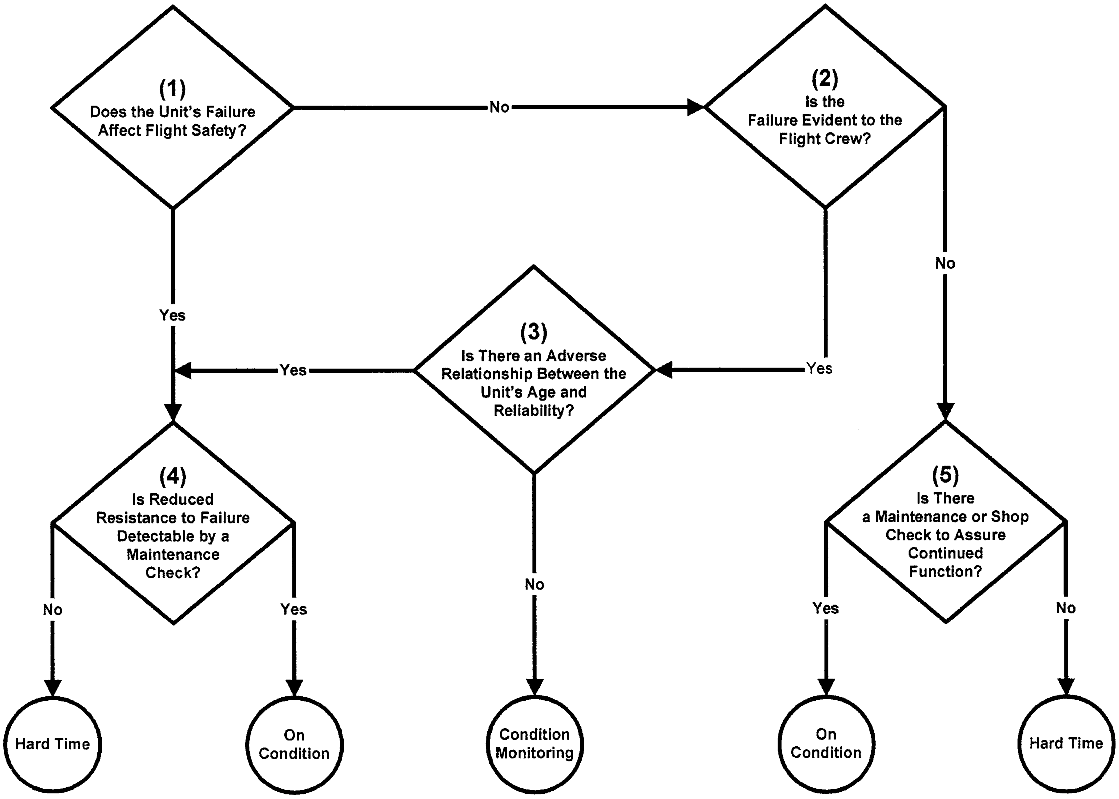


Figure 2-1 Simplified MSG-2 flow chart.

Process-Oriented Maintenance

Process-oriented maintenance programs are developed for aviation using decision logic procedures developed by the Air Transport Association of America (ATA). The MSG-2 process is a bottom-up approach whereby each unit (system, component, or appliance) on the aircraft is analyzed and assigned to one of the primary maintenance processes, HT, OC, or CM.

In general, hard time means the removal of an item at a predetermined interval, usually specified in either so many flight hours or so many flight cycles. In some cases the hard time interval may be in calendar time. On-condition means that the item will be checked at specified intervals (in hours, cycles, or calendar time) to determine its remaining serviceability. Condition monitoring involves the monitoring of failure rates, removal rates, etc. to facilitate maintenance planning. Let us look at each process in more detail.

The hard time (HT) process

Hard time is a failure preventive process which requires that the item be removed from the vehicle and either completely overhauled, partially overhauled (restored),

or discarded before exceeding the specified interval. The hard time interval may be specified by calendar time, by engine or airplane check interval (engine change, "C" check, etc.), by landing or operating cycles, by flight hours, by block hours, by specified flights (over water, terminating, etc.), or in conjunction with another process (OC for instance).

When HT is specified, the component will be removed from the vehicle and overhauled, restored, or discarded, whichever is appropriate. This will be done before the component has exceeded the specified time interval. The component overhaul or restoration will restore the component to a condition that will give reasonable assurance of satisfactory operation until the next scheduled removal. Ideally, hard time would be applied to a component that always fails at X hours of operation. This component would then be replaced at the last scheduled maintenance period prior to the accumulation of X hours; thus, the operator would get maximum hours out of the component and the component would never fail in service (ideally).

Hard time is also applied to items having a direct adverse effect on safety and items subject to reliability degradation with age but having no possible maintenance check for that condition. The former components, as we will see later, are not eligible for condition monitoring because of the safety issue. The latter components, such as rubber products, do not lend themselves to any periodic check for condition; i.e., there is no OC check to determine how much serviceability is remaining.

As an example, structural inspection, landing gear overhaul, and replacement of life-limited engine parts are all controlled by hard time. Frequently, mechanical linkages and actuators, hydraulic pumps and motors, electric motors and generators, and similar items subject to a definite wear-out cycle will also be identified as hard time. For items having clearly defined wear-out periods, hard time is probably the most economical process. However, these items can also be OC or CM, depending on the operator, as long as they are not safety related.

The on-condition (OC) process

On-condition is a failure preventive process that requires that the item be periodically inspected or tested against some appropriate physical standard (wear or deterioration limits) to determine whether or not the item can continue in service. After failing an OC check, the component must be overhauled or restored to the extent of at least replacing out-of-tolerance parts. Overhaul or repair must restore the unit to a condition that will give reasonable assurance of satisfactory operation for at least one additional OC check interval. If the item cannot be overhauled or restored, or if it cannot be restored to a condition where it can operate one more OC check period, then it should be discarded.

On-condition must be restricted to components, equipment, or systems on which a determination of continued airworthiness may be made by measurements, tests, or other means without doing a tear-down inspection. These on-condition checks are to be performed within the time limits (intervals) prescribed for each OC check. On-condition determination of continued airworthiness is a

quantifying check with specified tolerances and/or wear limits which must be set forth in the operator's maintenance manuals.

The periodically scheduled OC checks must constitute meaningful determination of suitability for continued operation for another scheduled OC check interval. If the check performed provides enough information regarding the condition and failure resistance of the item to give reasonable assurance of its continued airworthiness during the next check period, the item is properly categorized as on-condition. If the check constitutes merely a maintenance task—servicing, adjustment, or a go/no-go determination—and is not making a meaningful disclosure of actual condition, the item is, in fact, operating as a condition monitored item. It should be classified as CM and not OC. In some cases, it could even be classified as HT. A simple operational check is *not* an acceptable requisite for the on-condition process. On-condition checks must measure or evaluate the wear and/or deterioration condition of the item.

The on-condition process also encompasses periodic collection of data that will reveal the physical condition of a component, system, or engine. Through analysis and evaluation, OC data must be able to ascertain continued airworthiness and/or deterioration of failure resistance and imminence of failure. On-condition data must be directed to an individual component, system, or engine (by serial number). It is a priori (before the fact) failure data that can be used to measure decreasing life expectancy and/or predict failure imminence. Examples of OC checks are as follows: (*a*) tire tread and brake linings, (*b*) scheduled borescope inspections of engines, (*c*) engine oil analysis, and (*d*) in-flight engine performance analysis (i.e., engine condition monitoring or ECM). In each of the above stated cases, one can measure degradation and determine, from established norms, how much life or serviceability remains.

Most of the commercial airplane operators in the United States use the on-condition process to control engine overhaul. The determination of when to remove an engine is based on engine data collected by an ECM program. Data showing engine performance degradation, such as oil and fuel consumption, borescope inspection results, trends in recorded in-flight instrument readings, oil analysis, etc. are compared to standards to predict decreasing engine reliability and failure imminence. Engine data programs attempt to provide data to indicate the need to remove engines before an in-flight shutdown (IFSD) occurs; i.e., they are failure preventive processes.

Two points to remember about the on-condition process: (*a*) if a satisfactory on-condition check can be accomplished to ensure serviceability with reasonable probability until the next OC check, or if evaluation of the OC data collected will predict failure imminence, then the OC process will achieve close to maximum life on components and engines; and (*b*) on-condition applicability is limited by the requirement for a satisfactory condition measurement or pertinent failure predicting data.

Examples of components susceptible to the on-condition process are as follows:

1. *Brake wear indicator pins*: Compare brake wear condition against a specified standard or limit. Brake wear will vary considerably among operators due

to operational conditions and crew habits, but the wear indicator pin OC check will help attain near maximum usage out of each set of brakes.

2. *Control cables*: Measure these for diameter, tension, and broken strands.
3. *Linkages, control rods, pulleys, rollers tracks, jack screws, etc.*: Measure these for wear, end or side play, or backlash.

The condition monitoring (CM) process

The condition monitoring process is applied when neither the hard time nor the on-condition process can be applied. The CM process involves the monitoring of the failure rates, removals, etc. of individual components or systems that do not have a definite lifetime or a noticeable wear-out period. Condition monitoring is not a failure preventive process as are HT and OC. There are no maintenance tasks suitable for evaluating the life expectancy of the CM item and there is no requirement to replace the item before it fails. Neither time nor condition standards can be used to control CM items because these components do not have such attributes. Therefore, CM components are operated until failure occurs and replacement of CM items is an unscheduled maintenance action.

Since CM items are operated to failure, the ATA states that these items must comply with the following conditions[1]:

1. A CM item has no direct, adverse effect on safety when it fails; i.e., the aircraft continues to fly to a safe landing. Generally, CM items have only this indirect, nonadverse effect on safety due to system redundancy.
2. A CM item must not have any hidden function (i.e., a malfunction that is not evident to the crew) whose failure may have a direct adverse effect on safety. However, if there is a hidden function and the availability or operation of that hidden function is verified by a scheduled operational test or other nonmeasurement test made by the flight crew or maintenance crew, CM can still be used.
3. A CM item must be included in the operator's condition monitoring or reliability program; i.e., there must be some sort of data collection and analysis for those items for maintenance to get a better understanding of the nature of failure for those components or systems.

In addition to the above ATA stipulations, CM items usually have no adverse relationship between age and reliability (i.e., no predictable life expectancy). They exhibit a random failure pattern.

The most appropriate application of the condition monitoring process is to complex systems, such as avionics and electronics components, and to any other components or systems for which there is no way to predict failures. Typical components and systems suitable for CM include navigation and communications equipment, lights, instruments, and other items where test or replacement will not predict

[1] *Airline/Manufacturer Maintenance Program Development—MSG-2*; R&M Subcommittee of ATA, March 25, 1970. (*Note*: This document is no longer kept up to date by ATA.)

approaching failure nor result in improved life expectancy. In aviation, CM is frequently applied to components where failure has no serious effect on safety or airworthiness, due to redundancy, and to items not affecting airworthiness at all, such as coffee makers, lavatories, passenger entertainment systems, etc.

Condition monitoring systems consist of data collection and data analysis procedures that will portray information upon which judgments relative to the safe condition of the vehicle can be made. A CM program includes those kinds of evaluation programs that utilize the disclosure capabilities of the airplane or its systems and components to the degree that such disclosure information can be used to make judgments relative to the continuing safe condition of the airplane, its systems, engines, and components. Evaluation based on reports by flight crews, on-board data systems, and equipment for ground check of system performance may be used for CM actions. The basic elements of a CM program may include data on unscheduled removals, maintenance log entries, pilot reports, sampling inspections, mechanical reliability reports, shop findings, and other sources of maintenance data. These and other data may indicate a problem area and thus the need to investigate the matter (see Chap. 18).

Condition monitoring, which is primarily a data collection and analysis program, can also be used on HT and OC components for verifying or adjusting the HT and OC intervals. For example, if a hard time item is removed just prior to its expiration date and overhaul activities reveal that little or nothing needs to be done to restore the component, then perhaps the HT interval can be extended. Likewise, if OC checks reveal little or no maintenance requirement or that the lifetime of the component is longer than originally expected, the OC check interval can be changed. However, without the collection of data over a period of time (several HT periods or OC intervals), there would not be any solid justification to change the intervals. By the same token, CM data collection may indicate that the HT or OC intervals need to be shortened for some components. The CM program also provides data to indicate whether or not components are being monitored under the most appropriate process.

Note for the technical purists

Condition monitoring does not really monitor the "condition" of a component. It essentially monitors the failure or removal statistics of the unit. You monitor the component's condition with the on-condition process.

Task-Oriented Maintenance

Task-oriented maintenance programs are created for aviation using decision logic procedures developed by the Air Transport Association of America. The process called MSG-3 is a modification of and an improvement on the MSG-2 approach.

The MSG-3 technique is a top-down consequence of failure approach whereby failure analysis is conducted at the highest management level of airplane systems instead of the component level as in MSG-2. The MSG-3 logic is

used to identify suitable scheduled maintenance tasks to prevent failures and to maintain the inherent level of reliability of the system. There are three categories of tasks developed by the MSG-3 approach:

1. Airframe system tasks
2. Structural item tasks
3. Zonal tasks

Maintenance tasks for airframe systems

Under the MSG-3 approach, eight maintenance tasks have been defined for airframe systems. These tasks are assigned in accordance with the decision analysis results and the specific requirements of the system, component, etc. under consideration. These eight tasks are listed and defined below:

1. *Lubrication.* An act of replenishing oil, grease, or other substances that maintains the inherent design capabilities by reducing friction and/or conducting away heat.
2. *Servicing*. An act of attending to basic needs of components and/or systems for the purpose of maintaining the inherent design capabilities.
3. *Inspection*. An examination of an item and comparison against a specific standard.
4. *Functional check.* A quantitative check to determine if each function of an item performs within specified limits. This check may require use of additional equipment.
5. *Operational check.* A task to determine if an item is fulfilling its intended purpose. This is a failure-finding task and does not require quantitative tolerances or any equipment other than the item itself.
6. *Visual check.* An observation to determine if an item is fulfilling its intended purpose. This is a failure-finding task and does not require quantitative tolerances.
7. *Restoration*. That work necessary to return the item to a specific standard. Restoration may vary from cleaning the unit or replacing a single part up to and including a complete overhaul.
8. *Discard*. The removal from service of any item at a specified life limit.

Maintenance tasks for structural items

Airplanes are subjected to three sources of structural deterioration as discussed below.

1. *Environmental deterioration.* The physical deterioration of an item's strength or resistance to failure as a result of chemical interaction with its climate or environment. Environmental deteriorations may be time dependent.

2. *Accidental damage*. The physical deterioration of an item caused by contact or impact with an object or influence that is not a part of the airplane, or damage as a result of human error that occurred during manufacture, operation of the vehicle, or performance of maintenance.
3. *Fatigue damage*. The initiation of a crack or cracks due to cyclic loading and subsequent propagation of such cracks.

Inspection of airplane structures to determine if deterioration due to the above has occurred requires varying degrees of detail. The MSG-3 process defines three types of structural inspection techniques as follows:

1. *General visual inspection*. A visual examination that will detect obvious, unsatisfactory conditions or discrepancies. This type of inspection may require removal of fillets or opening or removal of access doors or panels. Work stands and ladders may be required to facilitate access to some components.
2. *Detailed inspection*. An intensive visual inspection of a specified detail, assembly, or installation. It is a search for evidence of irregularity using adequate lighting and, where necessary, inspection aids, such as mirrors, hand lenses, etc. Surface cleaning and detailed access procedures may also be required.
3. *Special detailed inspection*. An intensive examination of a specific location. It is similar to the detailed inspection but with the addition of special techniques. This examination may require such techniques as nondestructive inspections (NDIs): dye penetrant, high-powered magnification, magnetic particle, eddy current, etc. (see Chap. 17 for details on these test methods.) The special detailed inspection may also require the disassembly of some units.

Zonal maintenance tasks[2]

The zonal maintenance program ensures that all systems, wiring, mechanical controls, components, and the installation contained within the specified zone on the aircraft receive adequate surveillance to determine the security of installation and general condition. The logical process is normally used by type certificate (TC) and supplement type certificate (STC) holder for developing their maintenance and inspection for zonal maintenance by using MSG-3 logic to develop a series of inspections, and a numerical reference is assigned to each zone when it is analyzed. Due to aging aircraft, the FAA has established specific damage tolerance criteria based on inspection of an aircraft operator's continued airworthiness program. The AC 120-93 provides for detailed damage tolerance inspection (DTI) for repair and alterations that affect fatigue-critical

[2]*Electrical Wiring Interconnection System (EWIS) and AC 120-102 Electrical Wiring Interconnection system Instructions for Continue Airworthiness for Operator Program of Enhanced Zonal Analysis Procedures for Airplane System/Fuel Tank Safety;*. issued May 4, 2010. AC 25-27A. This program was initiated after the TWA flight 800 crash.

structure of the aircraft. The DTI process includes the area to be inspected, the inspection methods and techniques, and the inspection procedures.

The program packages a number for general visual inspection tasks, generated against the item in the system's maintenance program, into one or more zonal surveillance tasks. Zonal maintenance and inspection level techniques are performed in two types as in the following list.

1. General visual inspection
2. Detailed visual inspection

The Current MSG Process—MSG-3

The MSG-2 process was modified in 1980 in a document released by the Air Transport Association of America.[3] The document states "MSG-3 did not constitute a fundamental departure from the previous version, but was built upon the existing framework of MSG-2 which had been validated by 10 years of reliable aircraft operation using the maintenance programs based thereon."

The MSG-3 program adjusted the decision logic to provide a more straightforward and linear progression through the logic. The MSG-3 process is a top-down approach or consequence of failure approach. In other words, how does the failure affect the operation? It does not matter whether a system, subsystem, or component fails or deteriorates. What matters is how the failure affects the aircraft operation. The failure is assigned one of two basic categories: safety and economic. Figure 2-2 is a simplified diagram of the first step in the MSG-3 logic process.[4]

The maintenance tasks resulting from the MSG-3 approach may include hard time, on-condition, and condition monitoring tasks similar to those of MSG-2, but they are not referred to by those terms. The MSG-3 approach is more flexible in developing the overall maintenance program. The flow chart of Fig. 2-2 is used to determine if the failure is evident to the flight crew or hidden from them (level I analysis). Those failures that are evident are further separated into safety related and operationally related with the latter split into those that are of economic significance and those that are not. These types are numbered 5, 6, and 7. The significance of these categories will be addressed later. Those failures that are determined to be hidden from the crew are divided into safety related and nonsafety related items. These are designated as categories 8 and 9.

---

[3] *Airline/Manufacturer Maintenance Program Development Document;* issued September 30, 1980. Revised several times (March 1988; September 1993, March 2000; and March 2001). Latest version is called *Operator/Manufacturer Schedule Maintenance Development,* revision 2000.1. The latest changes were in revision 2001.1; 2002.1; and 2003.1. The 2002.1 and 2003.1 incorporated revised procedures for fault-tolerant systems. The latest revision 2005.1 refers to aircraft system and power plant analysis procedures.

[4] Each block in Fig. 2-2 is numbered. The numbers on the output block (5 through 9) are used later to identify the category of the failure (hidden, evident, safety, etc.). These numbers will be referenced later in this discussion.

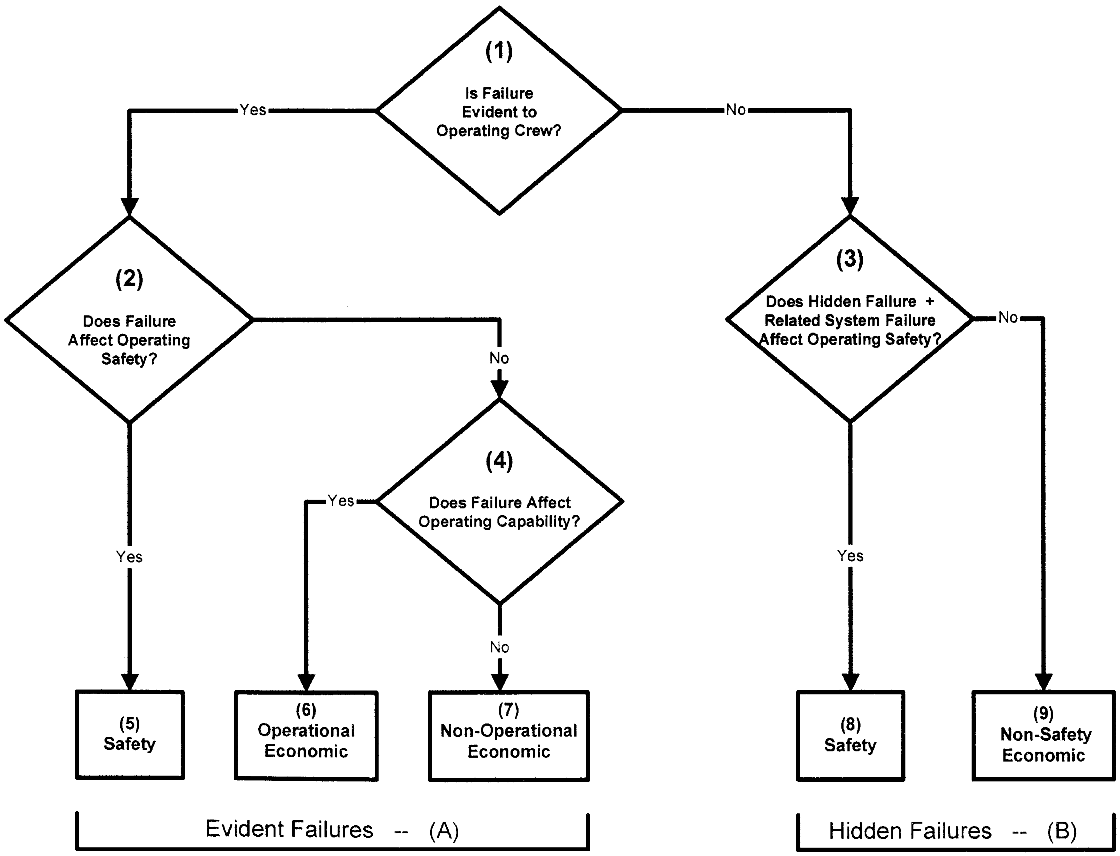


Figure 2-2 MSG-3—level I analysis—failure categories. (*Courtesy of Air Transport Association of America, Inc. Reprinted with permission. Copyright © 2003 by Air Transport Association of America, Inc. All rights reserved.*)

Figures 2-3 and 2-4 (level II analysis) are used to determine the maintenance tasks required to accommodate the functional failure. Although the questions are similar, there is a slight difference in the way evident and hidden failures are addressed. Note that some of the flow lines in Figs. 2-3 and 2-4 are identified as Cat 5 or Cat 8 only. This requires some explanation.

The first question in each chart, regarding lubrication or servicing, must be asked for all functional failures (categories 5 through 9). Regardless of the answer to this question (Yes or No), the analyst must ask the next question. For categories 6 and 7 in Fig. 2-3 and category 9 in Fig. 2-4, the questions are asked in sequence until a Yes answer is obtained. At that point the analysis stops. For categories 5 and 8 (safety related), however, all questions must be answered regardless of the Yes or No response to any of them.

The last block of Figs. 2-3 and 2-4 also requires some explanation. These flow charts are used for the development of a maintenance program for a new aircraft or derivative. If progression through the chart ends up in this block for

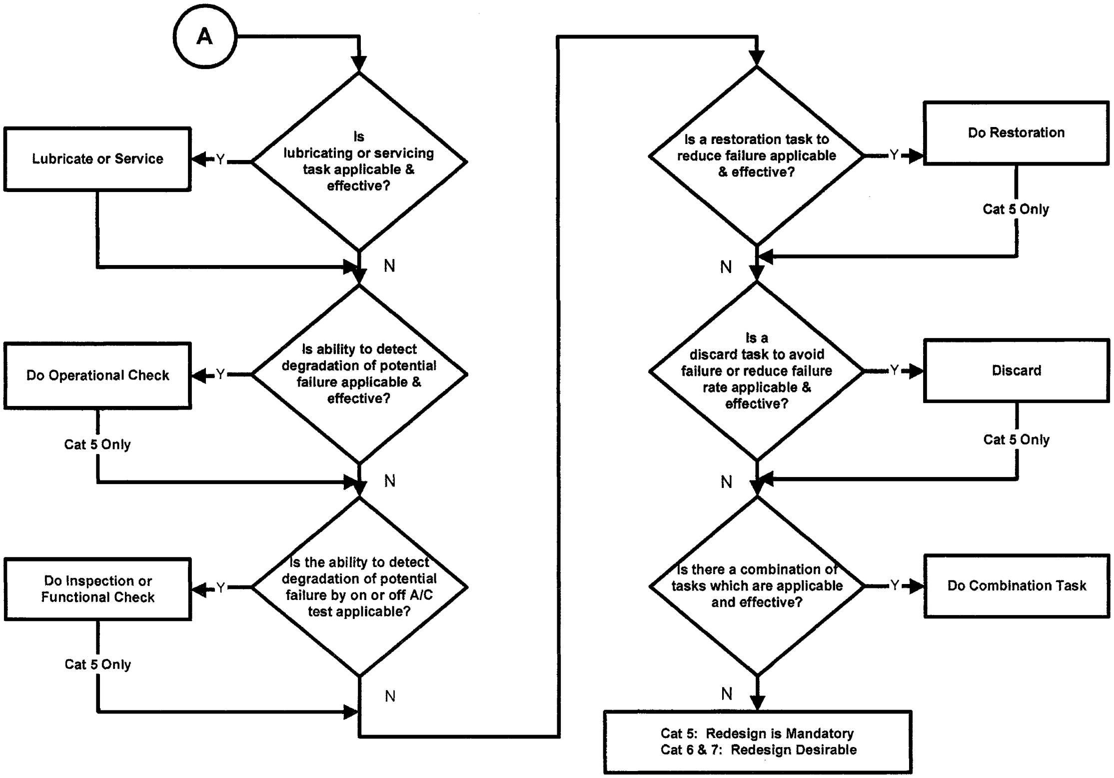


Figure 2-3 MSG-3—level II analysis—evident failures. (*Courtesy of Air Transport Association of America, Inc. Reprinted with permission. Copyright© 2003 by Air Transport Association of America, Inc. All rights reserved.*)

categories 6, 7, and 9, then a redesign on the equipment involved may be considered by the design engineers. However, if the item is safety related—categories 5 or 8—then a redesign is mandatory. Once the initial maintenance program is developed, the airline mechanics will use that program. Mechanics do not have the option of redesign unless that is indicated by the reliability program as discussed in Chap. 18.

The MSG-3 process can be best understood through a step-by-step explanation of what the working groups would do for a given analysis. Each working group will receive information about the systems and components within their respective groups: (*a*) the theory of operation; (*b*) a description of the operation of each mode (if there is more than one mode); (*c*) the failure modes of each operational mode; and (*d*) any data available (actual or estimated) on the failure rates, removal rates, etc. [such as mean time between failures (MTBF) and mean time between unscheduled removals (MTBUR) for repairable parts; and mean time to removal (MTTR) for nonrepairable parts].

If the system is the same as, or similar to, that used on an existing model aircraft, the group members may only need refresher training on the operation and

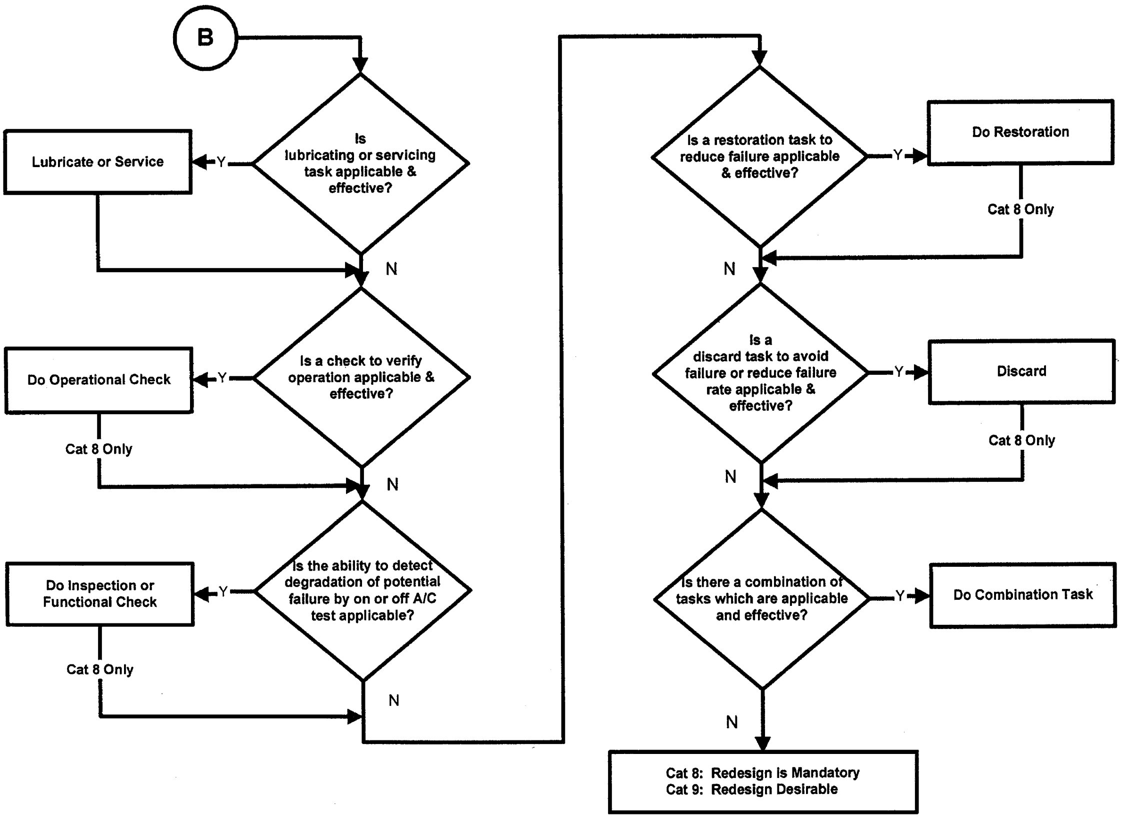


Figure 2-4 MSG-3—level II analysis—hidden failures. (*Courtesy of Air Transport Association of America, Inc. Reprinted with permission. Copyright© 2003 by Air Transport Association of America, Inc. All rights reserved.*)

on the failure modes. If the equipment is new, or has been extensively modified for the new model aircraft, the learning process may take a little more time. The airframe manufacturer is responsible for providing this training to the working groups. The manufacturer is also responsible for furnishing any available performance and failure rate data to the working groups.

Once the group assimilates this information, they begin to run through the logic diagrams, answering the questions appropriately and determining the maintenance approach that best suits the problem. Each failure in each operational mode is addressed. The working group first determines if the failure is hidden to the crew or is obvious (block 1 of Fig. 2-2). Then they determine whether or not the problem is safety related and, in the case of evident failures, whether or not it has operational impact. Next, they determine which maintenance tasks should be applied using Figs. 2-3 and 2-4 (level II analysis). Finally, the group determines at what maintenance interval that task should be performed. This latter exercise makes use of the failure rate data as well as the experience of the working group members.

iSpec 2200

In the year 2000, the ATA's Technical Information and Communication Committee (TICC) incorporated ATA Spec 100 and ATA Spec 2100 into iSpec 2200[5]: Information Standards for Aviation Maintenance. It is currently used in aerospace for its content, structure, technical documentation, and electronic exchange of aircraft engineering, maintenance, and flight operations information. It is used in the specification of maintenance requirements, procedures, aircraft configuration control, and flight operations. As always, the objective is to keep costs to a minimum among operators and manufacturers and to improve information quality, which can facilitate manufacturers' delivery of data for operational needs.

The Maintenance Program Documents

The result of the MSG-3 analysis constitutes the original maintenance program for the new model aircraft and the program that is to be used by a new operator of that model. The tasks selected in the MSG process are published by the airframe manufacturer in an FAA approved document called the *Maintenance Review Board Report* (MRBR). This report contains the initial scheduled maintenance program for U.S. certificated operators. It is used by those operators to establish their own FAA approved maintenance program as identified by their operations specifications (see Chap. 4).

The MRBR includes the systems and power plant maintenance program, the structural inspection program, and the zonal inspection program. It also contains aircraft zone diagrams, a glossary, and a list of abbreviations and acronyms.

In addition to the MRBR, the manufacturer publishes its own document for maintenance planning. At Boeing, this document is called the maintenance planning data (MPD) document. McDonnell-Douglas called it the on aircraft maintenance planning (OAMP) document. At Airbus Industries, it is called the maintenance planning document (MPD). We will use the acronym MPD/OAMP to refer to all such documents. These documents contain all the maintenance task information from the MRBR plus additional tasks suggested by the airframe manufacturer. The MPD/OAMP also sorts the tasks in various ways to aid in planning. This document often groups by letter check and by hours, cycles, and calendar time.

These manufacturer's documents also contain diagrams showing the location and numbering of access doors and panels, aircraft dimensions, and other information to aid the development of maintenance programs and the planning of maintenance checks. The latter includes man-hour requirements for each task. These are only estimates of the time required to do the actual work prescribed. They do not include the time required to open and close doors or panels, position work stands, to analyze or troubleshoot problems, or to correct any discrepancies

[5]ATA Spec 100 and Spec 2100 will no longer be updated beyond 1999 revision.

found during conduct of the task. These estimated times must be altered by the operator to accommodate the actual task requirements when planning any given check activity.

Maintenance Intervals Defined

The maintenance work interval depends on the aircraft manufacturer with the cooperation of the airline's operator discretion. Various maintenance checks have been named and defined in the MSG-3 process and are to be considered standard. However, many airlines have defined their own named intervals, but as long as the integrity is maintained of the original maintenance required task or an approved FAA deviation. Aircraft maintenance checks are normally driven by total air time (TAT), the number of hours an aircraft has flown, and total landing cycles (CYC), which translates into each time an aircraft lands it generates one cycle. Under FAA oversight, airlines and aircraft operators must prepare a continuous airworthiness maintenance program (CAMP) under their operations specification. The CAMP program outlines routine and detailed inspection. Airlines and aircraft operators and airworthiness authorities commonly refer to these types of inspections as checks. These checks are known as A, B, C, D checks (detailed in Chap. 9).

The following are the examples of standard intervals:

Daily checks

Daily checks consist of the oil level check. The oil level on the aircraft engine must be checked between 15 and 30 minutes after engine shutdown to obtain an accurate reading. This means that the oil level cannot be checked and replenished prior to the first flight of the day. It can only be done soon after landing. (If one must check the oil level prior to first departure, the engine must be run for 2 minutes or more to warm up the oil. Fifteen minutes after shutting down, the oil level can be checked. This is not a normal procedure, but it is necessary in some cases.)

The daily checks also include any time-deferred maintenance items, such as an aircraft engine being on oil watch. ETOPS-type aircraft also receive a predeparture service check, which is also part of the daily checks.

48-hour checks

A 48-hour check, for most aircraft models, replaces what used to be called a daily check. The 48-hour check is performed every 48 hours depending on airline operations specifications. This check may include tasks that are more detailed than the daily checks; for example, items such as wheel and brake inspection, replenishment of fluids such as engine oil and hydraulic, auxiliary power unit oil replenishment and inspection, general visual inspection of the fuselage, wings, interior, and flight deck.

Hourly limit checks

Certain checks determined by the MSG analysis have maintenance tasks assigned by the number of hours the unit or system has been operating: 100, 200, 250 hours, etc. This approach is used for engines, airplane flight controls, and numerous other systems that are operating on a continual basis during the flight or on the ground.

Operating cycle limit checks

Other airplane systems are maintained on a schedule determined by the number of operating cycles they have endured. For example, landing gear is used only during takeoffs and landings, and the number of those operations will vary with the flight schedule. Airframe structures, power plant/engine components, such as LP and HP impellors and HP turbine blades and some other components are also subject to cyclic stresses and will have numerous tasks in this category.

Letter checks

Until the development of the Boeing 777, all aircraft utilizing the MSG-3 processes for maintenance program development had various letter checks identified in the maintenance program. These checks were identified as A, B, C, and D checks. The Boeing 777, using a modified MSG-3 process (called MSG-3, Revision 2) eliminated the letter checks.[6] Every task that was not on the transit check was identified by hours or cycles only, and these tasks were not grouped into letter checks as was done for previous model aircraft. This produced an optimum maintenance program in that it allowed maintenance to be done at the most appropriate time for the equipment or system. For the operator, it makes the program more adaptable to their needs. Some operators, however, still schedule this maintenance in blocks at specific time or cycle intervals.

Changing Basic Maintenance Intervals

Operational conditions will often require that an operator change the basic maintenance program to better address the organizational needs and to accommodate the fifth objective of a maintenance program (see Chap. 3). For example, operation in hot humid climates may require that corrosion control tasks be performed more often than the MRB report indicates while operating the same vehicles in a dry, desert climate may reduce the needed frequency for these tasks. In the latter situation, however, items sensitive to sand and dust will need increased attention in the maintenance program.

[6]The same is true for the Boeing 737, new generation (NG) airplanes, and other airplanes designed after the 737 NG.

It is expected that an operator will change the original maintenance intervals for certain tasks or for entire letter checks whenever in-service experience dictates. However, to do this, the operator must have proof that a change is warranted. The accepted proof for such maintenance interval changes is in the form of data collected through the operator's condition monitoring program or reliability program. Details on this will be covered later in Chap. 18. As aircraft get older, task intervals for certain items may have to be shortened while others may be lengthened. Maintenance is a dynamic process.

Chapter 3

Definitions, Goals, and Objectives

Definitions of Important Terms

In the classic children's book *Through the Looking Glass*, a young girl named Alice (of Wonderland fame) is having an argument with Humpty Dumpty on the meaning of words.[1]

> "When I use a word," Humpty Dumpty said in rather a scornful tone, "it means just what I choose it to mean—neither more nor less."
>
> "The question is," said Alice, "whether you can make words mean so many different things."
>
> "The question is," said Humpty Dumpty, "which is to be the master—that's all."

They go on with further discussion about words which we will omit here but this dialogue illustrates an important point. All through the history of science and engineering it has been customary for authors to specifically define, early in their texts, the words they use. This text will not be any different: i.e., a word means what we say it means—no more, no less—and will be so defined.[2]

This section discusses some basic terms used in aviation maintenance and engineering. Some of the conventional definitions will be modified or replaced in this text to better define their meaning and purpose. There are some word pairs used in aviation that are, in conventional usage, synonymous, but in the world of science and engineering—and especially aviation—they take on subtle differences. These word pairs will be defined and discussed, also, to ensure that the reader is aware of the precise meaning when the terms are used hereafter. We will begin with the most important definition: the definition of maintenance.

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[1]Carroll, Lewis, *Through the Looking Glass,* in *Alice in Wonderland and other Favorites*. Pocket Books, NY, 1974.

[2]In this text, conventional definitions will be shown in quotes. Definitions new to this text will be boxed.

Maintenance

We have talked about maintenance and how the approach to maintenance has evolved over the years; but just what is it that we mean when we use the term *maintenance*? In the front of this book, we have quoted a very elegant definition of maintenance by Lindley R. Higgins, defining maintenance as art, science, and philosophy. In this text, however, we will address the subject in less poetic and more practical terms.

Numerous other authors have defined the term maintenance, but their definitions are somewhat unsatisfactory. Most of them are not incorrect, but they are often inadequate to describe the full scope and intent of the maintenance effort. We will look at a few of these and discuss the differences. Then we will provide the reader with our own definition of maintenance which, as you will see, falls into place with other definitions and concepts discussed in the text.

Typical airline definition of maintenance

This definition was taken from the text of a "typical" airline's technical policies and procedures manual (TPPM). *Maintenance* is defined as "those actions required for restoring or maintaining an item in a serviceable condition, including servicing, repair, modification, overhaul, inspection, and determination of condition."

This is not incorrect. However, it merely describes what maintenance people do; it is not descriptive of the intent or the result of maintenance activity.

Moubray's definition of maintenance

In the mid-1970s, a process was developed for the U.S. military to develop the initial maintenance program for their equipment similar to the MSG process used for civilian aircraft. The process was called reliability-centered maintenance or RCM.[3] The RCM process is primarily for scheduled maintenance and gives a definition of *preventive maintenance* only: "… the program of scheduled maintenance tasks necessary to ensure safe and reliable operation of the equipment."[4]

John Moubray, an industrial consultant in the United Kingdom, took the RCM philosophy and applied it to the maintenance of machines and equipment in a typical manufacturing plant. He presented the following definition of maintenance in his book on the subject.[5] *Maintenance* is "… ensuring that physical assets continue to do what their users want them to do."

Even though one can easily read into this definition what was intended, it is wide open to interpretation. It just so happens that, in some rare cases, users

[3]Nowlan, F. Stanley and Howard F. Heap, *Reliability-Centered Maintenance.* National Technical Information Service, Washington, DC, 1978.

[4]Nowlan and Heap, p. 11.

[5]Moubray, John, *Reliability-Centered Maintenance*, 2nd ed, Industrial Press Inc., NY, 1997.

want a tool, machine, or system to do something other than what it was designed to do. Using a glass bottle for a hammer is a good example. All the maintenance in the world cannot ensure that the bottle will be an adequate hammer. This definition seems a bit ambiguous for our purposes.

FAA definition of maintenance

In the Federal Aviation Regulations, FAR part 1, *maintenance* is defined as "… inspection, overhaul, repair, preservation, and replacement of parts."[6] Again, this describes what maintenance people do, but it is not a definitive description of what maintenance is intended to accomplish.

Hessburg's definition of maintenance

Jack Hessburg, former chief mechanic for the Boeing 777 design effort, has provided a definition of maintenance which gives a broader view of the field. "*Maintenance* is the action necessary to sustain or restore the integrity and performance of the airplane."[7] He goes on to say that maintenance "includes inspection, overhaul, repair, preservation, and replacement efforts." This definition is more accurate.

Kinnison's definition of maintenance

The author of this textbook feels that the above definitions—although well intended and, in most cases, adequate in general terms—are not fully descriptive of what the maintenance process is about. The definition in the box below will be used in this book.

> *Maintenance* is the process of ensuring that a system continually performs its intended function at its designed-in level of reliability and safety.

This definition implies the servicing, adjusting, replacement, restoration, overhaul, and anything else needed to ensure the proper and continual operation of the system or equipment, but it emphasizes the notion that the equipment was designed for a specific purpose (or purposes in the case of multifunction systems) with an inherent or designed-in level of reliability and safety. Not all systems and components, however, will require the same attention to accomplish the required maintenance. For example, some items need continual servicing and adjustment; others need oil, lubrication, or other fluids replaced or replenished; still others may require overhaul, or parts replacement to achieve this ultimate goal.

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[6]Federal Aviation Regulation part 1 contains definitions and abbreviations.

[7]Hessburg, Jack, *MRO Handbook*. McGraw-Hill, NY, 2000, p. 246.

We cannot make a system any better than its designed-in capabilities no matter how much maintenance we perform. We can only restore it to its designed-in level after deterioration has occurred. This definition, then, is more descriptive of the purpose of maintenance and what maintenance is supposed to accomplish for the operator.

Inherent Reliability

Inherent reliability is a term used frequently in aviation and already discussed in this text (Chaps. 1 and 2). This term may require some clarification. Nowlan and Heap state that "the inherent reliability of an item is not the length of time it will survive with no failures; rather, it is the level of reliability the item will exhibit when it is protected by preventive maintenance and adequate servicing and lubrication."[8] The authors go on to say that the degree of reliability achieved depends upon design characteristics of the equipment and the process used for determining the maintenance requirements (i.e., the MSG process). In other words, the inherent reliability of a system or component is both a function of the design and a function of the maintenance program established for it. The two are interrelated.

Mechanics, Technicians, Maintainers, Engineers

The terminology used by the world's airlines to identify maintenance personnel varies. The terms *mechanic*, *technician*, and *maintainer* are often used to identify those who perform the scheduled and unscheduled maintenance tasks of the unit's aircraft. In some organizations, however, these same people are called engineers, while in others, the term *engineer* is reserved for those personnel who have college degrees in one of the engineering fields. These people usually perform duties quite different from those of the line, hangar, and shop maintenance people.

In this book, for the sake of standardization of the discussion, we will define those who work on the scheduled and unscheduled aircraft maintenance tasks (line, hangar, or shop) as mechanics, technicians, or maintainers, while those who work in the technical services organization as specified in Chap. 7 will be called engineers.

Word Pairs Used in Aviation

There are a number of word pairs that we use in aviation that are assigned very specific meanings. These meanings are more precise than those addressed in the dictionary. Here are a few of them.

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[8]Nowlan and Heap, p. 103.

Verification and validation

These words are used in aviation, as well as in the railroad industry, in relation to determining the adequacy of maintenance processes and procedures. Although some dictionaries define one of these words with the other one, in the world of engineering and technology there are various definitions given depending on the application. In aviation, it is generally accepted that the two words have distinctly different meanings. Many procedures are written to test or measure the condition, accuracy, or availability of equipment and systems. The words *verification* and *validation* describe different approaches or concepts used to assure that maintenance has been properly addressed by such procedures.

Verification means that a test or procedure has been written and that, when read and understood by a knowledgeable person, it is correct, adequate, and acceptable for the purpose for which it was intended.

Validation, on the other hand, means that the written test or procedure has been performed by an appropriately trained maintenance person, and the procedure, as written, is understandable, adequate, and, most importantly, proven to accomplish the intended purpose.

In other words, verification means that the procedure exists and is acceptable based on the knowledge and understanding of the related equipment and on perusal of the procedure itself. Validation means that the procedure has actually been performed as written and is adequate and acceptable.

Operational and functional

Although these words are often used interchangeably in daily life, in aviation they are distinctly different. The terms are used in conjunction with the process of testing equipment, systems, or components; the difference is in the complexity of the testing.

Operational check means to operate the equipment, system, or component as usual (all modes and functions) and determine whether or not it is useable for its intended purpose. No special test equipment or tools are needed and no measurements are taken. An operational check is defined as "a task to determine if an item is fulfilling its intended purpose. This is a failure-finding task and does not require quantitative tolerances."[9]

Functional check means that the equipment, system, or component has been checked out using the necessary equipment and tools to measure certain parameters for accuracy (i.e., voltages, frequencies, and physical measures, such as gap size, length, weight, etc.). The official definition for a *functional check* is "a quantitative check to determine if each function of an item performs within specified limits."[10] The term *limits* here implies a check or measurement against some standard.

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[9]Air Transport Association of America (ATA); *Common Support Data Dictionary* (CSDD); revision 2001.1.

[10]ATA CSDD.

As an example of the differences in these two types of tests, consider the check-out of a radio. If you turn on the radio, tune in a station (by ear), and check for clarity of reception and adequacy of volume control, you have performed an operational check. If you use additional equipment to check the accuracy of the frequency dial and the magnitude of the volume, the input signal strength, etc., you have performed a functional check. The operational check uses only the equipment itself; the functional check uses additional equipment or tools for a more accurate measurement of the various parameters of the unit.

Functional and potential failure

The role of the maintenance program is to reduce failure. A failure is any unsatisfactory situation which can be unacceptable now or in the future.

Functional failure is the inability of an item to meet a specific performance standard. It is no longer satisfactory. It may have broken, or just lost capability to meet the standard. It must be corrected.

Potential failure is a detectable condition which shows that a functional failure is imminent or could happen very soon. Maintenance must be done if functional failure is to be prevented. When potential failure is detected, it alerts maintenance to perform actions to reduce the probability of a functional failure.

Both functional and potential failure can be classified in terms of their detection. The primary question is, can the operating crew detect that a problem has occurred or is about to occur? This will become very important to the decision logic used to develop the maintenance program.

Goals and objectives

There seems to be considerable confusion throughout the engineering profession, and perhaps other fields as well, about the similarities and differences between goals and objectives. Some modern dictionaries, as they have done with so many pairs of similar words, define one word with the other one making the two nearly synonymous. But these two words—*goals* and *objectives*—have always had specific meanings to this author and to many other people in the technical fields. We have taken the liberty of writing our own definitions for these terms in order to establish a clear understanding and application of the two words for use throughout this book.

> A *goal* is a point in time or space where you want to be; a level of accomplishment you want to achieve.

> An *objective* is the action or activity you employ in order to help you achieve a specific goal.

In other words, a goal is where you want to be; an objective is how you plan to get there.

Example: Suppose a person living in Seattle, Washington, wants to be in Dallas, Texas, for Christmas with family members. First, the mode of travel must be determined (private auto, bus, train, or airplane) and then, depending on which mode is chosen, the desired dates of departure and return must be determined. Of course, there are numerous decisions that must be made, and each possible choice will have its own pros and cons. This must be worked out ahead of time. In this simple example, being in Dallas for Christmas is the goal. The objective is to make the trip happen and that involves the planning and decision-making activities, which would vary with the mode of travel chosen.

Goals and Objectives of Maintenance

We have already established the fact, in Chap. 1, that we cannot make perfect systems and that the systems we have will fail at various times and for a variety of reasons. We have also established, in Chap. 1, various management actions to minimize the effects of service interruptions caused by these failures (LRUs, redundancy, minimum dispatch requirements). Also, the manufacturer has established a maintenance program (see Chap. 2) that includes numerous tasks at scheduled intervals, as well as references to other tasks and maintenance manual procedures for addressing the unscheduled failures. These procedures, however, are not quite enough. To establish an effective airline maintenance program that will effectively implement these tasks, achieve the reliability and safety standards we desire, and still maintain an adequate flight schedule to stay in business, we must have some additional guidelines. Namely, we need to establish some goals and objectives for an airline maintenance program.

Goals of a maintenance program

The purpose of any transportation company is to move people and/or goods from one place to another, usually for a profit. This means, to some people, that the operational part of the unit is more important than the maintenance part. As you will see later, the two are actually on a par as far as management and administration are concerned. But, the fact remains that the maintenance organization is in business to support the unit's operation. Maintenance must ensure that the flight department has vehicles available to carry out the flight schedule, and this schedule should be met with all required maintenance completed. Therefore, the goals of an airline maintenance program can be stated as follows:

1. To deliver airworthy vehicles to the flight department in time to meet the flight schedule
2. To deliver these vehicles with all necessary maintenance actions completed or properly deferred

The FAA requires maintenance to be done at specified intervals and to accepted standards. The FAA also requires that this work be done at or before the appointed time. If there are circumstances that prevent work being done (lack of parts or qualified maintenance personnel, time constraints, etc.) the FAA allows such maintenance to be deferred to a more opportune time. Deferrals of certain items can be in accordance with the MEL; others can be deferred through the short-term time escalation program identified in the FAA approved maintenance program. The accepted standards include the manufacturer's, the regulator's, and the operator's standards of safety and reliability. The time limits refer to the maximum number of hours or cycles of operation and any calendar limits (days, months, etc.) as prescribed by the approved maintenance program. The repair must be completed within the specified deferral time, and this cannot be extended.

Maintenance program objectives

To achieve the stated goals of a maintenance program, we need to identify the objectives we will employ. The Air Transport Association of America (ATA) has identified four objectives of a maintenance program.[11] The FAA, the airframe manufacturers, and the airlines repeat these objectives throughout their own literature. These objectives were developed in conjunction with the establishment of the initial maintenance program when a new airplane model was being developed (i.e., the MSG-3 process of Chap. 2). These objectives are not quite sufficient for a good, effective maintenance program at the operator's level once the equipment enters service. For this in-service activity, five objectives of a maintenance program are established and addressed in this textbook. The list below contains the ATA objectives of the MSG-3 maintenance development manual with the addition of one very important objective—objective number 3 in this new list. The objectives of an airline in-service maintenance program are as follows:

1. To ensure the realization of the inherent safety and reliability levels of the equipment
2. To restore safety and reliability to their inherent levels when deterioration has occurred
3. To obtain the information necessary for adjustment and optimization of the maintenance program when these inherent levels are not met
4. To obtain the information necessary for design improvement of those items whose inherent reliability proves inadequate
5. To accomplish these objectives at a minimum total cost, including the costs of maintenance and the cost of residual failures

[11] ATA MSG-3—*Operator/Manufacturer Scheduled Maintenance Development*, Revision 2001.1. Air Transport Association of America, Inc., Washington, DC, 2001.

The ATA MSG-3 manual states the following:

> These objectives recognize that maintenance programs, as such, cannot correct deficiencies in the inherent safety and reliability levels of the equipment. The maintenance program can only prevent deterioration of such inherent levels. If the inherent levels are found to be unsatisfactory, design modification is necessary to obtain improvement.

We need to modify that statement to accommodate the third objective we added. The maintenance program as developed by the manufacturer is only a general guideline intended for use by new operators of new equipment. In service, this program may have to be adjusted to fit specific airline operations. Experience may show an operator that maintenance intervals established by the manufacturer may not be the best for that airline's operational environment. The results of maintenance may also be less than expected because of bad parts, improper or inadequate procedures, or even the lack of proper training of the mechanics. All of these could affect the overall reliability and safety of the equipment, and they should be addressed by the airline before calling the manufacturer and requesting or demanding a redesign of that equipment as implied by objective 4. This is the reason for the added objective.[12]

Contrary to popular belief, the manufacturers cannot be blamed for all the problems occurring with the equipment once it is in the field. Therefore, the airline must look into its own operation first. Keep in mind, however, that any serious problems in any of the areas relating to the airline's ability to meet its objectives could affect the operator's FAA certification. So these conditions should always be monitored closely and corrected if found to be lacking.

Maintenance Program Content

The ATA MSG-3 manual discusses what a maintenance program should be as stated below.

> The maintenance program consists of two groups of tasks: a group of scheduled tasks to be accomplished at specified intervals and a group of non-scheduled tasks which result from (a) conducting the scheduled tasks, (b) from reports of malfunctions, and (c) from data analysis.
>
> An efficient [maintenance] program is one which schedules only those tasks necessary to meet the stated objectives. It does not schedule additional tasks which will increase maintenance costs without a corresponding increase in reliability protection.

Thus, a maintenance program consists of scheduled maintenance tasks to keep equipment and systems in top operating condition (objective 1); unscheduled maintenance tasks to address in-service failures (objective 2); a continuing analysis and surveillance activity to optimize the total maintenance effort by

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[12]More on the discussion of causes for not achieving the inherent level of safety and reliability can be found in Chap. 18.

improving the maintenance program (objective 3) or by requesting a redesign of equipment (objective 4); and an effort to minimize maintenance costs (objective 5).

Discussion of the Five Objectives

Objective 1. To ensure the realization of the inherent safety and reliability levels of the equipment. This objective is satisfied by a series of scheduled maintenance tasks. The scheduled maintenance tasks may be developed by the manufacturer of the equipment, by the maintenance organization of the airline, a third-party maintenance company, by some industry-supported organization (trade association), or by some combination of these. Usually, the manufacturer supplies the operator with basic information on how the equipment works and some basic troubleshooting techniques, as well as servicing, removal/installation procedures, and maintenance procedures.

In the commercial aviation industry, the manufacturers, the vendors, and the operators get together and develop a maintenance program for the scheduled maintenance. The program developed is based on knowledge of the equipment, as well as knowledge and experience with the equipment in the operational environment. The process used to do this was discussed in Chap. 2.

Objective 2. To restore safety and reliability to their inherent levels when deterioration has occurred. This objective is satisfied by unscheduled maintenance tasks developed by the MSG process and contained in the manufacturer's maintenance manual. Unscheduled maintenance tasks result from a combination of activities: (*a*) troubleshooting actions that determine the nature and cause of the problem; (*b*) removal and replacement of parts or components to effect repair or restoration; and (*c*) performance of certain tests and adjustments to ensure proper operation of the system or equipment after the "fix" has been implemented. Unscheduled maintenance tasks, developed by the manufacturer, are sometimes modified, in the field, by the operators through experience. Such modifications, however, must be approved by the FAA.

Reports of malfunctions come from operators and users through various means, usually a logbook kept in the airplane or by verbal or written reports from operators, flight crews, cabin crews, users, or maintenance personnel. Maintenance tasks that result from data analysis are usually actions that result from some form of reliability program or other failure-rate analysis activities conducted by quality control (QC).

Objective 3. To obtain the information necessary for adjustment and optimization of the maintenance program when these inherent levels are not met. This objective concerns the adjustment or optimization of a maintenance program by an operator. If it is not possible to meet the inherent safety and reliability of the system, or if failure rates or removal rates of certain items are too high, the problem must be investigated to determine the reason for this condition. The problem

could be in the quality of maintenance performed, the inferiority of parts or components used in maintenance, the inadequacy of the maintenance processes and procedures used, or in the maintenance intervals themselves. In some cases, the problem may be electromagnetic or mechanical interference from other systems in the airplane or on the ground. As a result of such investigations, the airline may need to adjust its maintenance program, provide additional training to its personnel, or adjust its parts control procedures to achieve the equipment's inherent level of safety and reliability.

Objective 4. To obtain the information necessary for design improvement of those items whose inherent reliability proves inadequate. This objective is applied when the operator cannot achieve the desired level of reliability due to some deficiency in the design. If the investigation associated with objective 3 shows no deficiency in the operator's program or in the performance of the mechanics, then objective 4 is applied. Coordination with other operators using the same equipment and with the manufacturer is usually involved here. A joint effort to resolve the problem usually results in redesign by the manufacturer and subsequent modification developed by the manufacturer and incorporated by the operator. Other operators of the same equipment, as well as regulatory authorities, may take part in the investigation and redesign process. (This objective can also be applied when, in the opinion of the operator, a higher level of performance is deemed desirable for a given system.)

Objective 5. To accomplish these objectives at a minimum total cost, including the costs of maintenance and the cost of residual failures.[13] This objective is important to a good, effective maintenance program. A loose interpretation of this objective is "do not do any more maintenance than you have to, to meet inherent levels of safety and reliability; and do not do any less maintenance than necessary to meet those levels." In other words, a good maintenance program, to be effective, must provide airworthy vehicles to the operations department at a reasonable cost.

As an example, suppose a component or system is checked daily, in accordance with the scheduled maintenance program, and a problem is found maybe every 2 or 3 weeks (or even less often). It is sensible, then, to reschedule this check to perhaps a weekly or even a biweekly interval to reduce maintenance costs.

When it comes to maintenance, more is better but only up to a point. Too little maintenance may lead to early degradation and failure. But increasing the maintenance beyond that which restores the inherent level of safety and reliability will provide no additional benefit, although it will cause increased maintenance costs.

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[13]Residual failures are those failures that would occur because the airline deemed that, for economic reasons, certain maintenance tasks were not employed or certain modifications were not installed. All costs must be considered when making such decisions: the cost of incorporation as well as the cost of continued maintenance (failures) resulting from not incorporating.

Economy must also be considered when modifications are suggested by the manufacturer or others. Objective 5 requires that the airline weigh the cost of making the modification against the benefits derived from the modification. The benefits may result in increased operational capabilities and at the same time reduced maintenance costs. At times, however, the cost of modification may not be justified. If the cost of modification exceeds the savings, then the modification is not justified unless the measurable increases in performance and/or safety can justify the cost.

Summary

This chapter has addressed various terms relating to the maintenance effort which will be used or referenced throughout the remainder of the textbook. The use and understanding of these terms and definitions should become second nature to the student.

Chapter

4

Aviation Industry Certification Requirements

Introduction

The aviation industry is the most heavily regulated of all the transportation modes. With the exception of certain requirements for a business license and licensing of the vehicles and drivers, one can enter the taxicab business quite easily. Trucking is pretty much the same. Transit buses, generally operated by nonprofit or government entities, have similar licensing requirements for vehicles and drivers but the vehicles themselves are built and sold with little government regulation except for safety and air pollution items. The railroads undergo more stringent controls, however, as do the operators of commercial water vessels. But in the aviation industry, there is a considerable amount of regulation, from the design of the vehicles through the manufacturing efforts to the operation and maintenance of the vehicles. There are also regulatory requirements for the business side.

Aircraft Certification

There are three certificates necessary for full certification of the airplane. These documents—the type certificate, the production certificate, and the airworthiness certificate—certify, respectively, the aircraft design, the manufacturing process, and the aircraft itself.

Type certificate (FAA form 8110.9)

To begin with, each aircraft designed and built for commercial as well as private operation must have an approved type certificate (TC). This certificate is applied for by the designers of the vehicle once the basic design has been determined. The TC defines the vehicle, engines and/or propellers, and the various

instruments, systems, and equipment that make up the model. If more than one engine type (i.e., derivatives of existing engines or engines from different manufacturers) is offered for the same vehicle, the TC must cover the characteristics and limitations of all of them. The same is true on other equipment, systems, and accessories. The TC also defines the capabilities and limitations of the vehicle, such as passenger and cargo carrying limits, altitude limits, fuel capacity, and top speed as well as cruising speed. All of these parameters combined, which define the airframe/engine combination, must be identified on a data sheet attached to the certificate. The aircraft/engine combination is designed to exacting safety and airworthiness standards set by the FAA, and this design must be proven to the FAA by means of inspections and test flights. A final FAA proving flight is conducted before the TC is awarded.

The TC is applied for early in the design stages but is not awarded until the aircraft is actually built, tested in flight, and proven to meet the standards of safety and airworthiness. For example, the Boeing Company applied for the TC for the 757-200 airplane in 1978; it was awarded by the FAA's Aircraft Certification Office (ACO) in 1982.

For variations, or derivatives, of a given model, the TC can be amended. Suppose the manufacturer builds and sells a passenger airplane. After this model enters service, the manufacturer decides to produce an all-cargo version of the same basic airplane. The resulting design will be different: no passenger windows, different flooring (to handle cargo pallets), and other variations which change the basic characteristics of the vehicle. This will require further FAA approval but, instead of issuing a new TC, the FAA will supplement the original TC which is known as supplemental type certificate (STC). The STC will define the existing product design change and how the new modification will be affecting the existing product. The model/type will be added to the certificate and an additional data sheet will be attached to delineate the new model's characteristics and differences. A flight test proving of the new configuration will be required, and a supplemental TC will be issued. The FAA will only issue type certificates (design approvals) for products manufactured in the United States or for foreign-made products intended for use under U.S. registry or by U.S. operators under lease or charter.

A sample of the TC is shown in Fig. 4-1. This is the first page showing the airplanes covered. Additional information concerning the design is given in the data sheets (not shown) attached to the TC. The TC remains in effect until superseded, revoked, or a termination date is established by the FAA. Figure 4-2 shows a an STC.

Production certificate (FAA form 8120-4)

Once the TC is awarded, the manufacturer applies for the production certificate (PC) by submitting application form 8110.12 to the FAA's Manufacturing Inspection District Office (MIDO). The production certificate is awarded after the FAA is satisfied with the quality control system that also consists of necessary manufacturing and production facilities, effective quality system for compliance as per requirements of 14 CFR part 21, and approved design data of each unit

The United States of America

Department of Transportation

Federal Aviation Administration

①

Type Certificate

②

Number ______ ③

This certificate issued to ④ certifies that the type design for the following product with the operating limitations and conditions therefor as specified in the Federal Aviation Regulations and the Type Certificate Data Sheet, meets the airworthiness requirements of Part ⑤ of the Federal Aviation Regulations.

⑥

This certificate, and the Type Certificate Data Sheet which is a part hereof, shall remain in effect until surrendered, suspended, revoked, or a termination date is otherwise established by the Administrator of the Federal Aviation Administration.

Date of application: ⑦

Date of issuance: ⑧

By Direction of the Administrator

(Signature)______________________

⑨

(Title) ______________________

This certificate may be transferred if endorsed as provided on the reverse hereof.

Any alteration of this certificate and/or the Type Certificate Data Sheet is punishable by a fine not exceeding $1,000, or imprisonment not exceeding 3 years, or both.

FAA FORM 8110-9 (2-82)(Representation)

Figure 4-1 FAA type certificate (sample). (1) Type of product (airplane, engine, propeller); (2) "IMPORT" if applicable; (3) TC number as assigned; (4) applicant's name; (5) applicable Federal Aviation Regulation; (6) product type designation: "Airplane Model 120." Additional models if applicable; (7) date of original application; (8) date TC is issued. When later models are added, retain original date and add new date; (9) signature of manager, FAA accountable directorate.

United States of America

Department of Transportation-Federal Aviation Administration

Supplemental Type Certificate

Number

This certificate, issued to

certifies that the change in the type design for the following product with the limitations and conditions therefor as specified hereon meets the airworthiness requirements of Part of the Regulations.

Original Product-Type Certificate Number:

Make:

Model:

Description of Type Design Change:

Limitations and Conditions:

This certificate and the supporting data which is the basis for approval shall remain in affect until surrendered, suspended, revoked, or termination date is otherwise established by the administrator of the Federal Aviation Administration.

Date of application: Date reissued:

Date of issuance: Date amended:

By Direction of the Administrator

(Signature)

(Title)

Any alteration of this certificate is punishable by a fine not exceeding $1,000, or imprisonment not exceeding 3 years, or both.

This certificate may be transferred in accordance with FAR 21.47.

FAA FORM 8110-2 (10-68)(Representation)

Figure 4-2 FAA supplemental type certificate (sample).

(aircraft) built to the TC standards. In other industries, it is possible to build a hand-made prototype of a product which often differs from the mass-produced units. This is then used to demonstrate the unit's capabilities. This is not the case in aviation. Each copy of the aircraft must be built to the type certificate standards.

A manufacturer usually gets one production certificate. Each subsequent aircraft manufactured by that company will be added to the original PC by the FAA. Figure 4-3 shows the first page of a typical production certificate. A production certificate may have a production limitation record (PLR), shown in Fig. 4-4, which lists all the TCs and STCs issued to that manufacturer as well as any limitations. The PC is effective for as long as the manufacturer complies with the requirements of the original issuance. For new technology, or for derivative or new aircraft, the FAA may conduct additional inspections of the manufacturer's facilities and processes if it deems that to be necessary. The FAA may cancel, suspend, supersede, or revoke the PC for just cause at any time.

Airworthiness certificate (FAA form 8100-2)

The third certificate, the airworthiness certificate (AC), is awarded by the FAA's MIDO to each aircraft produced by a manufacturer. This certificate confirms that the aircraft to which it is awarded has been inspected and found to conform with its type certificate and to be in airworthy condition. This airworthiness certificate is applied for by the manufacturer and awarded by the FAA after the aircraft has passed all inspections and a successful flight test—when the aircraft "rolls out the door"—just prior to delivery to the customer. The airworthiness certificate contains the aircraft's unique serial (tail) number.

The standard AC remains in effect as long as the following conditions are met: (*a*) the aircraft meets its type design; (*b*) the aircraft is in a condition for safe operation; (*c*) all applicable airworthiness directives (ADs) have been incorporated; and (*d*) maintenance and alterations are performed in accordance with applicable FARs. The FAA can cancel, suspend, supersede, or revoke the AC if, in its opinion, any of the above have been violated.

Figure 4-5 shows a typical airworthiness certificate. FAA rules require that this certificate be prominently displayed in the aircraft. In passenger airliners, it is usually posted by the main entry door. Look for it the next time you board a commercial aircraft. If you do not see it, ask a crew member where it is.

The FAA form 8100-2 is also allowed for the following categories of vehicles, including normal, utility, acrobatic, transport, and special classes. Special airworthiness certificate FAA Form 8130-7 is not used for commercial aircraft/airline use. The FAA authorization is required to operate any type of aerial vehicle in U.S. airspace. The following are the examples of categories:

Primary. Aircraft flown for pleasure and personal use

Restricted. Agriculture, forest, and wildlife, surveying, patrolling, weather use

Light-Sport. Light sport aircraft, ultralight vehicle use

Experimental. R&D, air racing, crew training, unmanned aircraft system use

The United States of America

Department of Transportation

Federal Aviation Administration

Production Certificate

Number **6CE**

This certificate, issued to

ABC AIRCRAFT COMPANY

whose business address is

4954 AIRPORT DRIVE

KANSAS CITY, MISSOURI

and whose manufacturing facilities are located at

752 PRIMROSE LANE

St. LOUIS, MISSOURI

authorizes the production, at the facilities listed above, of reasonable duplicates of **airplanes**
which are manufactured in conformity with authenticated data, including, drawings, for which Type Certificates specified in the pertinent and currently effective Production Limitation Record were issued. The facilities, methods, and procedures of this manufacturer were demonstrated as being adequate for the production of such duplicates on date of **5 May, 1999.**

Duration: ***This certificate shall continue in effect indefinitely, provided, the manufacturer continuously complies with the requirements for original issuance of certificate, or until the certificate is canceled, suspended, or revoked.***

By direction of the Administrator

Date issued:
August 10, 1999

J.J. Jones *. J. J. Jones*
Manager, Manufacturing Inspection Office

This Certificate is not Transferable , **AND ANY MAJOR CHANGE IN THE BASIC FACILITIES, OR IN THE LOCATION THEREOF, SHALL BE IMMEDIATELY REPORTED TO THE APPROPRIATE REGIONAL OFFICE OF THE FEDERAL AVIATION ADMINISTRATION**

Figure 4-3 FAA production certificate (sample).

The United States of America
Department of Transportation
Federal Aviation Administration

Production Limitation Record

The holder of
Production Certificate No. **6CE**
may receive the benefits incidental to the possession of such certificate with respect to

AIRCRAFT
(OR AIRCRAFT PROPELLERS, AIRCRAFT ENGINES, AS APPLICABLE)

manufactured in accordance with the data forming the basis for the following Type Certificate(s) No.

Type Certificate	Model	Date Production Authorized
A 920CE	ABC 2047R	August 10, 1978
A 9CE	ABC 258D	August 10, 1978
STC 492CE	Drawing List HC-B2YK-6	August 10, 1978

(Note: Any number of columns may be used provided the material is neat and legible. Additional PLRs may be used when necessary. Additional PLRs shall be numbered "1 of 2," "2 of 2," as appropriate to the number of pages involved.)

LIMITATIONS:

(if any)

August 10, 1999
Date of issuance

By Direction of the Administrator
J. J. Jones
J. J. Jones
Manager, Manufacturing Inspection District Office

FAA FORM 8120-3 (7-67)

Figure 4-4 FAA production limitation record (sample).

UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION FEDERAL AVIATION ADMINISTRATION

STANDARD AIRWORTHINESS CERTIFICATE

1. NATIONALITY AND REGISTRATION MARKS	2. MANUFACTURER AND MODEL	3. AIRCRAFT SERIAL NUMBER	4. CATEGORY
N12345	**Boeing 747-400**	**197142**	**Transport**

5. AUTHORITY AND BASIS FOR ISSUE
This airworthiness certificate is issued pursuant to the Federal Aviation Act of 1958 and certifies that as of the date of issuance, the aircraft to which issued has been inspected and found to conform to the type certificate, therefor, to be in condition for safe operation, and has been shown to meet the requirements of the applicable comprehensive and detailed airworthiness code as provided by Annex 8 to the Convention on International Civil Aviation, except as noted herein:

EXEMPTION NO. 1013A FAR 25.471(b): Allows lateral displacement of C.G. from airplane centerline.

6. TERMS AND CONDITIONS
Unless sooner surrendered, suspended, revoked, or a termination date is otherwise established by the Administrator, this airworthiness certificate is effective as long as the maintenance, preventive maintenance, and alterations are performed in accordance with Parts 21, 43, and 91 of the Federal Aviation Regulations, as appropriate, and the aircraft is registered in the United States.

DATE OF ISSUANCE	FAA REPRESENTATIVE	DESIGNATION NUMBER
11/29/92	**John Q. Publican** *John Q. Publican*	**DMIR ANM 1234**

Any alteration, reproduction, or misuse of this certificate may be punishable by a fine not exceeding $1,000, or imprisonment not exceeding 3 years, or both. THIS CERTIFICATE MUST BE DISPLAYED IN THE AIRCRAFT IN ACCORDANCE WITH APPLICABLE FEDERAL AVIATION REGULATIONS.

FAA Form 8100-2

Figure 4-5 FAA airworthiness certificate (sample).

Delivery Inspection

Prior to delivery to a customer, the aircraft usually undergoes an inspection by that customer to ensure that the vehicle has been built to the customer's specifications and requirements. This includes basic design, options, and customer-furnished equipment (if any), down to the shape, color, and positioning of the airline logo. This inspection by the operator may be cursory or detailed and often includes a test flight by their own flight and cabin crews. Any discrepancies found should be corrected by the manufacturer before delivery is taken. Commercial carriers will often fly the aircraft "around the flag pole" at the builder's delivery center to perform this checkout. Some may take the aircraft on a "shakedown flight" from the delivery center to the carrier's home base. Once the customer accepts the aircraft from the manufacturer, that customer is fully responsible for maintaining the unit in airworthy condition in accordance with its own maintenance program and regulatory authority rules.

Operator Certification

An operator cannot just buy an aircraft and enter into commercial service simply by getting a license and petitioning the market for customers. In aviation, for a prospective operator to enter the business, he or she must meet the requirements of both the Department of Commerce, with respect to the business aspects of airline operation, and the Department of Transportation (DOT), primarily the FAA, with respect to the technical aspects. In short, the prospective operator must provide the necessary information to ensure that he or she understands the business of commercial aviation; understands the operational and maintenance aspects of commercial aviation operation; and has the necessary people, facilities, and processes in place needed to carry out that business.

The secretary of the DOT issues a "certificate of public convenience and necessity" authorizing the recipient to enter into commercial transportation. The secretary determines that the applicant is "fit, willing, and able" to perform the service.[1]

An operating certificate (OC) is then issued by the Flight Standards District Office (FSDO) of the FAA to the airline company. This certificate authorizes the carrier to operate scheduled air transportation service under the Federal Aviation Act of 1958 as amended. The operating certificate is not transferable to another operator.

The OC remains in effect indefinitely unless it is surrendered by the operator, superseded by another certificate, or revoked by the FAA. The OC states, in part, that the airline is authorized to operate in accordance with the Federal Aviation Act and its rules and regulations, and "the terms, conditions, and limitations contained in the operations specification."

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[1]Kane, Robert M. *Air Transportation*, 13th ed. Kendall/Hunt, Dubuque, IA, 1999.

In part, the Federal Aviation Act of 1958 requires the airline to develop an operations specifications document (Ops Specs) for each type of aircraft to be operated in commercial service. The Ops Specs is a parent document; i.e., in addition to specific information listed in the document, it may identify other airline documents, by reference, that fully describes certain airline operations that apply to the model. The Ops Specs outlines such operational activities as (*a*) the type of service to be offered, passenger, cargo, or combination; (*b*) the type of aircraft to be used; (*c*) the routes to be flown; (*d*) the airports and alternate airports that will be used; (*e*) the navigation and communications facilities to be utilized on each route; (*f*) the way points used in navigation; and (*g*) the takeoff and approach routes, including any alternate approach routes, at each airport.

The Ops Specs must also identify the maintenance and inspection program applicable to the model, including the scheduled and unscheduled maintenance programs; the inspection program; and the engine and equipment repair program (off-aircraft maintenance). Other aspects of maintenance, such as the quality assurance and reliability programs, will also be defined. If any portion of the aircraft or systems maintenance is performed by a third party, that agreement must also be addressed in the Ops Specs.

The operations specifications document is a detailed document and is put together by the principal maintenance inspector (PMI) assigned to the airline by the FAA and by the airline personnel. It is tailored to each operation.

Certification of Personnel

The minimum requirements for airline operations under part 121 state that the airline must have sufficient full-time qualified management and technical personnel to ensure a high degree of safety in its operations. The basic personnel requirements are a director of safety; a director of operations, a director of maintenance, a chief pilot, and a chief inspector. This is only a suggestion, however. The FAA goes on to say that they may approve any other number of positions and any other titles as long as the operator can show that it can perform the operation safely.[2] The people in such positions must have the necessary "training, experience, and expertise"[3] for conducting the business of aviation and must be knowledgeable of the regulatory and airline policies and procedures as they relate to their specific jobs. The airline identifies the "duties, responsibilities, and authority"[4] of these management personnel.

Aviation Maintenance Certifications

Training begins with someone who is interested in becoming an aircraft maintenance technician. This normally starts in high school. Some high schools have

[2]Federal Aviation Regulation 119.65 (a), (b).

[3]Federal Aviation Regulation 119.65 (c), (d).

[4]Federal Aviation Regulation 119.65 (e).

contracts with aviation maintenance training schools that allow student to take classes and graduate with Airframe and Power Plant (A&P) licenses concurrent with their high school graduation.

The aviation maintenance training schools must train all individuals and certify them in accordance with FAA regulations. To earn an A&P license, aviation schools must fulfill three requirements, which are the bare minimum, prior to taking the FAA's A&P exam. The Avionics/FCC license course is optional.

1. General aviation course
2. Airframe course
3. Power plant course
4. Avionics/FCC license course

General aviation course

The general aviation course is a building block for or a foundation to aviation maintenance. When a person starts an aviation program, he or she has never set foot in the world of aviation maintenance and does not know if they will succeed, since not everyone is suited for this type of work. The general aviation course provides a systematic training approach to an industry where things change overnight. The history of aviation, from the Wright Brothers to the moon landing to supersonic flights, has created a desire to better understand the place of maintenance in aviation. That is where the general aviation fundamental kick-starts and delivers necessary information for one to obtain airframe and power plant ratings. General aviation courses are easy to understand with cross references, diagrams, and subject matter, and they are an excellent resource for someone who is starting a career in aviation maintenance. General courses also include Federal Aviation Regulations (FAR) and Advisory Circulars (AC).

Airframe course

The airframe course book is one of the heaviest text books I have ever come across. It is full of all kinds of information about aircraft metals, structure, and all other components, excluding the aircraft engines, which we will discuss in the power plant section. Aircraft construction requires different types of components, structures, and subassemblies to build an aerodynamic aircraft. Aircraft manufacturers have a systematic approach to building an aircraft, such as body of the aircraft, tail section, and wings.

Airframe courses provide an understanding of aircraft structures and components. While students are going through these courses, they are working hands-on in shops on aircraft, learning how to cut, tear, weld, and lubricate aircraft systems and components as they progress through the airframe course. Aviation schools mimic the aviation maintenance shop that you will find in any aircraft maintenance facility of a repair station or an airline. An aviation school is where a student would learn how to use complex tooling to remove and replace components, aircraft instruments, and hydraulic and pneumatic systems.

Power plant course

Power plant history can be traced back to Leonardo daVinci. The power plant course is an introduction to aircraft engines, their design, and the construction of reciprocating engines and turbine engines. This course provides a basic breakdown of power plant system/aircraft engine maintenance, the dismantling and repairing of reciprocating and turbine engines, and learning knowledge about the future of power plant maintenance. The power plant course also covers the operation of fuel delivery systems of an engine, functioning of cooling and exhaust, and maintenance and troubleshooting of ignition systems.

After completion of all three general, airframe, and power plant courses, the student must take oral and practical exams. Oral and practical tests are proctored by an FAA flight standard inspector or by an FAA-designate mechanics examiner (DME). Oral exams are based on knowledge of aircraft and power plants, and there are a series of questions. In the airframe and power plant practical test, the DME will generate any type of airframe and power plant situation of inconsistency problem, and the student must use his or her knowledge of airframes and power plants to correctly fix the problem by using the aircraft maintenance manual as required. The aircraft maintenance technician goes through a rigorous training and advances to master all the systems. The new training methods are eliminating the need for avionic technicians. Now an A&P technician can perform avionics functions as well, due to new training, user-friendly manuals, AMT-friendly aircraft, and new troubleshooting systems.

Avionics/FCC license course

Avionics courses are designed to prepare a student for an entry-level position in the electronics/avionics field. The curriculum is an introduction to electronic and avionic theory and practical applications. Avionics technicians normally work in a line maintenance environment where they are troubleshooting aircraft electronic systems, radar, GPWS, terrain collision and avoidance systems, removing and replacing LRUs, and soldering broken wires. Being an avionics technician requires great attention to detail.

Aviation Industry Interaction

The aviation industry is made up of aircraft manufacturers; manufacturers and vendors of parts, systems, and accessories for the aircraft; airline operators; third-party maintenance organizations; trade associations, such as the Air Transport Association of America (ATA) and the International Air Transport Association (IATA); flight crew, cabin crew, and mechanics' unions; and regulatory authorities. This integrated group of professionals is constantly working together to develop and improve aviation both technically and operationally. This is somewhat unique compared to other transport modes. This continuous quality improvement (CQI) concept was in effect in the commercial aviation field long before it became standard procedure in other industries.

Chapter

5

Documentation for Maintenance

Introduction

The documentation for maintenance is required by the FAA. Advisory Circular AC 120-16E, Air Carrier Maintenance Programs, refers to the air carrier maintenance manual system, maintenance record/documentation keeping system, and various other requirements. It has been said that the paper documentation required for the maintenance of a modern jet airliner weighs about as much as the aircraft itself! Whether this is true or not, there is a considerable amount of documentation required to understand, identify, and implement the maintenance requirements. In recent years, computers have replaced paper, but the reduction is less than it seems, since the requirements for data and reporting remain the same.

The aircraft documentation system can be defined as "cradle to grave." When the aircraft is built, the documentation starts, and throughout its service life the documentation is gathered in the form of maintenance performed log pages, Engineering Order (EOs), Airworthiness Directive (ADs), Service Bulletins (SBs), Fleet Campaign Directives (FCDs), records of any minor or major repairs, and phase checks. When an aircraft is sold, decommissioned, and retired, all the paperwork must follow the aircraft.

In this chapter we will not be talking about required maintenance forms; those will be discussed later in Chap.10. The main focus of this chapter is to understand documentation that identifies an aircraft, its systems, and the necessary work to repair and maintain them. Some of the documents will be customized for the operator by the aircraft manufacture vendor to the manufacturer, while others will be generic. Most of these documents have standard revision cycles, and changes are distributed on a regular basis by the airframe manufacturer.

Controlled documents are used in operation and /or maintenance of the aircraft in accordance with the FAA regulations. These types of documents have

limited distribution within the airline and require regular revision with a list of revisions and active and rescinded page numbers. The operator is required to use only up-to-date documents. The written information is provided by the airframe manufacturer and the manufacturer of the systems and equipment installed on the aircraft. The documents provided by the regulatory authority and the documentation written by the airline itself detail the individual maintenance processes. We will be discussing the following documentation:

1. Manufacturer's documentation
2. Regulatory documentation
3. Airline-generated documentation
4. ATA document standard

Manufacturer's Documentation

Table 5-1 indicates the documents provided to an operator by the airframe manufacturer for the maintenance of the aircraft. The form and content of the documents sometimes varies from one manufacturer to another. The table identifies, basically, the type of information the airframe manufacturer makes available to its customers. Some of the documents can be customized for the airline or operator to only include configuration and equipment. These are called *customized documents* by the manufacturer and are noted at the bottom of Table 5-1.

TABLE 5-1 Manufacturer's Documentation

Title	Abbreviation
Airplane maintenance manual*	AMM
Component location manual	CLM
Component maintenance manual	CMM
Vendor manuals	VM
Fault isolation manual*	FIM
Illustrated parts catalog†	IPC
Storage and recovery document‡	SRD
Structural repair manual	SRM
Maintenance planning data document	MPD
Schematic diagram manual*	SDM
Wiring diagram manual*	WDM
Master minimum equipment list	MMEL
Dispatch deviation guide	DDG
Configuration deviation list	CDL
Task cards*	TC
Service bulletins	SBs
Service letters	SLs

*Customized to contain customer configuration.
†Customized on request.
‡Information may be included in AMM for recent model aircraft.

Other maintenance documents that normally accompany aircraft manufacturer documents are the vendor documents. These documents contain engine manufacturer, flight crew seats, passenger seats, aircraft galley manuals, and other suppliers' component repair manuals.

Airplane maintenance manual

The airplane maintenance manual (AMM) is a formal document containing all the basic information on the operation and maintenance of the aircraft and its on-board equipment. It starts with an explanation of how each system and subsystem works (detailing description and operation) and describes such basic maintenance and serving actions as removal and installation of LRUs and various tests performed on the system and equipment, such as functional test, operational check, adjustments, the replenishing of various fluids, and other servicing tasks. The AMM normally excludes any type of repair which may include structures or fiberglass paneling. The AMM uses the ATA coding system. Upon completion of a discrepancy or maintenance task, a technician signs off the log book or nonroutine work card (NRWC) using the AMM reference associated with the ATA chapter and subchapter system. (See ATA coding later in the section on the ATA document standard).

Component and vendor manuals

Any component built by the airframe manufacturer will be accompanied by a component maintenance manual (CMM) written by the manufacturer. Normally, the aircraft manufacturers make the aircraft, while other systems, such as engines, landing gears, flight crew seats, and passenger seats, are purchased from outside vendors, but when the aircraft manufacturer sells the aircraft, the other vendors' CMMs accompany these items, in case parts need to be repaired or replaced. The CMM shows the breakdown of all components that make a complete part. The components installed on the aircraft are chosen by the airlines and are installed during or after the aircraft is completed.

For example, in the flight crew seat, if the vertical adjusting cable is broken the technician refers to the CMM for the cable part number and removes and replaces it. The maintenance task is accomplished, restoring a component and bringing it back to a serviceable state. CMM are commonly used in a shop situation, since airlines normally remove and replace complete part assemblies to save time. The CMM is part of the technical data normally approved by the FAA.

Fault isolation manual (FIM)

The FIM contains a set of fault isolation trees provided by the aircraft manufacturer to help troubleshoot, isolate the section where the fault occurred, and identify and pinpoint problems related to various systems and components on the aircraft. The aircraft faults system normally shows the fault occurrence at the flight deck on the engine-indicating and crew-alerting system (EICAS)

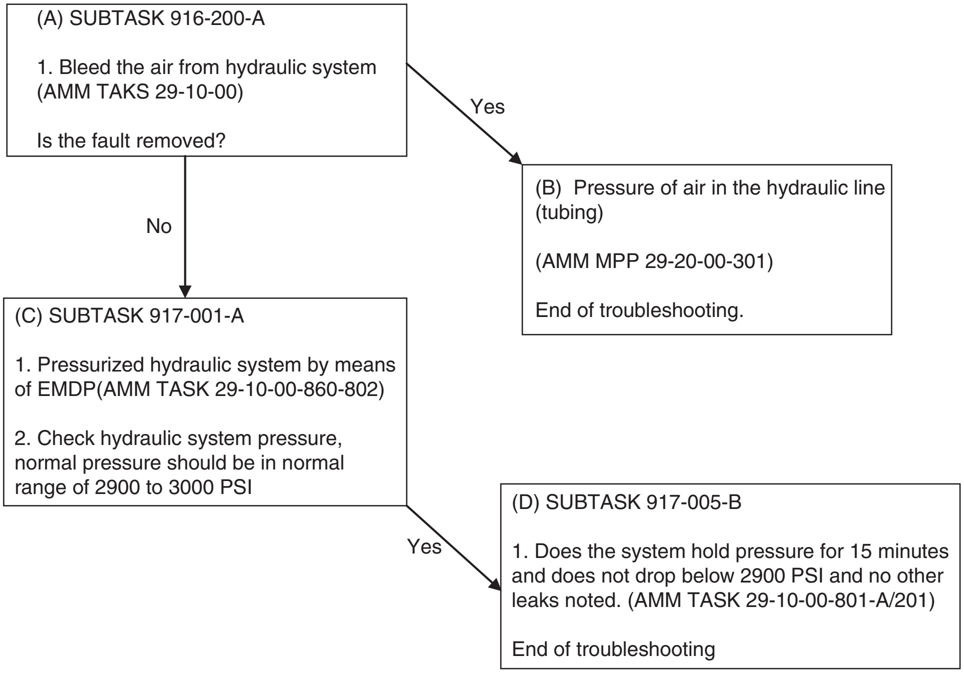

Figure 5-1 Example of an FIM.

message screen. The EICAS shows faults in a yellow/amber color, which alerts the flight crew that a fault has occurred.

The FIM is a block diagram that provides a reference to AMM tasks and subtasks. At the end of each task, it will ask, "Is the fault removed?" The AMT must follow the subsequent arrows indicating Yes or No to further troubleshoot. If no further maintenance is required, the discrepancy has been resolved and no further action needs to be taken. The flow diagram is designed to locate many but not all problems within the various systems.

Figure 5-1 is an example of an FIM:

Example: The hydraulic system does not reach normal operation range of 2900 to 3000 PSI.

Component location manual (CLM)

The CLM provides the location of all the major equipment items of the aircraft. Normally, AMTs know how to locate a component when replacing it, but the CLM is a great tool for finding the part number of the component and its location as well. The CLM works with four different sections within the manufacturer's manual system: (1) ATA coding system, (2) fin number system, (3) illustrated parts catalog (IPC) system, and (4) item location figures. The ATA system is used to find or locate the item with the ATA chapters. The fin number works with the

illustrated parts catalog (IPC) system with item location in an alphanumeric system. This is a great tool for helping avionics technicians to find relays and other hidden items; just type in the fin number and part name, and the number and manual reference is displayed. The ATA zone is the zone system designated by the manufacturer as per ATA chapters. The fourth item is the location figure, where each zone of the aircraft is highlighted upon selection. This presents an overview of the entire zone, including the components' pictures and part numbers with their respective locations.

Illustrated parts catalog (IPC)

The IPC is produced by the airframe manufacturer and includes list and location diagrams of all parts used on the aircraft. This includes all parts for all systems and is usually not customized to the airline's configuration. However, when the aircraft is customized it will show parts by figure, part number, and item number with aircraft applicability. Every aircraft is given a serial number, along with an aircraft registration number, which is used in the IPC for affectivity reason when searching for a part by using the ATA chapters. The IPC shows assemblies, subassemblies, alternate part numbers, and part interchangeability along with any modifications if performed on parts by the service bulletin, the IPC will show these parts as pre- or postmodification.

Storage and recovery document (SRD)

The SRD contains information needed to address maintenance and servicing of aircraft that are to be out of service and stored for long periods of time. This includes the procedures for draining certain fluids, moving the aircraft so that tires will not go flat, and protecting components from the weather. In the older model aircraft, this document was produced separately by the airframe manufacturer. For more recently manufactured aircraft, this information is included in the applicable AMM (ATA, Chapter 10).

Structural repair manual (SRM)

The SRM is an airframe-specific manual that provides the aircraft operator with information regarding aircraft skin and other specific tolerances and procedures in the event of minor structural damage. The SRM gives the acceptable dimensions and limits of damage to the aircraft structure so the operator knows when the damage should be fixed.

For example, when an aircraft incurs damage such as a dent, usually the dent is measured in by its depth and in relation to its surrounding area to make sure there is no damage to the ribs area and to check for any evidence of a crack. The operator then looks into the SRM for the area where the dent is located on the aircraft to see if it will be a minor or a major repair. The SRM provides the damage tolerance which will determine if the aircraft can fly with a minor dent that can be repaired later. The SRM will also indicate the number of hours the aircraft can fly with the dent.

There are some damages beyond SRM limits, and the maintenance department will have to contact engineering in order for specific repair schemes to be issued. If the damages are beyond SRM limits, the airline engineering department is in contact with the aircraft manufacturer's engineers. The repair is usually done by using an engineering order (EO) that will guide the aircraft maintenance department and inspection department on how to repair and sign off, bringing the aircraft back to an airworthy condition.

Maintenance planning data document (MPD)

This document (called the on aircraft maintenance program by McDonnell-Douglas) provides the airline operator with a list of maintenance and servicing tasks to be performed on the aircraft. It contains all items of the MRB report along with other information. Some of these tasks are identified as certification maintenance requirements (CMRs) and are required by the FAA in order to maintain certification of the aircraft. All other tasks, which were developed by the MSG process (see Chap. 2) are included along with other tasks recommended by the manufacturer. The tasks are divided into various groupings for older aircraft models—daily, transit, letter checks, hourly limits, and cycle limits—and are used for planning purposes by the airline. Later models do not group the tasks by letter checks, only by hours, cycles, and calendar time.

Schematic diagram manual (SDM)

The SDM contains schematic diagrams of electrical, electronic, and hydraulic systems on the aircraft, as well as logic diagrams for applicable systems. The diagrams in the AMM and other manuals are usually simplified diagrams to aid in describing the system and assist in troubleshooting. The schematic manual, however, contains the detailed information and identifies wiring harnesses, connectors, and interfacing equipment.

Wiring diagram manual (WDM)

The WDM is an essential tool for troubleshooting. The WDM provides information on the wiring runs for all systems and components containing such elements. Due to the complexity of the modern aircraft and its electrical system, such control devices as gauges and sensors provide and relay information to the flight deck in a complicated network of wiring runs like a network system. The WDM shows the wire routing from the aircraft's nose to tail and from other sections to different connectors, on-board sensors, and control devices. Normally wires that are routed in bundles from the airframe side of the aircraft are also shown in the WDM.

The wiring harness is a type of wiring bundle as well, but when referring to the wiring harness, we usually are referring to the power side of the aircraft. The wiring harness normally is connected to a fire wall, which is a connection point from the engine wire harness to the aircraft airframe system.

When removing the aircraft engine, the wiring harness (bundle) stays with the aircraft engine, and only the cannon plugs are disconnected from the fire wall. (Cannon plugs are the ends of the wire bundles or harnesses where all the wires are connected by pins that provide electric current to the system when initiated). Wire harnesses are easy to repair and troubleshoot since they do not exceed more than a few feet in length, versus the aircraft airframe side of the wires, which can be hundreds of feet in length, depending on their routing. (Wiring harness concepts are also used for automobile radios and other equipment, which makes for easy installation and troubleshooting.)

Aircraft wires are normally made from standard copper, and in some cases they are coated with different alloys to prevent corrosion. Due to the large amount of current required for carrying longer distances, aluminum wire is frequently used. Normally it is insulated by a fiberglass braid.

Aircraft wire is measured in the American Wire Gauge (AWG) system, which has been in use since the late 1850s. In the AWG system, the largest number represents the smallest wire. The following is an example of the AWG system found in the WDM:

***** K15B-25 *****

K → Alphabet letter—System in which a wire is being used

15 → Two-digit number—Individual wire number

B → Alphabet letter—Wire segment/section of wire power source

25 → Two-digit number—Wire size (AWG size)

Unfortunately, there is no set standard for wire identification by the aircraft manufacturers, but there are markings on aircraft wire every 15 inches or less that indicate a wire's location and type of circuit, which can be found in the WDM.

Master minimum equipment list (MMEL)

The MMEL is issued by the airframe manufacturer and developed by the manufacturer's flight engineering group. Prior to issuing the MMEL, the aircraft manufacturer submits a proposed master minimum equipment list (PMMEL) to the type certificate office of the aircraft manufacturing country (in the United States, FAA Flight Operation Evaluation Board). Once it is approved by the authority it becomes an MMEL.

The MMEL is used to identify the equipment that may be degraded or inoperative at the dispatch time of the aircraft. These are the systems that the flight crew, under certain circumstances, may agree to accept at dispatch in degraded or inoperative condition, provided the system is fixed within the prescribed time limit set by the MMEL. The MMEL contains information on all equipment available on the aircraft model to which it applies. It is the airline's responsibility to develop its own manual tailored to its specific equipment. This document, called the MEL, is discussed later in the airline-generated documentation.

Dispatch deviation guide (DDG)

Some of the MMEL items that are inoperative or degraded at dispatch require maintenance action prior to the deferral and dispatch. This may be the need to pull and placard certain circuit breakers, disconnect power, tie up loose cables for removed equipment, and various other actions to secure the aircraft and the system against inadvertent operation. The instructions necessary for these actions are provided in the DDG. This guide is written by the manufacturer's AMM staff and is coordinated with the MMEL.

Configuration deviation list (CDL)

The CDL is similar to the DDG but involves configuration of the aircraft rather than the aircraft's system and equipment. The CDL identifies any external part of an aircraft's panels, gear doors, flap hinge fairings, cargo doors, and all door indication and warning systems. These items could have been inoperative, cracked, broken, or missing. Normally, these items are discovered during the line checks or at pre- or postflight checks of the day. The CDL items do not affect the airworthiness and safety of the aircraft, and scheduled flight operation can be resumed. Some CDLs, when applied or issued, may have icing conditions or flight speed restrictions (e.g., gear door, flap hinge fairing, etc.).

The CDL system normally has category C placement, where it needs to be fixed in 10 flight days, excluding the day of discovery. This cycle of repair is customized by the aircraft operator.

Nonessential equipment and furnishing (NEF) items

The NEF contains the most commonly deferred items, such as paneling (flight deck, cabin), cup holders, missing paint off panel in flight deck or cabin area—cosmetic items which could be broken, cracked, chipped, or missing. NEF items are located throughout the aircraft and do not affect the safety or airworthiness of the aircraft.

The NEF uses a deferral program customized from the MMEL as a basis for air carriers to develop their air carrier-specific items. NEF items do have a transitioning period or a repair interval, which means that they must be fixed at the first available opportunity, depending on parts availability, or no later than what is described in the NEF manual, which normally does not exceed the next A check.

FAA policy letter 116 (PL -116) gives a brief description of what became global changes (GC-138) authorized by the establishment of an NEF program.

Task cards (TC)

Certain tasks in the AMM for removal/installation, testing, servicing, and similar maintenance items are extracted from the AMM and produced on separate cards or sheets so that the mechanic can perform the action without carrying the entire maintenance manual to the aircraft. (The Boeing 767 manual is about 20,000 pages.) These task cards can be used "as is" or they can be modified by the operator for reasons discussed in the section Airline-Generated Documentation.

Service bulletins, service letters, and maintenance tips

Whenever the airframe manufacturer or the engine manufacturer have modifications or suggestions for improving maintenance and/or servicing, they issue appropriate paperwork to the affected airlines. A service bulletin (SB) is usually a modification of a system that will provide improved safety or operation of a system and includes a detailed description of the work and parts required. An SB is usually optional and the airline makes the choice (see Chap. 8), except in certain cases involving an FAA airworthiness directive (AD) discussed below in Regulatory Documentation. A service letter (SL) usually provides information to improve maintenance actions without equipment modification. The maintenance tip is a suggestion for maintenance personnel to assist in their work or improve conditions.

Regulatory Documentation

The FAA issues numerous documents related to maintenance of aircraft and their systems. Table 5-2 lists the more significant of these documents.

Federal aviation regulations (FARs)

In the United States, Federal laws are collected into a document known as the code of federal regulations or CFRs. Those laws related to commercial aviation are under title 14 of this code, aeronautics and space, parts 1 through 200. The regulations relating to certification and operation of large, commercial aircraft—part 121—would be noted as 14 CFR 121. We usually refer to this as FAR part 121. In this book we will use the FAR terminology and form since it is so common in the industry. These FARs address all aspects of the aviation field, including private, commercial, and experimental aircraft; airports; navigational aids; air traffic control; training of pilots, controllers, mechanics, etc.; and other related activities.

Advisory circulars (ACs)

An advisory circular is a document issued by the FAA to provide assistance to operators on meeting the requirements of various FARs. These ACs are not binding as law but are merely suggestions as to how to comply with other requirements. An AC often states that it is "a means, but not the only means" of complying with a regulation. The FAA allows some leeway in how its regulations

TABLE 5-2 Regulatory Documents

Title	Abbreviation
Federal aviation regulations	FARs
Advisory circulars	ACs
Airworthiness directives	ADs
Notice of proposed rule making	NPRM

are met in order to achieve the desired results without trying to micromanage the operator.

Airworthiness directives (ADs)

The airworthiness directives are substantial regulations issued by the FAA to correct an unsafe condition that exists in a product (aircraft, aircraft engine, propeller, or appliance) and a condition that is likely to exist or develop in other, similar products.[1] An AD, whose incorporation is mandatory, may be issued initially by the FAA when an unsafe condition is noted or it may result from FAA action after the airframe manufacturer has issued a service bulletin (SB) relative to some noted problem. Incorporation of an SB is optional but, if it is made into an AD by the FAA, incorporation becomes a mandatory requirement.

Aircraft owners or operators are required to maintain the aircraft in compliance with all ADs.[2] Typically, an AD will include (*a*) a description of the unsafe condition; (*b*) the product to which the AD applies; (*c*) the corrective action required; (*d*) date of compliance; (*e*) where to get additional information; and (*f*) information on alternative methods of compliance if applicable.

Notice of proposed rule making (NPRM)

The NPRM is an FAA process that indicates the intent to change or amend an existing Federal Aviation Regulation (FAR). This provides an advance notice and invites public comment on proposed rules, which includes holding public hearings or specific activities, rendering a decision, and issuing a new rule, directive, or requirement in the form of an FAR.

Airline-Generated Documentation

Table 5-3 lists the documentation that the airline will generate in order to carry out its maintenance activities. Again, these documents may vary in name and actual content from one operator to another, but the information identified here must be addressed by airline documentation.

Operations specifications

The operations specifications (Ops Specs) document has been discussed in Chap. 4 as an FAA requirement for airline certification. It is written by the airline in accordance with strict FAA requirements and usually with the help of an FAA representative. The Ops Specs is required for each aircraft type flown by the airline. It is a parent document, which refers to numerous other documents to avoid duplication and details the airline's maintenance, inspection, and operations programs.

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[1]Federal Aviation Regulations 39.3 and 39.5.

[2]Federal Aviation Regulation 91.403.

TABLE 5-3 Airline-Generated Documentation

Title	Abbreviation
Operations specifications	Ops Specs
Technical policies and procedures manual	TPPM
Inspection manual	IM
Reliability program manual	RPM
Minimum equipment list	MEL
Task cards*	TC
Engineering orders†	EOs

*May be manufacturer written, customer written, or a combination.
†Issued for maintenance not identified in standard maintenance plan.

Technical policies and procedures manual (TPPM)

The TPPM[3] is the primary document for the airline's M&E operation and, with other documents supplied by the airframe manufacturer, serves as the FAA requirement for a maintenance manual per AC 120-16E. It is usually written by engineering, to ensure technical accuracy, from inputs supplied by management of the various M&E organizations. It should define exactly how all M&E functions and activities will be carried out. The TPPM is a detailed document and may be several volumes. Personnel in all units of M&E must be trained on the TPPM, especially those parts that relate directly to that unit's operation, so that the operation will go smoothly. Details of the TPPM contents are discussed later in this chapter.

Inspection manual (IM)

The IM may be a separate document distributed primarily to QC personnel, or it can be a chapter in the TPPM (usual approach).[4] Contents of the IM relate to all inspection activities within M&E: (*a*) mechanic inspection tasks from the MPD/OAMP or the MRB report; (*b*) QC inspector's tasks; (*c*) special inspections (hard landings, bird strikes, etc.); (*d*) the airline's required inspection item (RII) program; and (*e*) the paperwork, forms, and reports required to carry out these functions. Some IMs may indicate details on the calibration of tools and test equipment, since these are QC functions, or these may be in a separate chapter of the TPPM.

[3]The TPPM is sometimes called the policies and procedures manual (PPM), general maintenance manual (GMM), or the maintenance organization exposition (MOE).

[4]The reason this and other documents listed below are often separate from the TPPM is so that changes can be made when necessary without issuing a change for the entire TPPM. In these cases, the TPPM merely identifies the detailed document as a reference, thus making the TPPM complete.

Quality assurance (QA) manual

The QA manual could be a special manual for QA auditors only, it could be part of the inspection manual, or it could be a separate chapter in the TPPM as desired. The QA manual defines the duties and responsibilities of the QA organization and defines the processes and procedures used in the annual quality assurance audits conducted on the M&E units, suppliers, and outside contractors. Forms used and reports are also covered along with the procedures for follow-up and enforcement of QA write-ups.

Reliability program manual

An airline's reliability program, under FAA rules, must be approved by the regulatory authority, so it is usually published as a separate document. This document defines the reliability program in detail (see Chap. 18) so that the FAA can evaluate and approve all its elements at one time.

Minimum equipment list (MEL)

The MMEL provided by the aircraft airframe manufacturer includes all equipment and aircraft configuration information available for the model to which it applies. The airlines pick and choose from the MMEL system the type of MEL they would rather have due to specifications, weight variants, options installed, software and hardware upgrades, retrofit status, engines, and airframe configuration, which later in the airline's version becomes an MEL. The MEL cannot be less restrictive than the MMEL.

Aircraft are designed with highly reliable equipment and systems with redundancies, but a failure can occur at any time, and the object of an MEL is to reconcile an acceptance level of safety while operating profitably and with inoperative equipment. The MEL book is part of the aircraft library and includes the configuration deviation list (CDL) and nonessential equipment and furnishing list (NEF). The MEL book is a mandatory item for any airline's dispatch.

The MEL system is designed as an alleviating document, and its sole purpose is to discourage the operation of any aircraft with inoperative equipment. It is almost never desirable for any airline to dispatch aircraft with any inoperative equipment. There are some MELs that when issued require a big penalty in passenger and cargo carrying capacity. In some such cases, the airline often decides it is better to keep the aircraft on the ground and fix the aircraft discrepancy rather than to fly the aircraft with such penalties. The pilot in command has the authority to refuse to fly an aircraft with an MEL such as pressurization, air-conditioning, and antiskid system malfunctions. An aircraft can also be grounded by the flight crew and dispatch if the MEL has been opened and closed repeatedly and is open at the time of refusal.

The MEL repair interval and category is a time in which the aircraft is operated until it is fixed prior to MEL expiration, or an aircraft is grounded on the last day of MEL. One note to remember: the day the MEL is issued is not counted. For example, if the MEL is opened on January 15 and the repair is category B,

the time interval, which is 3 days, will begin on January 16, and it will expire on January 18 at midnight.

MEL categories may vary from operator to operator. There are four MEL categories:

Category A MEL is normally 1 to 2 days, unless specified for such MEL where it could be a 1-day flight MEL, depending on the restrictions.

Category B MEL is normally issued for 3 consecutive calendar days.

Category C MELs shall be repaired within 10 days.

Category D MEL items must be replaced in 120 calendar days. This is a part that is normally considered for replacement.

Task cards

The task cards produced by the airframe manufacturer are usually for one action only. These procedures may call for the mechanic to open panels, set certain circuit breakers "in" or "out," turn other equipment "on" or "off," etc., prior to the work and to reverse these processes at the completion. Much of the work done at an airline during an aircraft check, however, involves the combination of several tasks to be performed by the same mechanic or crew within the same area or on the same equipment. To avoid unnecessary duplication of certain actions, and the unnecessary opening and closing of the same panels, etc., most airlines write their own task cards to spell out exactly what to do, using the manufacturer's cards as a guide. This eliminates the duplicated or wasted efforts. Some airlines find it sufficient, or perhaps more expedient, to provide mechanics with all the manufacturer's task cards for a given work project and allow him or her to avoid the duplications during the work activity. Often there will be an airline task card attached to this package of cards with special instructions for working the group of cards. Whichever approach is used, the engineering section is responsible for creating these cards to ensure technical accuracy.

Engineering orders (EO)

Any maintenance work not covered in the standard maintenance plan developed by engineering from the MRB report or Ops Specs data must be made official by the issuance of an EO. This is official paper work, issued by engineering and approved by QA, and is usually implemented through the production planning and control (PP&C) organization. In some airlines, the document may be called simply a work order. Details of the EO are discussed in Chap. 8.

ATA Document Standards

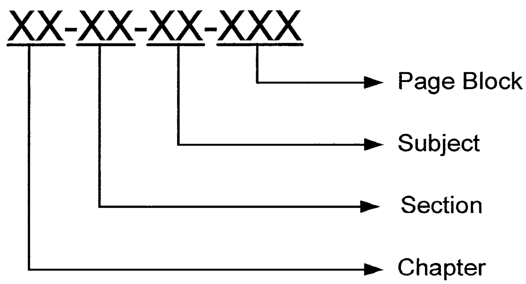
Line maintenance people for most airlines, especially those doing contract maintenance for other carriers, will have the opportunity to work on a wide variety of aircraft during the course of their shift or work week. Since aircraft

manufacturers are independent, they each (in the past) had their own way of doing things. This meant that their maintenance manuals were as different as their aircraft (or perhaps more so). To reduce confusion on the line, the ATA stepped in and standardized the overall format of the maintenance manuals so that all manufacturers' documents would be more compatible. ATA codes are designed to help understand different systems or system types on aircraft and their subsystems and are assigned a chapter number. Table 5-4 shows the chapter assignment as per ATA standard. The example will be the aircraft landing gear, which consists of landing gear, tires, brakes, antiskid system, etc. When aircraft maintenance technicians perform any type of maintenance, such as replacing a tire, they will need to sign off the maintenance discrepancy as "remove and replace #1 tire," not the entire landing gear. The sign-off will consist of ATA code 32 (landing gear system) subsystem 40 (wheel and tire assembly) and 00 at the end of the sign-off along with TAT and aircraft cycles. This will help records personnel understand which tire has been replaced at what time and know the aircraft's times and cycles. This also can help the continuous analysis and surveillance system (CASS) and the reliability department keep track of any premature failure and warranty work.

TABLE 5-4 ATA Standard Chapter Numbers

ATA	Subject	ATA	Subject
5	Time limits, maintenance checks	37	Vacuum
6	Dimensions and access panels	38	Water/waste
7	Lifting and shoring	45	Central maintenance system
8	Leveling and weighing	49	Airborne auxiliary power
9	Towing and taxiing	51	Standard practices and structures—general
10	Parking, mooring, storage, and return to service	52	Doors
11	Placards and markings	53	Fuselage
12	Servicing	54	Nacelles/pylons
20	Standard practices—airframe	55	Stabilizers
21	Air conditioning	56	Windows
22	Auto flight	57	Wings
23	Communications	70	Standard practices—engines
24	Electrical power	71	Power plant (package)
25	Equipment/furnishings	72	Engine (internals)
26	Fire protection	73	Engine fuel control
27	Flight controls	74	Ignition
28	Fuel	75	Air
29	Hydraulic power	76	Engine controls
30	Ice and rain protection	77	Engine indicating
31	Indicating/recording system	78	Exhaust
32	Landing gear	79	Oil
33	Lights	80	Starting
34	Navigation	82	Water injection
35	Oxygen		
36	Pneumatic	91	Charts (miscellaneous)

Source: From Air Transport Association (ATA); iSpec 2200. Reprinted with permission.



Example:

52	Doors
52-11	Passenger Doors
52-11-02	Passenger Door Handle
52-11-02-401	R/I Procedure for Pax Door Handles

Figure 5-2 ATA format for maintenance manuals. (*Source*: *Air Transport Association of America (ATA); iSpec 2200. Reprinted with permission.*)

These ATA coding systems are uniform for all models and types of aircraft, and all aircraft manufacturers use the same coding system. If there are any aircraft systems that require maintenance, such as the navigation system, an A&P technician or avionics technician will know that they can find such information in ATA Chapter 34 of the aircraft maintenance manual.[5]

The ATA codes are further broken down into three sets of two-digit numbers followed by a three-digit number. This identifies the chapter, subject, section, and page block, respectively. Figure 5-2 shows the structure of the number. The first two digits (ATA Chapter) are the same for all manufacturers and are used throughout the maintenance manual system. The second (section) and third (subject) groups may vary from one manufacturer to another and from one model aircraft to another of the same manufacturer because of differences in the structure of the systems to which they apply.

The last group of digits (page block) is the same for all maintenance manuals. The page blocks refer to specific types of information contained in the airplane maintenance manual. For example, pages 001–099 are reserved for the description and operation of the chapter's systems. Pages 301–399 contain removal/installation procedures for the various components within the system or chapter (see Table 5-5 for a list of page blocks).

The advantage of this system is quite apparent to a line maintenance mechanic who works on a Boeing 757, then a Douglas MD-80, an Airbus A320, and then a Lockheed L-1011 in the course of a single day. No matter what the aircraft, if a write-up concerns a hydraulic system component, the mechanic

[5]Air Transport Association of America, ATA; iSpec 2200.

TABLE 5-5 Airplane Maintenance Manual Page Block Assignments

Block	Title	Description
001–099	Description and operation	Identifies the various operational modes of the system and describes how the system and its essential components work
101–199	Fault isolation	Fault trees used to perform fault isolation for various problems occurring within a system
201–299	Maintenance practices	An R/I procedure followed by a BITE test, a functional test, an adjustment procedure, or servicing instructions
301–399	Servicing	All servicing tasks: check, fill and replacement of oil, hydraulic fluid, water, fuel, etc.
401–499	Removal/installation	Detailed, step-by-step instructions on how to remove a line replaceable unit (LRU) and replace it with a like item
501–599	Adjustment/test	Procedures for making adjustments or performing tests to the systems whenever a component or system has just been replaced or after normal maintenance when such adjustments or tests are required
601–699	Inspection/check	Zonal inspections of aircraft
701–799	Cleaning/painting	Procedures for cleaning and painting of the aircraft
801–899	Approved repairs	Repairs to structure and aircraft skin approved by FAA for airline maintenance organization incorporation

Source: Air Transport Association (ATA); iSpec 2200. Reprinted with permission.

knows that any maintenance manual information he or she needs will be found in ATA Chapter 29. If there is a discrepancy in the aircraft landing lights, help will be found in ATA Chapter 33 regardless of the aircraft. The following paragraphs discuss each page block of the AMM.

Description and operation (pages 001–099)

The description and operation (D&O) page block tells what the system does, identifies the various operational modes, and describes in detail how the system and its essential components work. Mechanics and technicians often consider this part of the manual too detailed for their needs on the line and in the hangar, but the information provided here is necessary for serious troubleshooting. Maintenance personnel need to understand the theory of operation and the operating modes of the system in order to effectively determine what is wrong with a deviant system. The engineering staff needs this data in order to identify changes or improvements in the maintenance program as well as to assist maintenance in solving the more difficult problems.

Fault isolation (pages 101–199)

This page block includes fault trees used to perform fault isolation for various problems occurring in a system. Contrary to popular belief, these fault trees will not find all the problems which might develop within a given system throughout its lifetime. These procedures were written to find specific faults based on flight deck effects, such as lights, messages, warnings, etc., that are available to the flight crew during the flight. These troubleshooting procedures were not necessarily written to find every fault that could ever exist in a given system. Many procedures have been modified over the years, due to faults occurring in the field that were not conceived of when the manual was originally produced. But for complex equipment it is often quite difficult to write a step-by-step procedure or fault tree to find every possible fault the system could experience. If that were possible, the resulting fault tree would be too long and the procedure too complicated to be useful. (That is why we have included an appendix on troubleshooting techniques in this book.)

Maintenance practices (pages 201–299)

The maintenance practices block is used whenever two or more actions must take place to complete the maintenance activity. Usually a 200 page block procedure will be an R/I procedure followed by a BITE test, a functional test, or an adjustment procedure or even servicing instructions. If the auxiliary procedure is simple, it is included in the 200 page block along with the main procedure for convenience. If it is too long or too complex to repeat, the main procedure will reference the appropriate auxiliary procedure by chapter, section, subject, and page block.

Servicing (pages 301–399)

The 300 page block includes all servicing tasks: fill and replacement of oil, hydraulic fluid, water, and fuel; lubrication actions; and the handling of waste, etc. These procedures include step-by-step instructions as well as a list of required materials and their specifications where applicable.

Removal/installation (pages 401–499)

Removal/installation (R/I) procedures are written to provide detailed, step-by-step instructions on how to remove a line replaceable unit (LRU) and replace it with another like item. With simple installations, such instructions are not necessary to a mechanic or technician who is worth the title. But other equipment requires a specific sequence of steps to prepare for removal and then to remove the components. In many instances, certain conditions must be met prior to removal, such as pulling circuit breakers, disconnecting power, hydraulics, etc. These conditions are addressed in the procedure. The installation requires an equally meticulous series of steps. In some cases, additional procedures, such as ground tests, must be performed after installation. These are identified and referenced in the R/I procedure but are covered in the other page blocks.

Adjustment/test (pages 501–599)

The 500 page block contains procedures for making adjustments to the systems whenever a component or system has just been replaced (by an R/I) or during normal maintenance (scheduled or unscheduled) when such adjustments are required. This page block also contains the operational test procedures used to check out a system without test equipment. This is a relatively simple check to verify proper operation using only what is available in the aircraft. The 500 page block also contains the functional test procedures which are used for more detailed system checkout. These tests usually require additional test equipment and/or tools and may involve the measurement of certain parameters of the system.

Inspection/check (pages 601–699)

The 600 page block covers the zonal inspection activities. Each identified zone of the aircraft is inspected for various discrepancies.

Cleaning/painting (pages 701–799)

The 700 page block contains procedures for washing, cleaning, and painting the aircraft. It includes specifications for materials to be used.

Approved repairs (pages 801–899)

The 800 page block identifies repairs to structure and aircraft skin that have been approved by the FAA for operator accomplishment.

A Closer Look at the TPPM

The purpose of the TPPM is to identify all aspects of the maintenance and engineering organization. This would include (*a*) the identification of key personnel, descriptions of their job functions and their qualifications; (*b*) a definition of the operator's philosophy and goals; (*c*) layout drawings and maps of the maintenance facilities including shops, hangars, ramps, and other significant buildings and areas related to maintenance activities; (*d*) specific items in accordance with FAA regulations as well as items, at the discretion of the operator, which describe, in detail, how specific maintenance, inspection, and testing activities will be accomplished.

The TPPM is a controlled document and therefore should be issued in limited distribution only to those units within the airline that need the information. Some airlines provide full copies to all M&E units, while others provide only those portions of the manual that apply to that organization. For example, information relating to specific flight line operations need not be available to hangar or shop personnel. Likewise, information concerning engineering responsibilities need not be distributed to the flight line or to outstations unless the information is directly related to those activities. The entire document, however, should be available in the central maintenance library (see Chap. 10).

TABLE 5-6 Technical Policies and Procedures Manual (TPPM)

General
- Manual control system
- Organization of the TPPM
- Administration
  - Organizational chart
  - Key personnel
- Operations specifications
- Maps of key locations
- Listing of approved manuals
- Glossary of terms

Quality assurance and control
- Organization
- Liaison with regulatory authority
- Inspection methods and standards
- Airworthiness release
- Required inspection items (RIIs)
- Special inspections
- Parts and material inspections
- Calibration of tools and test equipment
- Continuing analysis and surveillance program
- Quality assurance audits
- Reliability analysis program
- Short-term time escalation program
- Test, ferry and special flights
- M&E record keeping system

Engineering
- Organization
- Airworthiness directives
- Service bulletins/service letters
- Engineering orders
- Fleet campaigns
- Minimum equipment lists (MEL) Development
- Configuration deviation lists (CDL) Development
- Maintenance program development
- Weight and balance control program
- Publications/technical library[*]

Production planning and control
- Organization
- Airplane routing[†]
- Production forecasting
- Task card development
- Maintenance planning
- Manpower planning
- Material planning
- Facility planning
- Production scheduling and control
  - On-airplane
- Production scheduling and control
  - Shops
- Performance measurement
- Budgeting and cost control

(Continued)

TABLE 5-6 Technical Policies and Procedures Manual (TPPM) (*Continued*)

Airplane maintenance
- Organization
- Approved maintenance arrangements
- Contractual arrangements for maintenance
- Airplane logbooks
- Airworthiness release
- Nonroutine maintenance
- MEL, DDG, and CDL
  - Usage
- Deferred maintenance
  - Authorizations
  - Procedures
- Repeat mechanical discrepancy system
- Parts robbing
- Maintenance control center (MCC)
- Standard maintenance practices

Shop repair and overhaul
- Organization
- Contractual arrangements
- Maintenance release
- Component repair/overhaul control
- Standard shop practices
- Shop records

Tools, equipment and facilities
- Organization
- Motorized equipment
- Fuel storage and handling
- Facility maintenance
- Tools and test equipment

Maintenance and inspector training
- Organization
- General policy
- Personnel licensing
- Basic training requirements
- Training categories and courses
- Initial training
- Recurrent training
- Contractor training
- Training records

Material management
- Organization
- Stock numbering system‡
- Serviceability of aircraft parts
- Shipping and receiving
- Rotable/repairable parts tracking system
- Storage of parts and supplies
- Satellite stores
- Purchasing
- Inventory control
- Parts pooling/parts borrowing
- Parts loan control
- Warranty claims control
- Outside repair of rotable/repairable items

(Continued)

TABLE 5-6 Technical Policies and Procedures Manual (TPPM) (*Continued*)

Safety program
Organization
Policy
Safety procedures
Accident/incident reporting
Maintenance forms
Policy
Responsibility
Preparation and distribution instructions
Samples and usage instructions

* If library is part of engineering. Otherwise it would be listed separately.

† This may be a joint effort with flight operations.

‡ Some airlines assign their own stock numbers for all parts and supplies in order to standardize the number format.

The TPPM should contain a list of effective pages (LEP), the revision number or letter identification, and revision dates. A list of terms and acronyms used in the document should also be included. The manual must make provisions for distribution to maintenance and ground personnel. If the manual is in more than one volume, the contents of all volumes should be listed in each volume.

These guidelines were based on the information contained in the FAA Airworthiness Inspector's Handbook, which defines the minimum contents of the manual. Consideration should be given, however, to inclusion of additional internal policies and procedures that provide complete instructions to maintenance and engineering personnel on the performance of their duties and responsibilities.

This manual is an administrative tool used to control and direct the activities of maintenance personnel. It should define all aspects of the maintenance operation. The manual should include detailed instructions or specific references for accomplishing inspection and maintenance functions. It should also include forms, instructions, and references for recurring, nonroutine requirements, such as engine changes, and abnormal occurrences such as hard landings, lightning strikes, bird strikes, etc.

The manual should enable the operator's maintenance and servicing personnel to assure airworthiness of the airplanes. The complexity of the manual varies with the complexity of the operation. The manual must describe areas of application for manufacturer's technical manuals. Since this manual is the bible of the unit, it should also be used extensively in the maintenance training activities of the airline. Table 5-6 shows the outline of the TPPM for a typical midsized airline. Other airlines may be organized differently and thus would have a different manual layout.

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Chapter

6

Requirements for a Maintenance Program

Introduction

The five objectives of a maintenance program were discussed in Chap 3. In this chapter, we will begin to outline a maintenance program that will address these five maintenance objectives. There are certain regulatory requirements that each airline must adhere to and certain additional necessary maintenance activities that airlines need to have in place to carry out their approved maintenance program requirements. The aircraft and aircraft systems are sophisticated, with miles of wires to chase, electromechanical valves, airframe systems, engines, auxiliary power units, hydraulic systems, and navigation systems, all of which require a well-trained professional technician with aircraft systems knowledge, experience, and a keen mechanical ability to correct any kind of discrepancy according to the approved maintenance program. These mechanical tasks and maintenance programs require oversight and monitoring to make sure airlines and aircraft operators are carrying out them out effectively.

The FAA has outlined the aviation maintenance program in advisory circular AC 120-16E. We will discuss the FAA requirements first. Discussion of additional requirements will follow. These will be combined in Chap. 7 into a workable aircraft maintenance and engineering organizational chart.

Aviation Maintenance Program Outlined (AC 120-16E)

The AC 120-16E is the type of information provided by the FAA to the aviation community. The FAA requires each commercial airline to have an operations specifications (Ops Specs) document authorizing maintenance program, the maintenance manuals required by FAA regulations, and their operational equipment as a commercial airliner. The AC requirement is under Title 14 of the Code

of Federal Regulations (14 CFR), part 119, air carrier commercial operation under 14 CFR parts 121 and 135. This AC also applies to each individual employed or engaged in air carrier maintenance, preventive maintenance, or alteration of its aircraft.

The Ops Specs also describes the airline's responsibility for performing all approved maintenance and alterations whether the work is accomplished by the airline or its contractor (repair station), yet the primary burden of responsibility of the maintenance task and their approval is carried out by the maintenance provider, who is responsible for ensuring that each aircraft released into service is airworthy and safe. The FAA feels that its guidance can be used to avoid any future accidents or mishaps.

The following is an example of a maintenance AC 120-16E. It describes the scope and content of an air carrier aircraft maintenance program. It explains the background of these programs as well as the FAA regulatory requirements.

FAA AC 120-16E describes the elements listed below:

1. Airworthiness responsibility
2. Air carrier maintenance manual
3. Air carrier maintenance organization
4. Maintenance record keeping system
5. Accomplishment and approval of maintenance and alterations
6. Maintenance schedule
7. Required inspection items (RII)
8. Contract maintenance
9. Personnel training
10. Continuous analysis and surveillance system (CASS)

Federal Aviation Regulation (FAR) 121.373 requires each operator to have a "continuing analysis and surveillance" effort in place to ensure that the airline's maintenance and inspection programs are effective. In the past, this requirement, by all reasonable interpretation, established an internal audit program, usually called quality assurance or QA, and a reliability program, which is similar to the condition monitoring process discussed earlier in Chap. 2. Together, they constituted a continuing analysis and surveillance program (CASP) to satisfy the FAR requirement. The recent revision to AC 120-16E, however, incorporated a CASS as part of the basic maintenance program. Other important FAA requirements are related to record keeping and are outlined in FAR 121.380 (maintenance recording requirements), FAR 121.380a (transfer of maintenance records), FAR 43.2 (records of overhaul and rebuilding), and FARs 43.9 and 43.11 (content, form, and disposition of records …). These have also been incorporated into the revised advisory circular. These 10 items from AC 120-16E will be discussed individually below.

Airworthiness responsibility

Under FAA regulation, an air carrier or operator is responsible for all maintenance and alteration on that airline's aircraft. The airline must have operations specifications for each model aircraft flown and must adhere to the FAA approved maintenance program the Ops Specs identifies. This program can be modified if the airline can show through data and records that a change is warranted. The FAA must approve the changes. The airline must also follow its own policies and procedures as well as those of the regulatory authority in carrying out the maintenance and inspection program. In certain instances, an airline may have another carrier or third-party maintenance organization do some or even all of its maintenance under contract. However, the operating airline is responsible for ensuring that any work done for them by these outside contractors is done to the airline's own maintenance schedule, standards, and requirements, and in accordance with the airline's regulatory authority requirements regardless of those requirements governing the contracted organization. In short, the airline (i.e., the operating certificate holder) is responsible for maintaining its own aircraft in an airworthy condition regardless of who actually performs the work.

Air carrier maintenance manual

The airframe manufacturer and the vendors of equipment installed on the aircraft provide maintenance manuals for the equipment. The maintenance manuals required by AC 120-16E, however, are the the air carrier's manual system and an expansion of the manufacturer's manuals. While the AC specifies how to maintain and revise, it also identifies, describes, and defines the manuals and offers detailed procedures for accomplishing these tasks. The maintenance manuals discussed in the AC involve other areas of concern such as administration policies and procedures, administration management and accomplishment, audit and inspection of the maintenance program.

The AC also provides a reference in the event of a flight event, such as severe turbulence extreme maneuvers, and such ground events as hard landing and overweight landing, and the types of inspection and maintenance processes that must be performed following these events. The maintenance manual is the primary, all-inclusive expression of how maintenance will be conducted and how the air carrier maintenance program will be monitored and improved. We discussed manuals in Chap. 5. The TPPM (GMM or MOE) written by the airline should meet this requirement.

Air carrier maintenance organization

FAA states that an airline must have a maintenance organization "that is able to perform, supervise, manage and amend your program, manage and guide your maintenance personnel, and provide direction necessary to achieve your

maintenance program objectives."[1] The essential elements of this organization as discussed in the AC are summarized as follows:

1. A director of maintenance (DOM). Responsible for overall maintenance activity. Must hold a current FAA A&P rating.
2. A chief inspector. Responsible for all RII functions (for part 121 operator).
3. Management duties and responsibilities and their current functions as the maintenance site, including their names.
4. An organization or process to develop and upgrade maintenance manuals that describes all aspects of the maintenance program.
5. Procedures to ensure that all aircraft released for service after maintenance are airworthy and properly maintained with the highest possible degree of safety.
6. Management personnel are qualified and have sufficient experience and expertise to effectively delegate, manage, and control the maintenance program without any confusion.
7. The inspection function for RII, an integral part of maintenance, must be separated from other routine inspection and daily maintenance functions.
8. Oversight and management activities to ensure all maintenance functions are being accomplished in accordance and managements' effort to ensure that the maintenance program remains effective.

Maintenance record keeping

Commercial aircraft are delivered to the operator with a U.S. standard airworthiness certificate showing that the aircraft was built to the type certificate standards and is in an airworthy condition at delivery. It is the airline's responsibility to keep that aircraft in an airworthy condition. To ensure that this is accomplished, the FAA requires the operator to keep accurate records of maintenance and alteration activities. Failure to make and keep accurate records can subject the operator to substantial fines or imprisonment. Two types of records are required: summary information and airworthiness status information.

Other records, in various forms, must also be kept to conduct a successful program. One of these is the maintenance logbook. This book is maintained in the aircraft and includes flight information relative to each leg of the flight and includes flight times, fuel and oil uplift, crew data, etc. It also provides a place for the flight crews to identify any maintenance-related problems they encounter during flight. The form includes space for the mechanic to identify corrective action taken and to release the aircraft for service.

Other records must be maintained in the form of reports for certain types of maintenance problems. These would include the mechanical reliability report

[1]AC 120-16E, page 11, par 400.

(MRR), the mechanical interruption summary (MIS), and reports of major alterations and major repairs.

Accomplishment and approval of maintenance and alterations

The airline maintenance program as an entity is authorized to perform maintenance on their aircraft. The maintenance program must include instructions for conducting maintenance on the aircraft, as well as specific maintenance for engines, propellers, parts, and appliances. This will include scheduled and unscheduled maintenance. Scheduled maintenance consists of tasks performed according to maintenance time limitations, including required inspection checks. The unscheduled maintenance must follow procedures, instructions, and standards for maintenance that occurs on an unforeseen basis. A comprehensive procedure must be followed when performing unscheduled maintenance. The scheduled and unscheduled maintenance involves both on-aircraft and off-aircraft (shop level).

The airlines also must address major repairs and alterations that they perform with the approved technical data from the FAA. Although a list does not exist for composite structures, airlines are allowed to use their manuals to evaluate composite repairs or alterations of aircraft structures on a case by case basis. Aircraft structures are divided on primary or secondary basis. The airlines are encouraged to address aging aircraft and corrosion problems.

The RII process is heavily involved when performing modifications, major repair, or alterations to the aircraft and components. There must be a designated RII. The FAA defines it as “those items which could result in unsafe operation of the aircraft if maintenance is not performed correctly or if improper parts are used.”[2] These RIIs appear in all elements of the operator’s maintenance program and receive the same consideration regardless of when or where they occur. The FAA does not specify what should be on an operator’s RII list, but it does require an airline to identify its own unique items and to identify in writing the names of qualified and authorized personnel to perform those inspections.

Maintenance schedule

The FAA requires airlines to have maintenance time limitations or a maintenance schedule which identifies what maintenance will be done, how it will be done, and when or how often it will be done. These regulations are broad enough to permit airlines to tailor and organize all these individual maintenance tasks into a series of scheduled work packages. Normally, the airlines receive maintenance task schedules from the airframe manufacturers which are identified in the maintenance review board (MRB) report, an FAA approved document. Additional information and tasks related to maintenance may also be provided in other manufacturer documents, such as the maintenance planning data (MPD) document (Airbus or Boeing). Maintenance tasks are divided into groups

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[2]FAR 121.371.

based on suggested intervals—flight hours, flight cycles, or calendar items. Maintenance checks may be done daily, after each flight, or for a specific period of operation, such as every 200 or 300 flight hours, or every 100 cycles.

The manufacturer documents, however, are only guidelines. Each operator is different: airplane configuration, operational and environmental conditions, even the quality and extent of operations and maintenance differ from one airline to another. For these reasons, the maintenance program requirements and the schedule for when tasks must be performed will vary from airline to airline. It is an airline's responsibility to adjust the initial MRB schedules to comply with the airline's needs. These work packages were discussed in Chap. 2.

Required inspection items (RII)

The FAR 121.369(b) and 135.427(b) require airlines to designate maintenance tasks as required and deemed necessary for RII. The RII items are directly related to flight safety and airworthiness and, if not performed correctly as per the airlines' manuals, could jeopardize the safety of flight due to improperly performed maintenance tasks, parts failure, or system malfunction. The RII items' functions are related to scheduled and nonscheduled items, which can arise anytime during line maintenance or hangar operations.

The airlines' manuals must be designed to identify the RII procedures and RII authorization within the air carrier's organization. The airline must identify the RII requirement on work forms, job cards, and engineering orders (EO). The RII inspectors must be trained in the inspection items, and they can exercise their authority to accept or reject any item that requires an RII.

Contract maintenance

Although an airline is responsible for all maintenance on its aircraft, it does not perform all of the maintenance itself. Very often, some or all of the maintenance may be performed under contract with some other airline, repair station, or a third-party maintenance organization. Contract maintenance could be done on a regular basis, as is most often the case, but there are instances when the aircraft in need of servicing in a location where the airline has no maintenance activities of its own. In these cases, the airline will enter into a temporary, short-term, or permanent contract agreement with a repair organization.

Prior to entering into any contract type, an airline must determine that the contract maintenance provider complies with requirements of part 121, and/or part 135 as indicated in AC 120-16E. These requirements are demonstrated by an on-site audit, inspection of the facility and equipment, and the service provider having competent personnel to perform the necessary tasks as the airline's maintenance policies indicate. The airlines must perform random audit samples to determine risk factors which demonstrate the work performed is satisfactory. It is the airline's responsibility to make these arrangements to ensure that the work is done properly, according to the airline's own program and procedures, and maintenance actions must be properly signed off and documented.

The airline is responsible for providing these outside maintenance contractors with proper training on the airline's policies and procedures for showing clear authority, responsibility, direction, and for assuring that these outside maintenance personnel have the skills, facilities, and knowledge of airlines maintenance manuals to perform the work required.

Personnel training

The FARs are rather brief in stating the airline's training requirements for aviation maintenance. Part 121, subpart L of the FAR states, in part, that airlines should "have a training program to ensure each person (including inspection personnel) who determines the adequacy of work done for you is fully informed about procedures and techniques and new equipment in use and is competent to perform his or her duties."[3]

The AC 120-16E provides more information. When an AMT is hired, he or she must go through an initial training, which normally includes indoctrination or company orientation maintenance departments, policies and procedures, a course on the aircraft systems, ground equipment, and hazardous materials training. The airlines must validate the AMT's skills by using appropriate testing methods to ensure that he or she is capable of performing maintenance tasks. Airlines are also required to provide recurrent training, specialized training which focuses on the inspection process of RII, boroscope, and nondestructive testing or aircraft flight controls rigging. This training is provided to maintain their standard of competence. The airline training requirements also imply that any changes to equipment, procedures, or regulations, must be addressed by the airline's training organization to ensure that the AMTs are up to date in all aspects of their job.

Continuing analysis and surveillance system

In FAR 121.373 and 135.431, continuing analysis and surveillance, the FAA indicates the need for monitoring the airline's activity to ensure that the inspection, maintenance, preventive maintenance, and alteration programs outlined in Ops Spec are effective. Many operators interpret this to mean the establishment of a quality assurance program and a reliability program. The FAA's Advisory Circular AC 120-79A addresses the subject of developing and implementing an air carrier CASS. It is summarized in AC 120-16E as part of the suggested airline maintenance program.

Essentially, CASS is a program to detect and correct deficiencies in maintenance program effectiveness and performance through surveillance, analysis, and corrective action. It looks at possible problem areas, determines the corrective action required, and tracks the activity afterward to determine the effectiveness of the correction. This is accomplished through data collection and analysis and through the monitoring of all activities in the maintenance function of the airlines, its suppliers, and its contractors.

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[3]FAR 121, Subpart L.

Since the CASS program is a coordinated effort and system which includes several other departments, each department performs a CASS function and is responsible for updating policies, procedures, and guidelines as they see fit. These departments may include quality control (QC), quality assurance (QA), and maintenance reliability. The CASS system requires audits and analysis of its effectiveness at identifying deficiencies, continuous cycles of surveillance, safety management, risk management, investigation analysis, corrective action, and follow-ups.

The CASS audits data trends and analysis ensures the effectiveness of the airline's maintenance operations, which leaves little room for maintenance errors and human errors. Effective corrective action plans and incorporating them in the maintenance audit will reduce safety risks and improve risk management. This also requires management, aircraft maintenance technicians, and everyone who is involved in day-to-day operations of aircraft maintenance to make this program work. There are times when airlines or air carriers must "self-disclose" any finding to the FAA to obtain leniency before it becomes a catastrophe. The FAA's Advisory Circular AC 00-58A outlines the program regarding self-disclosure or voluntary disclosure. These self or voluntary disclosures may well be applied to aircraft maintenance, aircraft flight operations, and drug and alcohol misuse programs. This AC or its program is not applicable to aircraft maintenance reporting failures, malfunctions, and defects under the code of federal regulation, 14 CFR. part 21. The FAA also has developed a program with its partnership approach to aircraft maintenance personnel and airline operators to improve aircraft safety. This partnership is known as the Aviation Safety Action Partnership (ASAP). This also involves aircraft maintenance reliability, aircraft maintenance training, and flight operations.

Summary of FAA Requirements

The objectives of an airline maintenance program were stated in Chap. 3 as follows:

1. To ensure the realization of the inherent safety and reliability levels of the equipment
2. To restore safety and reliability to their inherent levels when deterioration has occurred
3. To obtain the information necessary for adjustment and optimization of the maintenance program when these inherent levels are not met
4. To obtain the information necessary for design improvement of those items whose inherent reliability proves inadequate
5. To accomplish these objectives at a minimum total cost, including the cost of maintenance and the cost of residual failures

To meet these objectives, an organization must perform certain scheduled maintenance tasks (objective 1) to maintain the equipment capability. Unscheduled tasks are done whenever the equipment has deteriorated below acceptable standards or has completely failed (objective 2). Objective 3 requires that the operator have some sort of data collection program in place to monitor reliability levels of the equipment and investigate problem areas to effect maintenance program improvement when applicable. Objective 3 can also address deficiencies in the management and administrative aspects of the maintenance program. Objective 4 requires that the operator initiate action to effect redesign if reliability standards cannot be met and this deficiency is not attributed to the operator's maintenance program. Objective 5 indicates that the maintenance program should be a direct asset to the organization in that the operator does not waste time, money, or manpower performing unnecessary or ineffective maintenance but performs only that maintenance which is necessary and performs it in a timely manner.

To accomplish the above objectives, the programs and processes required by the FAA as described above must be put into place. An effective maintenance program is developed for the equipment and systems based on the best knowledge and ability of the manufacturers' and the industry's representatives. This maintenance program is then employed by the operator in an effort to maintain the equipment in top operating condition. Through the collection and analysis of performance data during actual operation, and through monitoring the effects of maintenance within the operator's own environment, the maintenance program can be tweaked and adjusted, as necessary, to optimize the entire set of processes. This results in an optimized maintenance program that not only satisfies objective 5 but also allows the operator to meet objectives 1, 2, 3, and 4.

Additional Maintenance Program Requirements

In addition to the maintenance program elements described in the previous sections, there are a number of other activities needed to carry out an effective maintenance and engineering program. The basic structure of the organization discussed here may not be adequate for all maintenance organizations. Some organizations may need to expand or combine activities, out of necessity, as dictated by the size of the specific operation. The important thing to remember is that, regardless of the organizational arrangement, these functions are necessary to carry out an effective and efficient maintenance and engineering program. These additional activities and their implementing organizations are generally called engineering, material, planning, maintenance control, training, computing, and publications. We will discuss each of these in subsequent sections.

Engineering

The primary purpose of the engineering section of the maintenance organization is to establish the initial maintenance program from the manufacturer's maintenance manual and other documents and to continually upgrade the program

over time. Engineering will also provide technical assistance in troubleshooting equipment problems; develop workable maintenance processes and procedures when required; review manufacturer's service bulletins and other maintenance tips, changes, or suggestions; and provide engineering expertise to the company or its hired consultants in designing and modifying the maintenance facilities (i.e., hangars, shop, ramps, etc.).

Material

The function of the material section is to provide the maintenance organization with parts and supplies necessary to carry out the maintenance activities. This would include the purchase and warehousing of the necessary spare parts, supplies, and tools for the maintenance activities; issuance of parts to mechanics as needed; handling of warranty claims on parts, equipment, and tools; and passing repairable components to the appropriate workshop or vendor for repair.

Planning

The planning section is responsible for planning all of the scheduled maintenance activities, including the manpower, facilities, and supplies needed for these activities. Planning also collects data on the time, manpower, and facilities actually used in the performance of the maintenance to accurately readjust these requirements for use with subsequent maintenance planning activities.

Maintenance control center

The maintenance control center (MCC), sometimes called the maintenance operations control center (MOCC), is the nerve center of the line maintenance organization; it is responsible for keeping track of all vehicles in operation. Vehicle location, maintenance and servicing needs, and other requirements are monitored by the MCC during the operational phase of activity via telephone, radio, facsimile, and any other available means of communication. The MCC keeps track of the vehicles and coordinates with key units throughout the operations, maintenance, and engineering activities so that maintenance, when needed, can be coordinated and expedited to minimize delays and down time. The MCC locates and dispatches the necessary personnel within the company who can provide whatever maintenance, troubleshooting, or parts assistance that is needed to support the operational phase of the activity. Maintenance crews at outstations can coordinate maintenance actions, the borrowing or buying of parts locally, and even the contracting of temporary third-party maintenance personnel through the MCC at the home base.

Training

Maintenance training is an ongoing process. Although maintenance mechanics receive initial training through certain formal training schools to qualify for the job, continual training is required to keep them current, to refresh their skills

when necessary, and to develop new skills and learn new processes and procedures as these are developed. The training section can be part of the maintenance and engineering organization or it can be part of the airline's overall training program that also covers the nonmaintenance training requirements. If a centralized training unit is used, maintenance and engineering should appoint one of their own managers as the training focal point so that M&E needs are met. The training section keeps records of the training received by all personnel. The training section is also responsible for training engineers, supervisors, managers, and inspectors, as required, so that they can carry out their respective duties within the company's maintenance and engineering operation.

Computing

The computing section provides the equipment, the software, the training, and the support for all computing activities within the maintenance and engineering organization. In some airlines this section may be included within the company's computer organization. It is recommended, however, that computer support for maintenance have dedicated personnel and that they work closely with, if not directly for, the maintenance and engineering organization. Various computer programs are available for maintenance activities, which include modules for data collection on malfunctions; for parts tracking and control; for collecting and manipulating reliability data, such as failure rates, removal rates, and time limitations for parts, etc.; for tracking of serial numbered parts; and for numerous other traceable information needs for monitoring maintenance activities. All maintenance activities need to be coordinated and tracked and the maintenance computer systems should be under the control of people who know maintenance as well as computers.

Publications

The publication section (or technical library) of the maintenance and engineering organization is responsible for keeping all technical publications up to date, whether they are on paper, microfilm, or electronic media. The publications section receives all publications and is responsible for distributing the documents or revisions (partial or complete) to the appropriate work centers. The work center personnel are responsible for inserting changes and disposing of obsolete pages, but technical publications personnel should spot check the work centers to see that this is being done. During the yearly audit of each unit, QA will check to see that all documents are up to date (see Chap. 16).

Summary

This section has discussed, in general terms, the kinds of activities and organizations needed to support the maintenance function. A suggested M&E organizational structure will be discussed in detail in the next chapter, "The Maintenance and Engineering Organization."

Chapter

7

The Maintenance and Engineering Organization

Organization of Maintenance and Engineering

The structure for an effective maintenance and engineering organization will vary with the size and type of organization. It may also vary with the management philosophy of the company. But one thing must be kept in mind: the organizational structure must allow the company to meet its goals and objectives and each unit within the company must be endowed with sufficient personnel and authority to carry out those objectives and meet those goals.

The following structure was determined, from experience and observation, to be the most efficient and effective one for a midsized commercial airline. For application to large or small airlines, this structure will have to be modified; but all of the functions identified here will have to exist separately or in combination to accomplish all of the functions and activities identified in Chap. 6 as essential for effective operation.

Organizational Structure

The basic organizational structure for our midsized airline is shown in Fig. 7-1. There are three basic concepts underlying the structure we have defined. Two of these come from traditional management thinking. These are the concepts of span of control and the grouping of similar functions. The third concept is somewhat unique to aviation: the separation of production activities (maintenance and engineering) from the oversight functions of inspection, control, and monitoring (quality assurance, quality control, reliability, and safety).

Span of control

The span of control concept may be considered passé to some, but it is still a useful concept. This concept states that a supervisor or manager can effectively

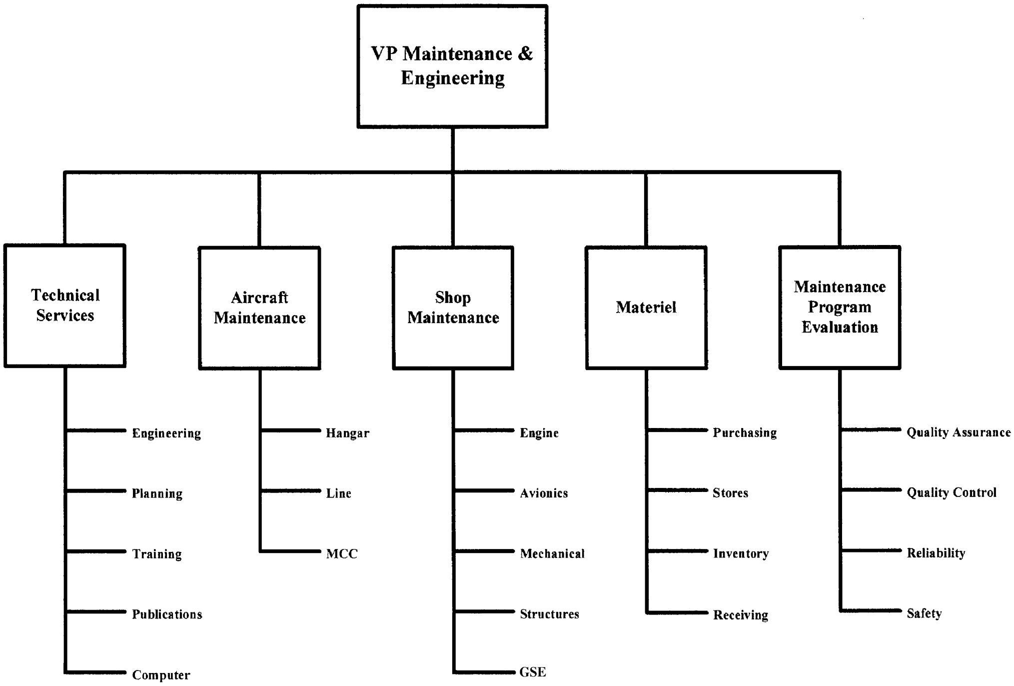

Figure 7-1 Typical maintenance and engineering organization.

supervise or control three to seven people. Any less than three would be ineffective use of time and manpower, and any more than seven would spread the boss too thin. In the organizational structure shown in Fig. 7-1, we have adhered to this concept. The VP of maintenance and engineering supervises five directors. Each director has the necessary number of managers under him or her to carry out the prescribed functions of the directorate. We find that by limiting the number of people that a manager has to supervise, the organization's work is divided into pieces that are more easily managed without losing the people-to-people contact that is so necessary for a happy and efficient work force.

At the lower levels of the organization, where the actual maintenance work is performed by workers with many different skills, the span of control is usually not so narrow. A line or hangar maintenance supervisor may have as many as 20 or 30 of these specialists to supervise. But at the upper management levels, we like to keep the span of control at the lower number. This is not to say that a wider span cannot be utilized, however. All management activities must be organized to work with the available resources and within the current management's capabilities and philosophy.

Grouping of similar functions

The second basic concept of the organizational philosophy we are using is the grouping of similar functions under one director, manager, or supervisor. What

this comes down to is that all maintenance activities (line, hangar, and MCC) are under one manager. All maintenance overhaul shop functions (electrical and electronics shops, mechanical shops, hydraulics, etc.) are likewise grouped. All inspection activities—whether it is inspecting the company's workers, inspecting parts, or inspecting the suppliers of parts—are grouped into one organization (maintenance program evaluation functions). Those handling the purchase of supplies, those performing engineering work, and those doing the planning are also grouped accordingly so that the managers and directors can maintain proper surveillance and control over areas in which they have expertise.

Separation of production and oversight functions

A third concept that is applied here may be unique to the maintenance organization. Under the FAA philosophy, an airline receives certification to operate as a commercial air transport company and that authorization is, for all practical purposes, permanent. Some foreign airlines must be recertified by their regulatory authority annually. Under the FAA rules, for an airline to be certificated, it must have certain programs in place, including a self-monitoring function to ensure that it is performing according to the rules (its own rules as well as those of the regulatory authority). This alleviates the FAA from having to recertify each airline every year. This requirement for self-monitoring is usually in the form of quality assurance (QA), quality control (QC), reliability, and safety programs. Combined, these functions constitute the core of the CASS requirement mentioned in Chap. 6.[1] It is recommended, and generally practiced, that these self-monitoring functions operate separately from the maintenance and engineering functions they are monitoring to prevent any conflict of interest problems. This separation is built into the organizational structure shown in Fig. 7-1 and is discussed below by selective grouping.

The M&E Organizational Chart

Figure 7-1 is the basic organizational chart for the maintenance and engineering organization of our "typical" midsized airline. We will briefly discuss each layer and each function. The structure starts with the VP level and continues downward with designations Director, Manager, and Supervisor as appropriate. Your organization may have other titles that their operatives prefer to use but the structure should be similar to Fig. 7-1.

General Groupings

Vice president of maintenance and engineering

The head of the entire maintenance and engineering function within the airline should be at a relatively high level of the airline's structure. He or she should be directly under the head of the airline or under the head of the company's

[1]See also FAA AC 120-79, Continuing Analysis and Surveillance System (CASS).

operational activity (President, Chief Operating Officer, or whatever title is used). The VP of M&E position should also be at the same level as the head of flight operations (VP Flight Ops or whatever he or she is called). Flight operations and maintenance are considered to be two sides of the same coin; they complement each other and carry equal weight.

The flight operations department is responsible for conducting the air transportation operations; i.e., the flying. Maintenance and engineering, on the other hand, is responsible for delivering airworthy vehicles to the operations department to meet the flight schedule. The M&E department is responsible for conducting all scheduled maintenance, modification, etc. on the vehicles within the specified limits of the maintenance schedule and still meet the operations department's flight schedule. Without maintenance, flight operations would be quite limited in their activities; without flight operations, maintenance wouldn't have much purpose in maintaining the equipment. They need each other and the airline needs both.

Directors of major functions

The five major functions shown in Fig. 7-1 are, in the order addressed in this book, technical services (which includes engineering, planning, training, technical publications, and computing); aircraft maintenance (flight line, hangar, outstations, and the maintenance control center); overhaul shops (for off-aircraft maintenance, repair, and overhaul); material services (responsible for ordering and maintaining supplies, handling warranties, and moving repairable and consumable parts through the system); and maintenance program evaluation (the monitoring activity for the organization, its workers and its suppliers). As you can see, there is more here than just maintenance and engineering. We will discuss each of these in more detail later.

Managers and supervisors

Within each directorate, there are several managers. Each of these managers has a specialized area of responsibility within the overall scope of the directorate's function. Specific activities within each manager's area of responsibility require staffs of specialists with supervision by knowledgeable people. In some large organizations, the supervisor may need additional separation of activities or duties and appoint "leads" or "straw bosses" to decrease his span of control to a workable size. However, for most operators, the span of control can be much wider at this level.

Manager Level Functions—Technical Services Directorate

The technical services directorate contains numerous activities and services that support the maintenance and inspection functions. In the typical setup of Fig. 7-1, we have identified various activities for each directorate. Each activity is under the direction of a manager. There may be further echelons of management, such as supervisors and leads as necessary.

Engineering

The manager of engineering is responsible for all engineering functions within the M&E organization. This includes (*a*) the development of the initial maintenance program (tasks, intervals, schedules, blocking, etc.); (*b*) the evaluation of service bulletins (SBs) and service letters (SLs) for possible inclusion into the airline's equipment; (*c*) oversight of the incorporation of those SBs and SLs that they deem beneficial; (*d*) overseeing the incorporation of airworthiness directives (ADs), the modifications that are required by the regulatory authority; (*e*) the evaluation of maintenance problems determined by the reliability program and for problems (if any) resulting from the maintenance checks performed by maintenance; and (*f*) for establishing the policies and procedures for the M&E organization. The engineering department employs a cadre of engineering specialists, usually enough to cover, with a high degree of expertise, any and all specialties within the aircraft's technical realm: power plant, structures, avionics, aircraft performance, and systems (hydraulic, pneumatic, etc.). These positions are at the supervisor level with several engineers in each group with their own specialties, if required.

The engineering department is also involved in the planning of facilities (new hangars, maintenance shops, storage facilities, buildings, etc.) for the airline, which are to be used by the M&E organization. Although engineering usually will not actually do the design and engineering work, they will work with the engineering consulting firm or contractor that has responsibility for the project to ensure that the final result meets the airline's requirements.

Production planning and control

The manager of production planning and control (PP&C) is responsible for maintenance scheduling and planning. This function must plan and schedule the manpower, parts, facilities, tools, and any special assistance required for all maintenance or modification activities. Included in the functions of PP&C are the following: (*a*) all planning activities related to maintenance and engineering (short, medium, and long term); (*b*) the establishment of standards for manhours, material, facilities, tools, and equipment; (*c*) work scheduling; (*d*) control of hangars; (*e*) on-airplane maintenance; and (*f*) monitoring of work progress in the support shops.

Training

The manager of technical training is responsible for curriculum, course development, administration, and training records for all formal training attended by the M&E unit's employees. The organization coordinates any training required outside the unit (vendor training) and coordinates with line and hangar maintenance personnel for the development of on-the-job training and remedial or one-time training activities. The training section must be able to establish new and special training courses to meet the needs of the airline. These course requirements are often the result of problem investigation by

reliability, incorporation of new equipment or modifications, or the addition of aircraft types to the fleet.

Technical publications

The manager of technical publications is responsible for all technical publications used by the M&E organization. The technical publications (Tech Pubs) keeps a current list of all documents received from manufacturers and vendors, as well as those produced in-house by the airline. Also on record are the number of copies, in paper, microfilm, or compact disc (CD) format, that each work center should receive. The Tech Pubs organization is also responsible for ensuring that appropriate documents and revisions are distributed to these various work centers. Work centers are responsible for keeping their own documents current, but Tech Pubs usually conducts periodic checks to see that this is being done. Tech Pubs is also responsible for maintaining the main technical library and any satellite libraries within the airline's system, including those at outstations.

Computing services

The manager of computing services is responsible for the definition of the M&E organization's computing requirements: (*a*) selection of software and hardware to be used, with usage information and requirements inputs from the individual units; (*b*) training of maintenance, inspection, and management personnel on computer usage; and (*c*) provide continuing support to the using organizations.

Manager Level Functions—Aircraft Maintenance Directorate

The aircraft maintenance directorate has responsibility for the major aircraft maintenance activities: maintenance on the flight line and maintenance performed in the hangar. Three managers report to the director of airplane maintenance: one for each of these activities and one for MCC. For airlines with different model aircraft or with two or more maintenance bases, the number of aircraft maintenance managers may be increased as necessary for the scope of the operation.

Hangar maintenance

The manager of hangar maintenance is responsible for compliance with the airline's policies and procedures relative to all work done on the aircraft in the hangar, such as modifications, engine changes, "C" checks (and higher), corrosion control, painting, etc. The hangar maintenance function also includes various support shops (welding, seat and interior fabric, composites, etc.), as well as ground support equipment.

Line maintenance

The manager of line maintenance is responsible for compliance with the airline's policies and procedures relative to the work done on the aircraft on the flight line while the aircraft is in service. Such activities include turnaround maintenance and servicing, daily checks, short interval checks (less than "A" check interval), and "A" checks. Sometimes, simple modifications can be done by line maintenance in order to avoid unnecessary use of the hangar. Line maintenance may also be utilized to perform line maintenance activities for other airlines under contract.

Maintenance control center

The function known as the maintenance control center (MCC) keeps track of all aircraft in flight and at outstations. All maintenance needs of these vehicles are coordinated through the MCC. The MCC also coordinates downtime and schedule changes with the flight department. Some airlines might have a supervisor of line stations to coordinate outstation activities, but he or she is often part of the home base MCC operation.

Manager Level Functions—Overhaul Shops Directorate

The overhaul shops directorate consists of those maintenance shops that perform maintenance on items removed from the aircraft. These shops include engine shop(s), electrical shop, electronics (or avionics) shop, and various mechanical shops. These may be separate shops or some may be combined for convenience, depending on the operation. Some of these shops may also perform contract work for other airlines.

Engine shops

The manager of the engine overhaul shops is responsible for all maintenance and repair done on the organization's engines and *auxiliary power units* (APUs). If more than one type engine is used, there may be a separate engine shop for each type performing the work, but these would usually be under one senior manager with a supervisor for each engine type. The engine build up activities would generally come under the engine shop manager.

Electrical and electronics (avionics) shops

The manager of electrical/electronics shops is responsible for all off-aircraft maintenance of electrical and electronics components and systems. There are a variety of components and systems in this field with wide variations in the equipment and in the skills needed to address them. There may be several shops (radio, navigation, communications, computers, electric motor–driven components, etc.) with separate supervisors. Shops are combined at times,

however, to optimize manpower and space and to reduce test equipment inventories.

Mechanical component shops

The manager of mechanical component shops has responsibilities similar to those of the manager of avionics shops. The only difference, of course, is that these shops would address mechanical components: actuators, hydraulic systems and components, aircraft surfaces (flaps, slats, spoilers), fuel systems, oxygen, pneumatics, etc.

Structures

The structures shop is responsible for maintenance and repair of all aircraft structural components. This includes composite material as well as sheet metal and other structural elements.

Manager Level Functions—Material Directorate

The material directorate is responsible for the handling of all parts and supplies for the M&E organization: (*a*) purchasing; (*b*) stocking and distribution (stores); (*c*) inventory control; and (*d*) shipping and receiving of parts and supplies used by the M&E organization. This includes not only the parts and supplies used in the maintenance, servicing, and engineering of the aircraft but also the supplies used for the administration and management of M&E (i.e., office supplies, uniforms, etc.).

Purchasing

The manager of purchasing is responsible for buying parts and supplies and tracking these orders through the system. This begins with the initial issue of parts when a new aircraft is added to the fleet and a continual replenishment of those parts based on usage. The purchasing unit is also responsible for handling warranty claims and contract repairs.

Stores

The manager of stores takes responsibility for the storage, handling, and distribution of parts and supplies used by the maintenance personnel in line, hangar, and shop maintenance activities. Stores areas, or parts issue points, are placed near the various work centers to allow mechanics quick access to parts and supplies and to minimize the time spent obtaining those parts and supplies.

Inventory control

The manager of inventory control is responsible for ensuring that the parts and supplies on hand are sufficient for the normal, expected usage rate without

tying up excessive funds in nonmoving items and without running out of stock too soon or too often for commonly used items.

Shipping and receiving

The manager of shipping and receiving is responsible for packing, waybill preparation, insurance, customs, etc. for outgoing materials, as well as customs clearance, unpacking, receiving inspection, tagging, etc. for incoming materials. This includes all parts being shipped into and out of the airline.

Manager Level Functions—Maintenance Program Evaluation Directorate

The maintenance program evaluation (MPE) directorate is an organization tasked with monitoring the maintenance and engineering organization. The MPE unit is responsible for the CASS activities. The unit's functions include quality assurance, quality control, reliability, and safety.

Quality assurance

The manager of quality assurance is responsible for assuring that all units of M&E adhere to the company policies and procedures as well as FAA requirements. The manager of QA sets the standards for the M&E operation, and the QA auditors ensure compliance to those standards through yearly audits. Quality assurance is also responsible for auditing outside suppliers and contractors for compliance with the company's, as well as the regulatory authority's, rules and regulations.

Quality control

The manager of quality control is responsible for conducting routine inspections of maintenance and repair work, certifying maintenance and inspection personnel, and management of the required inspection items (RIIs) program. This latter function involves the identification of RIIs and the certification of specific personnel authorized to inspect and accept the work. The QC organization is also responsible for the calibration of maintenance tools and test equipment and performs or oversees the nondestructive testing and inspection (NDT/NDI) procedures.

Reliability

The manager of reliability is responsible for conducting the organization's reliability program and ensuring that any problem areas are promptly addressed. This responsibility includes data collection and analysis, identification of possible problem areas (which are then addressed in detail by engineering), and publication of the monthly reliability report.

Safety

The safety organization is responsible for developing, implementing, and administering the safety- and health-related activities within the M&E organization. The safety manager is also responsible for handling all reports and claims regarding M&E safety issues.

Summary of Management Levels

For all of the above organizations, the respective directors, managers, and supervisors are also responsible for the more mundane activities that are necessary for any smoothly operating organization. Those activities include the handling of administrative and personnel duties; the budgeting and planning requirements for their respective organizations (both long and short term); and the necessary interactions with some or all of the other organizations, including those outside of M&E, through a plethora of meetings, letters, documents, memos, bull sessions, and chance meetings in the hallway.

Organizational Structure and the TPPM

The maintenance management organization discussed here is based on the conventional approach where we group similar activities and provide a structure within which all can work. It does not, however, subscribe to the "chain of command" philosophy where each hierarchical level has dominion over the lower tiers. Rather it is meant to encourage the more modern approach of "cross-functional coordination."

This maintenance management structure can be classified as a system (see Appendix A). Figure 7-1 represents a collection of structural and procedural components designed to work together efficiently to perform the maintenance management function. As with any system, the theoretical design may differ from what we actually attain when the plan is implemented in the real world. That is, even management systems contain some entropy, some imperfection, both natural and manufactured (see Chap. 1). Thus, it is important to understand management's dual role in setting up and running an organization. Management personnel have responsibilities similar to those of systems engineers: they must develop a workable system and they must strive for a minimum amount of imperfection (entropy) within that system. Management personnel also have responsibilities similar to those of system mechanics: their ongoing job is to combat the natural increase in entropy that their system will doubtless undergo over time.

A manager is, in a sense, similar to an airplane pilot. In the early days of flying, it was a vigorous effort for the pilot to fly the aircraft. In the Wright brothers' first airplane, the operator laid down on his stomach and operated the necessary controls with his hands, his feet, and his hips. Later models allowed him to sit upright. For many years the pilot flew the airplane by "feel." The vehicle was an extension of the pilot; the pilot and his or her aircraft were one unit; they

flew together. In today's modern aircraft, the pilot has the benefit of various communication, navigation, and control systems which almost fly the airplane unassisted. The pilot, then, after setting everything in working order, "sits back and manages the flight."

This does not mean that a pilot is less important and no longer needs rigorous training. On the contrary, he or she must know as much as—actually more than—any earlier pilot had to know. When something goes wrong, or does not go as well as planned, the pilot must know instantly what to do, how to take over from the automatic systems and fly the aircraft manually.

Management of maintenance and other technical activities is a similar effort for those managers confined to the ground. In our typical management structure, we have identified the organization necessary to carry out the M&E functions. Management has determined this structure based on the rules stated earlier: grouping of like functions, span of control, and separation of monitors from those monitored. Further establishment of M&E operations is spelled out in detail in the airline technical policies and procedures manual (TPPM) which is meticulously developed by management at the beginning of operations to ensure smooth, cross-functional coordination among the M&E units and to accomplish the stated goals and objectives of the organization. Once the M&E organization and its operational policies and procedures are established, and the hired personnel are trained on those elements, management can then "sit back and manage the operation."

Variations from the Typical Organization

It is obvious that the above organizational structure will not work for all commercial operators. Airlines smaller than our "typical" airline, as well as those which are much larger, cannot operate efficiently under this arrangement. There must be variations in this structure to accommodate the differences. These are discussed next.

Small airlines

Small airlines may not be able to organize in the manner shown in Fig. 7-1 for two reasons. One, they may not have enough personnel to populate all these positions; and two, they may not have enough work to keep all, or some, of these people occupied full time. It is obvious, then, that the management structure must be altered. This can be done in several ways.

First of all, we must state that all of the activities identified in the typical organizational chart must be addressed to some extent in any airline. All of these functions are necessary for efficient operation. However, due to size and personnel limitations, one individual or one section may be asked to perform more than one of these functions. For example, quality control functions might be assigned to personnel in the work centers. Mechanics and technicians would perform the inspection work as needed as an adjunct to their regular duties in maintenance. These QC inspectors, however, would be supervised by the quality

assurance organization (or QA person) regarding these inspection activities. More on this will be discussed in Chaps. 16 and 17.

Reliability and engineering functions might be combined in smaller airlines, also. Technical publications, training, and even production planning and control may be combined with engineering to utilize available skills. Line and hangar maintenance functions may be separate organizations but utilize many of the same personnel. The two functions may also be combined as one maintenance organization.

Large airlines

For the larger airlines, especially those with more than one maintenance base, an organizational structure different from Fig. 7-1 will be necessary. There will be a need for a hangar maintenance organization at each base where that type of work is done. For instance, MNO airlines may do hangar maintenance on their 757s at Denver and on their A310s at Kansas City. One hangar maintenance organization at the home base (wherever that may be) would not be adequate. It may be necessary, though, to have a corporate-level manager responsible for both units, as well as separate managers at each site. The same would apply to production planning and control and certain support shops for this arrangement. Again, it should be emphasized that it is important to have the functions listed in our "typical" structure addressed no matter how the airline is actually organized.

Full versus partial organizational structure

It should also be pointed out that this "typical" airline structure is not adequate for an airline that does not perform all the functions listed in Fig. 7-1. Many small airlines, and some larger ones, do not do their own hangar maintenance and, therefore, do not need the hangar maintenance organization. The same is true for those airlines that outsource their shop maintenance in one or more areas (avionics, hydraulics, etc.). But even if certain functions are not performed by the airline itself, these functions must be accomplished to properly maintain the equipment. The airline must designate someone in the M&E organization to be responsible for these functions, to see to their completion, and to coordinate these actions with other airline activities. These and other variations will be discussed in the appropriate chapters later in the book.

Part

II

Technical Services

The technical services directorate is responsible for providing technical support and assistance; continuous monitoring, updating, and development of maintenance programs for the airline's fleet type; maintenance program change; articulating aircraft manuals and their distribution; and all other M&E activities. Part II begins with Chap. 8, Engineering. This is the main group in technical services and sometimes, in small airlines at least, will include some or all of the other support functions. The main job of engineering is to establish the maintenance program and subsequent schedules and to provide engineering expertise in new notice of proposed rulemaking (NPRM), new airworthiness directives(ADs) review, aircraft manufacturer documents, service letters, notice to aircraft operators, service bulletins, and to provide technical assistance to all other units within the M&E.

Production planning and control (PP&C), discussed in Chap., 9, is the primary force driving the day-to-day work activities of aircraft maintenance. This department is responsible for planning and scheduling all aircraft maintenance activities in the airline. The other functions of technical services are Technical Publications, Chap. 10, which is responsible for document receiving, distribution, and updates. Technical Training, Chap. 11, is responsible for all training activities in M&E, including maintenance management, inspection, auditing personnel, and administrative support. Figure II-1 shows the organizational chart of the technical services units.

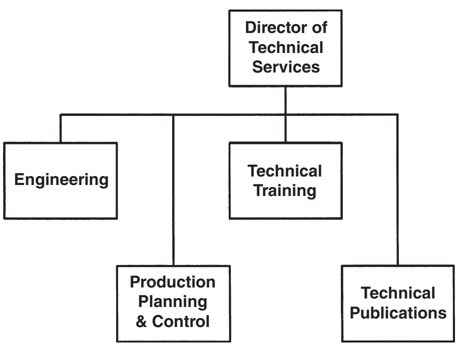

Figure II-1 Organizational chart for technical services.

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Chapter

8

Engineering

Introduction

There is discussion in the aviation industry about whether or not an airline needs an engineering component. In former times, airlines were instrumental in determining what they wanted in terms of aircraft size, range, and operating systems. The airlines would establish specifications and present these to the various airframe manufacturers who would then compete for the contract and ultimately produce the final product. In recent years, however, the general trend has been to leave the design and development of new aircraft to the airframe and engine manufacturers. The airlines' only stipulation is, essentially, "build something we can use effectively and something we can afford."

With this latter approach, many airlines considerably reduced the size of their engineering staffs and some eliminated them altogether. But there are other things to consider before closing the engineering office at an airline. Although the airline is not involved with design of new aircraft, other than defining basic requirements, there are still reasons for hiring people with engineering skills and background. These reasons are the subject of this chapter.

Engineering is defined by the Engineers' Council for Professional Development as the "profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize economically the materials and forces of nature for the benefit of mankind." The *Encyclopedia Americana* says "Engineers, unlike scientists, work toward the solution of specific practical problems." The *Encyclopedia Britannica* adds: "All engineers must have a positive interest in the translation of the theoretical into the practical." In other words, an engineer is one who applies mathematics and scientific principles to the effort of resolving practical problems.

Engineers are usually identified by some specialty: civil, mechanical, electrical, aeronautical, transportation, nuclear, to name a few. None of these specialties

apply directly to aviation except aeronautical, and these aero engineers would normally be involved with design and development of air and space systems and equipment which, as we have said, the airline no longer does. All the other engineering disciplines listed previously have specialties which may be applicable to some aspect of an airline operation, but we cannot afford to hire them all. We would not have enough work to keep them all busy, and they are not often capable of working in each other's area. What we do need in a typical airline maintenance organization are people trained as "maintenance engineers."

In Chap. 3, we defined *maintenance* as "the process of ensuring that a system continually performs its intended function at its designed-in level of reliability and safety." Maintenance engineers, then, are those degreed engineers who have knowledge, experience, and training in the field of aviation maintenance. That is, they need to know basic engineering as well as the technical details of the equipment used in aviation and the maintenance and operation of that equipment. Maintenance engineers at the manufacturer's plant develop maintenance programs from the MSG-3 activity (Chap. 2) and produce the various maintenance documents (Chap. 5). At the airline, maintenance engineers are responsible for applying the manufacturer's program and adjusting it, when necessary, to the real world situation. Most colleges and universities, however, do not have courses in maintenance engineering. Those who pursue this profession are very often experienced mechanics with interest in the engineering area, or they are engineers with an interest in the aviation maintenance field.

The engineering department of an airline can vary widely; they perform many functions for the airline as a whole and specifically for the M&E organization. In some airlines, engineering is a corporate unit separate from the M&E operations, and in others it is part of M&E. The size of the airline often determines which is most desirable. In those airlines where engineering is outside the M&E organization, their function is usually oriented toward major engineering type activities, such as the development and support of buildings and other facilities; major aircraft modification design; and detailed engineering studies of maintenance problems as well as other airline technical problems.

In most airlines, however, engineering is an integral part of the maintenance and engineering organization, and their main function is to support maintenance. The engineering section is also responsible for developing the maintenance program at the airline, for providing analytical assistance to the maintenance organization, and for providing troubleshooting assistance to line, hangar, and shop maintenance personnel on difficult problems.

Makeup of Engineering

The airline engineering department is made up of the more experienced people of the maintenance organization. They must be knowledgeable of the total maintenance operation as well as the airline and regulatory requirements. Ideally, an airline would have both degreed engineers and senior licensed mechanics in

the engineering department. There would be engineering staff for each type of equipment: avionics, electrical, hydraulic, pneumatic, power plant (engines and APU), structures, and mechanical systems. Avionics may even be divided into communications and navigation systems; and mechanical systems into flight controls, hydraulics, etc. Some airlines may have different groups of engineers for each model of airplane and/or engine.

This distribution of specialties is determined, for the most part, by the size of the airline, however. For very small operators, there may be only one or two people in engineering. These are usually senior mechanics but they are required to provide the same assistance discussed above on all types of equipment. The larger the airline, the larger and more diverse the engineering department will be.

Mechanics and Engineers

Some airlines have engineering departments made up entirely of mechanics, while others have departments made up entirely of degreed engineers. Neither of these schemes is entirely satisfactory for our purposes. Although the mechanics are fully versed in the details of the systems and components in service, are experienced in the governing rules and regulations, and understand the idiosyncrasies of their fleet, they often do not have the same analytical discipline and other training of engineers. On the other hand, graduates of engineering colleges, more often than not, lack a suitable understanding of airplanes, aircraft engines, and the multitude of systems and components needed to provide airworthy vehicles for air transportation. The engineering curricula provide no training in maintenance and very little about other engineering disciplines.

Engineers and mechanics are trained differently, and each approaches problems in different ways. While the mechanic's approach is somewhat reactive, the engineer's approach is more proactive. But, it takes both disciplines to run an effective engineering operation at an airline. Let's look briefly at each.

Mechanics

Mechanics and technicians study the practical aspects of aviation systems and equipment. They may specialize in avionics systems (electrical, electronic, communication, computer) or mechanical systems (hydraulics, pneumatics, flight controls, structures). This is the case particularly if they work in shop or hangar maintenance or for a third-party organization doing maintenance or overhaul. If the mechanic works on the flight line, preparing aircraft for flight or servicing and maintaining aircraft in transit, he or she may be required to address all systems.

In either case, the mechanic is trained to address each system or unit with an understanding of how it is supposed to work and how it is supposed to be operated. When there is a discrepancy, the mechanic follows standard procedures for troubleshooting, fault isolation, and repair. Procedures for removal and installation, as well as for testing the installed unit, are all standardized.

An experienced mechanic also knows what kinds of things can go wrong (in operation as well as in installation and testing) that require more detailed analysis for determination of the problem. This last skill only comes with experience; it can be taught only in a cursory manner (see Appendix C). But, no matter how well trained a mechanic may be and no matter how much experience he or she might gain, often there are problems that cannot be resolved with these standard approaches. The neophyte mechanic may conclude that these problems cannot be solved. The more experienced one will realize the need to dig deeper into the problem. If this fails to produce a solution, it may be necessary to call upon the engineering staff for help (assuming they are properly qualified).

Engineers

In this book, we use the term *engineer* to identify those who have academic degrees in some engineering field. These people are trained differently than mechanics. Engineers are trained in the basics of science and engineering (mathematics, chemistry, physics, etc.); in the techniques of inductive and deductive reasoning; as well as in the areas of statistical analysis, problem solving, and systems engineering. Engineers also specialize in one particular engineering discipline—civil, electrical, mechanical, aeronautical, structural. Seldom do engineers spread themselves over the gamut of aviation disciplines. But this is not to say that they are not capable of assisting the mechanics in problem solving.

The engineer should be able to pick up a problem where the mechanic leaves off. If all the common and usually effective procedures applied by the mechanic did not work, then the engineer (or any first-class mechanic for that matter) must begin by looking at the problem from a new angle. This requires that the engineer understand more than the basics of system operation. He or she must also understand the kinds of things that can go wrong and the kinds of things that can be influenced by outside forces not accounted for in the standard maintenance procedures. The engineer must be able to develop new and innovative procedures for studying and analyzing problems and must understand the "big picture" to effectively come to an appropriate answer. This is what engineers are supposed to do. Engineers are basically problem solvers.

Appendix C provides information on basic troubleshooting techniques that apply to both mechanics and engineers. Appendix D provides some insight to the engineer's approach to problem solving. Although this appendix relates primarily to reliability alerts (see Chap. 18), the approach can apply to any problem to be solved.

One important thing to realize, however, is that for all the engineer knows about engineering, about problem solving, and about systems and their interactions, he or she must also know the airplanes, the engines, and the associated systems on those airplanes to effectively apply this knowledge to the solution of real airplane problems. It takes both disciplines—engineering and maintenance—as well as both types of experts—engineers and mechanics—to make an effective and efficient maintenance and engineering organization run smoothly.

Engineering Department Functions

The engineering department provides preparation, study, and analysis of various aspects of the maintenance operation. They evaluate maintenance requirements and establish the maintenance program for the airline. They also evaluate suggested modifications of aircraft systems for possible incorporation into the fleet and provide technical assistance to maintenance. Engineering prepares the units for handling new equipment and facilities and provides assistance, where needed, in all other aspects of maintenance. These functions are discussed below.

Development of the maintenance program

Each airplane model has an initial maintenance program developed by the industry working groups and defined in the manufacturer supplied documentation. This is a suggested maintenance program for new operators and new equipment. Once in the field, operators can adjust the program to suit their own needs and operational environment (see Chaps. 2 and 18).

This initial maintenance program is a generalized program and must be tailored to the individual operator from the very beginning. The manufacturer produces the FAA approved MRB report and a maintenance planning document (see Chap. 2). It is the responsibility of the engineering department at the airline to package these tasks into workable units based on such factors as time, space, personnel, fleet schedules, and overall airline capabilities. For some airlines, the designated letter checks (A, B, C, and D) are sufficient. The fleet is large enough for the airline to schedule people and facilities for continuing checks (e.g., one airplane per week or per month). In small airlines, there are not enough airplanes to allow this continued scheduling of "C" checks. Due to the higher manpower requirements for the "C" check, it is necessary for the small airline to adjust the schedule to smooth out the work.

For most operators, the "A" check is done monthly. The "C" check comes about yearly (every 12 to 18 months for newer models) and requires a concentration of personnel for the 3 to 7 days required to perform it. For the small airline, staffing this annual effort is not feasible. To remedy the matter, the "C" check is divided into parts, called phases, and each part is conducted separately. For example, a "C" check could be divided into four phases (C1, C2, C3, and C4), each one carried out every 3 months until the entire "C" check is performed. An airline may divide the "C" check into 12 packages and perform one package a month along with each scheduled "A" check. In either case, the personnel utilization is more constant throughout the year, the checks are done within the prescribed time limit, and the airline workload is stabilized.

The responsibility for selecting the tasks to be done, for packaging the tasks into workable check packages, and ensuring that all task limits are met (time, cycles, etc.) lies with the engineering department. Actual scheduling of the checks for individual aircraft is a function of the production planning and control department (see Chap. 9).

The tasks performed by maintenance at any of these checks can be quite detailed. To ensure that they are carried out correctly, task cards are issued to the mechanics. Many airlines use task cards produced by the airplane manufacturers and some write their own cards. Still others develop a combination of the two. Whichever method is used, it is the responsibility of engineering to develop these task cards, assemble them into appropriate packages, and ensure that they are current and effective.

Develop technical policies and procedures manual for M&E

This document contains all the necessary information to describe the M&E organization, and its responsibilities. It identifies the organizational structure, provides information on duties and responsibilities of key personnel and key organizations, and provides a series of maps and layouts of the airline's facilities. It also gives detailed descriptions of how work is to be carried out, who is to perform the work, and how it will be managed, inspected, and released (if applicable). Engineering is responsible for developing this document with inputs from the other M&E units.

The FAA defines the minimum requirements for the manual in FAR 121.369, but consideration should be given to additional policies and procedures that provide complete instructions to maintenance and engineering personnel for the conduct of their work. The manual can be a single document in loose-leaf form, it can be a series of separate documents, or it can be a multiple-volume set. Chapter 5 gives an outline of a typical TPPM.

Evaluate changes in the maintenance program

From time to time there will be problems with the effectiveness of the maintenance program. Individual tasks may be ineffective or less than adequate. Some MRB tasks eliminated from the original program may, in retrospect, need to be reinstated. In some cases, it may be necessary or desirable to shorten or extend the intervals between repetitive tasks to improve the overall performance or reduce in-service failures of a system or component. This adjustment of the maintenance program is the job of the engineering staff. Data collection by the reliability organization and analysis of the problem by engineering are necessary to carry out this function.

Evaluate changes in aircraft or system configuration

From time to time, the airplane, engine, and component manufacturers develop modifications and improvements for their respective systems, which are intended to improve operations, reliability, and/or maintenance processes. These are issued as service bulletins (SBs) or service letters (SLs). If a safety or airworthiness issue is involved, the modification may be issued by the FAA as an airworthiness directive (AD).

Since service bulletins and service letters are not FAA requirements, the airline has the option to incorporate or ignore the modification. Many airlines will incorporate these suggestions on faith; others will ignore them. For most operators, however, the airline's engineering department will evaluate the feasibility of incorporation. They will look at the cost of incorporation and the benefits in terms of reduced maintenance, improved performance, or passenger convenience (or any combination of these) and, based on this cost-benefit analysis, make the decision to incorporate or not to incorporate.

Airworthiness directives are mandatory, so there is no need for engineering to evaluate the change. Engineering will, however, be required to provide the information needed by maintenance to accomplish the modification regardless of whether it is an AD, SB, or SL. This will be accomplished by issuing a detailed instruction produced in the form of an engineering order (EO) which is discussed below.

Evaluation of new aircraft added to the fleet

One of the primary functions of engineering is to evaluate new equipment for the airline. When the business people of the airline decide to expand the operation, one of the first questions to resolve is "What airplane/engine combination should we buy?" Part of this decision is based on the routes to be flown, the destination cities, the expected market share and, of course, the cost of the equipment versus the revenue expected. These are operations and business decisions based on market conditions and airline goals and objectives.

Another important part of the decision, however, is "What is the best equipment to buy from the maintenance and engineering standpoint?" The two decisions—business and technical—must be reconciled to the satisfaction of the overall airline goals. At this point, for the sake of the present course of study, we will skip the business decision and concentrate on the technical decision.

Let us assume that the choice is to be made between two new models—both are two-engine airplanes, the Boeing 767 and the Airbus A330. There are a number of questions to be answered in regard to maintenance.

1. What engines are available for these models? Are they the same or similar to engines in the airline's current fleet? This is important because there may be a need for additional maintenance and test facilities for these new engines. The cost and the feasibility of this is very important. Training needs for engine mechanics and additional staffing (if any is required) are also to be considered.
2. What is the range of these airplanes? Will the airline need to position their own line personnel at outstations or arrange for contract personnel at the site to support maintenance or turnaround on these new models? Can existing outstation personnel handle these new airplanes? Can they do so with or without additional training? Or with minimal upgrade training?

3. What new technology is included in these new models? Are the skills of the current maintenance and engineering staff sufficient to maintain these airplanes or will they require additional training? Additional manpower? Will this involve extensive training or "differences training" only?
4. Based on current knowledge of the maintenance programs for these two airplane models, will the scheduled checks be compatible with current schedules (i.e., check cycles) for the existing fleet? What changes will have to be made (if any) to existing maintenance activities (hangar space, production planning, flight line, MCC) to accommodate the new model?
5. Will additional ground support equipment (GSE) be needed for these new airplanes? If so, what equipment?
6. Will the existing hangars be suitable for these airplanes? Will they need to be modified or will a new hangar be required? This may require interface with outside builders or contractors.
7. What will be the increased need for parts and parts storage at the home base and at outstations to support the new airplanes? This could involve a considerable amount of financial investment for parts not common to the existing fleet.
8. What is the industry experience on these two models relative to maintenance support (i.e., parts availability, parts delivery, failure rates, removal rates, amount of maintenance required)?

These and other questions must be considered by the engineering department, with inputs from other units within M&E, prior to the decision as to which airplane should be purchased. This preliminary analysis must include information on costs as well as training requirements and time frames for upgrade of facilities and personnel. Once the decision is made on which airplane and engine to buy, the engineering department must then develop more detailed estimates and devise implementation plans for all aspects of the integration of the new model into the maintenance plan. These efforts must also include data on the number of airplanes to be purchased and the time schedule for delivery.

Evaluation of used aircraft to be added to the fleet

If the airline is contemplating the purchase or lease of used airplanes from another airline or leasing organization, other items must be considered in addition to the above items relating to equipment differences from the existing fleet. These items would include such information as the current configuration of the airplane, including engine type; the maintenance program and check schedule that the current operator is using; status of modifications (ADs and SBs). Are these requirements the same as, similar to, or different from your airline's current equipment? How will this affect training, maintenance support, material support, outstation activities, etc.? If airplanes are to be leased, what modification and configuration standards must be met by the operator; by the lessor? What configuration should the airplane be in at termination of the lease?

Note: There have been cases where an airplane in ETOPS[1] configuration was leased to an operator who did not fly the airplane in ETOPS service and, therefore, did not keep up with the newer ETOPS modifications. When the airplane was returned at the end of the lease, the airline discovered that they were responsible for returning the airplane to ETOPS configuration at their own expense.

The condition of the aircraft at termination of the lease and return to the lessor should be clearly stated and understood at the signing of said lease. What condition (state of ADs, SBs, configuration) as well as who is responsible for making the required adjustments—lessor or lessee—must be clearly stated at the outset.

Evaluation of new ground support equipment

On a smaller scale, the engineering department will also be called upon to evaluate the need for new equipment in support of aircraft added to the fleet. This would include tools, test equipment, stands, electric and pneumatic carts, heaters, tow bars, tractors, etc. Some existing equipment may or may not be usable with the new airplane models (purchased or leased). In some cases, the GSE, though usable, may not be available in sufficient quantity to serve the increased fleet size. Additional purchase would be necessary in such cases.

Development of new facilities for M&E

At times, it is necessary for the airline to build new facilities or expand existing ones to support new equipment, airline expansion, or modernization efforts. This would include such projects as hangars, engine test facilities, component shops, storage facilities for various types of equipment, and storage for special parts. The engineering department will not (usually) be involved in the design and construction of these new facilities. That will be contracted out to more appropriate companies. Engineering will, however, have a considerable input into the design in terms of requirements. A hangar, a workshop, or any other facility must be designed for the express use of the airline and the M&E organizations that will occupy it. Therefore, the engineering department will act as liaison between the users and the designers and builders to ensure that the finished product is acceptable.

Issuance of engineering orders

Any work performed by maintenance in the form of standard checks—daily, 48-hour, transit, "A" check, "C" check—is done on standing orders from the VP of maintenance and engineering as identified in the maintenance section of the

[1]ETOPS (extended range operations with two-engine airplanes) is discussed in Appendix E.

Ops Specs. Any work not included in these standard checks must be assigned by engineering order. Some airlines may call this document by another name, such as work order, technical order, or engineering authorization (EA). This EO is developed by engineering, with inputs from appropriate work centers, to define the scope of the job and schedule the work. Work performed as a result of SBs, SLs, ADs, and all work resulting from evaluation of problems defined by reliability investigations or QC reports, will be issued on an engineering order. All work centers involved in the particular project will be defined on the EO: maintenance (line, hangar, or shop as appropriate); material (for parts, supplies, tools); quality control (inspection of work if required); training (remedial, upgrade, or new course). Engineering releases the EO after all involved organizations (maintenance, material, planning, etc.) have agreed to its contents. Engineering then tracks the work progress and closes the EO when all has been completed. In certain instances, airline modifications are made to the fleet, either by directive or through the airline's own initiative. These "fleet campaigns" are also controlled by EOs. These EOs cannot be closed out until the entire fleet has been worked. The preparation of an EO is discussed at the end of the chapter.

Provide assistance in troubleshooting difficult problems

The day-to-day problems that mechanics run into on the line, in the hangar, and in the shops, are often routine and call for well-defined responses. At times, the problems are more elusive and the mechanic must apply his or her troubleshooting skills to resolve the problem. When the problem eludes the mechanic's expertise, assistance is available from engineering to get to the bottom of the problem. This assistance can be given to line, hangar, and shop people, as well as vendors handling warranty claims or working on contract. Parts suppliers who perform repairs on rotable units and contractors doing third-party maintenance may also require engineering's assistance. It should be noted that this is not the primary responsibility of engineering and should be used only in difficult circumstances. Engineering is not a substitute or replacement for maintenance.

Other engineering functions

Engineering can also provide expertise to training, material, the technical library, or any other M&E organization needing technical help. They are considered the technical experts of the organization and are available to lend technical assistance to anyone in the airline needing such assistance.

Engineering Order Preparation

Engineering initiates an engineering order for any work not included in the standard maintenance program plans as established by the Ops Specs. However, the need for an EO can be generated from various sources. Its implementation can

also take various paths depending on the type and complexity of the work involved. For example, EOs related to maintenance modifications and other directives (ADs, SBs, SLs, etc.) will be scheduled by the planning organization (PP&C). Other problems may necessitate changes in the maintenance program (intervals, tasks, etc.); change in processes; parts procurement activities; or may require training (refresher or upgrade; classroom or on the job). In these cases, the EO might be issued directly to the M&E unit or units involved. The following eight steps generalize the process:

1. A decision is made to do work based on one of the following: reliability program alert; work force requirement (QA, QC, maintenance manager, or mechanic); an AD, SB, SL, or fleet campaign.
2. Engineering analyzes the work requirements (problem and solution): troubleshoot or investigate the problem to determine scope and needs; analyze AD, SB, SL, etc. if applicable for time, personnel, etc. requirements.
3. Determine the approach to follow: incorporate work into PP&C check or other scheduled or unscheduled maintenance activity; schedule other corrective action as necessary; issue EO as required.
4. Identify the needs for schedule and performance of the work: engineering studies, plans, etc.; the need for special skills if any (in-house or contract); the need for parts and supplies (on hand or order, consider lead time for delivery); determine need and availability for special tools and/or test equipment needed.
5. Identify work required: personnel (maintenance, engineering, contract, etc.); facilities (hangar space, GSE, etc.); time requirements for work to be done.
6. Call a coordinating meeting to finalize EO (if necessary): all organizations involved in the work; coordinate and resolve difficulties.
7. Issue engineering order: PP&C will plan work and monitor execution; or EO may go directly to material, training, etc. as necessary.
8. Engineering closes EO when all work is completed: notification comes from each work center involved in the particular EO; for fleet campaigns, ADs, etc. involving entire fleets, EO remains open, PP&C schedules each aircraft for incorporation; engineering closes EO when fleet is complete.

Chapter

9

Production Planning and Control

Introduction

Production planning and control (PP&C), because of its key role in planning and scheduling, is the heart of the maintenance and engineering (M&E) organization. Although the title PP&C is common throughout the airline industry, the activities actually performed sometimes fall short of the ideal notion of what PP&C should be. The PP&C organization is primarily responsible for planning and scheduling all aircraft maintenance activity within the airline.

PP&C Organization

The planning work can be done by a centralized or decentralized PP&C group. In the centralized group, all functions—forecasting, planning, and control—are done within the organization, with liaisons to the work centers during actual performance of work. In a partially decentralized organization, the forecasting and planning would be done by PP&C, and the control would be done by personnel in the hangar or other work centers. In some airlines, the PP&C function is entirely decentralized. That is, all the planning and control is done by each work center. If the airline structure and size is such that the planning has to be done by the individual work centers instead of a centralized group, there must still be some coordination and control at the M&E organizational level.

The M&E organization is normally led by the vice president of maintenance and engineering. The production planning and control department typically reports to the VP of M&E. The PP&C department is normally overseen by a manager, followed by the maintenance planner, and long-range planner.[1]

[1]Each air carrier defines "planning department" as they see fit. Major airlines and regional airlines may have different planning structures with different titles.

Manager, PP&C

The PP&C manager is normally responsible for the planning department and its functions. This includes making sure that all assigned maintenance and inspection planning activities are accomplished according to the airline's policy, and FAR's and the company's required maintenance programs. The PP&C manager must have the cross-functional ability to work with other departments within the airline's organization; plan, coordinate, and route aircraft to maintenance bases in a timely manner; and take appropriate and necessary action which may affect the airline's daily operation.

Maintenance planner, PP&C

Maintenance planners are assigned to different maintenance bases. One maintenance planner can track two to three different maintenance bases and is normally the contact for maintenance bases for planning schedules. The maintenance planner's primary function is to develop all scheduled work and/or work scope needed for all line maintenance and hangar maintenance aircraft. It is the maintenance planner's duty to track and monitor the completion of all planned work assigned to a maintenance base and the aircraft. The maintenance planner coordinates the aircraft routing to the maintenance base and also coordinates with the stores department about any logistics required for maintenance planning.

Long-range planner, PP&C

The long-range planner does both short-term and long-term planning and forecasting of aircraft maintenance, which consists of "C" check and main base visit checks, structural repair (fatigue, crack, corrosion), painting, lease return, retirement, and any upcoming airworthiness directives (AD). The long-range planner designs the work plan, ascertains logistic availability, and decides which facility can best perform repair and modification due to its capability and the aircraft's location. If needed, the long-range planner relocates the aircraft to a facility for required maintenance and ensures that all work is completed according to the company's policy and manual and that the AD is credited for work performed satisfactorily.

The Production Planning & Control Department's Function

The PP&C title is a bit misleading. It implies two functions: planning and control. PP&C actually has three functions: forecasting, planning, and control. Forecasting activities include estimating maintenance workload for the existing fleet, creating business plans, and being aware of any changes in the forecast period. Planning involves scheduling upcoming maintenance, and includes planning and scheduling details (manpower, parts, facility) and timeframe requirements for such maintenance: less than "A" check items, daily items, 48-hour checks, and letter checks. These plans would include incorporation of SBs, fleet campaign directives (FCDs), SLs, and ADs, as well as other maintenance tasks, such as engine changes, fuel nozzle changes, gear changes, and generator changes deemed necessary by

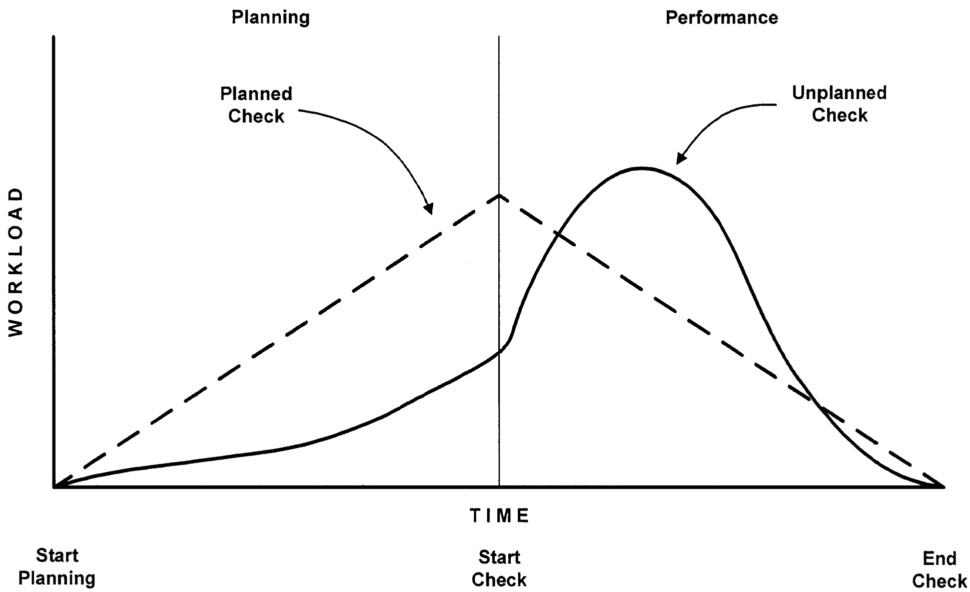

Figure 9-1 The importance of planning. (*Source*: *From a similar drawing in John Revere:* The Management of Aircraft Maintenance, *3rd ed., Keogh Management Services, Edina, MN. Reprinted with permission.*)

the airlines. The plan is somewhat idealized, however. During the actual performance of maintenance, many things occur that require altering the plan. The control function allows for adjustments to the plan and keeps (or attempts to keep) a check on schedule. There are several methods of adjusting the plan, including deferral of maintenance to a later check, addition of personnel to complete the work, or outsourcing the work to a contractor. Feedback from a check allows PP&C to adjust the planning effort for future checks.

There is an old saying that captures the gist of PP&C: "Plan your work and work your plan." The production planning aspect of PP&C does the planning. This is the first step in accomplishing the work at hand and must always precede action. Without planning, action would be impulsive and produce unpredictable results. The production control aspect of PP&C "works the plan." The control phase begins with a meeting of all involved work units before the plan is finalized. Control efforts continue during the performance of the work and immediately following it. This ensures compliance with the plan as closely as possible and takes action where necessary to adjust the plan as indicated by deviations and circumstances that invariably occur during real-world activities.

Figure 9-1[2] shows how work is expended on a typical project with and without proper planning. The preliminary planning consists of the development of the maintenance program and its schedule established by the engineering section

[2]This chart is a variation of a similar chart in John J. Revere, PMP: *The Management of Aircraft Maintenance*, 3rd ed.; Keogh Management Services, Edina, MN, 1995.

as well as the individual check planning efforts of PP&C. Once the check has begun, the work progresses smoothly. This proper approach is shown by the dashed line. Without the preliminary planning of PP&C, the implementation effort, as shown by the solid line, swells as the work progresses, mostly due to unexpected events and delays.

To illustrate this, take the example of the first "C" check performed by a new operator on a two-engine jet. Normally, this check would take 4 or 5 days depending on shift schedules. A certain (nameless) airline approached the task in the following manner. One week before the check was due, the management took the MPD document for the airplane from the shelf to see what was required for the "C" check. They discovered that, without adequate preplanning, they were unable to complete the check in 5 days. Instead, it took them 4 weeks to perform the check. They learned a valuable lesson that day: "Plan your work and then work your plan."

The goals of PP&C are (*a*) to maximize the M&E contribution to the airline; (*b*) to plan and organize work prior to execution; and (*c*) to adjust plans and schedules to meet changing requirements. We will discuss forecasting, planning, and control in turn. Then we will consider the advantages and disadvantages of the various organizational schemes for PP&C.

PP&C also tracks any loaned or borrowed parts from other airlines or repair vendors in the airline's fleet. Once the part becomes available, it is PP&C's responsibility to make sure that the borrowed part is replaced and sent back to the other airline or vendor with serviceable paperwork, which indicates time used and service time available.

Forecasting

Forecasting is concerned with the future workload of the M&E organization. The PP&C department is responsible for reviewing and providing upcoming maintenance on the aircraft fleet. This requires workload planning, goal setting, implementing, and monitoring. It must also take into account the routine and nonroutine maintenance requirements, as well as planned changes in future operations relative to maintenance. Any changes in fleet size, routine structure, facilities, manpower, or skill requirements are tracked. Future plans may also accommodate the aging and replacement of equipment, corrosion prevention control program, addition of new equipment, modification of equipment, and the upcoming ADs and SBs. Activities throughout M&E will change as these assets and requirements change. The forecast function ensures that M&E and PP&C are up to date on these changes and ready to adjust their processes and procedures accordingly.

Forecasts are usually made for the long and short term but often an intermediate-term forecast is also made. The long-term forecast would be for 5 to 10 years. The changes that are planned by the airline in the long term will affect maintenance and engineering activities. These changes will impact scheduling, budgeting, training, manpower, and facilities within M&E. Adjustments must be made

in all of these areas for M&E to meet its goals and objectives, so plans must be made in advance to accommodate the growing (or shrinking) airline. This long-term forecast is somewhat general in nature and is subject to revision on a yearly basis.

Short-term forecasts are more detailed and usually cover 1 to 2 years. These forecasts contain more definitive plans with attention to actual manpower and budget numbers. Schedules for checks and known modifications are finalized in the short-term plans.

Larger airlines may also develop intermediate forecasts for periods of 2 to 5 years. Thus, the three forecasts provide a continuous plan for M&E to follow in an effort to keep up with the changes in the operational climate and be ready to change the M&E activities accordingly.

Production Planning

While forecasting is long range and general, planning deals with the day-to-day activities of M&E. The goal of M&E is to deliver airworthy vehicles to the flight department in time to meet the flight schedule, with all maintenance activities completed or properly deferred. In business terms, this is what we "produce"—airworthy vehicles with all maintenance properly addressed. Thus, the activities of line, hangar, and shop maintenance constitute the production aspect of M&E. Production planning, then, is the planning of that work with the stated goals in mind.

Engineering has developed the maintenance plan from the MRB or Ops Specs document and divided the work into the appropriate work packages, identifying the tasks to be done, the intervals at which they will be done, and the manpower requirements for each task. The check package schedule for a typical midsized airline is depicted in Table 9-1. Planning must now take this engineering package and plan, schedule, and adjust the work for each check and for each aircraft, adding any additional tasks as necessary. Estimated man-hours are shown in Table 9-2 for our midsized airline.

Production planning involves the planning of all maintenance activities: daily, 48-hour, and transit checks; letter checks; and modifications due to airworthiness directives, service bulletins, service letters, and engineering orders. It also involves the planning and scheduling of all aspects of these checks, including manpower, parts, supplies, and facilities. Coordination with flight operations and with ground handling and support activities is also included in the planning effort.

The daily, 48-hour, and normal line maintenance checks are usually standardized and require no effort on the part of PP&C other than scheduling. The appropriate work packages are developed by engineering and issued as necessary for the required checks. Line maintenance is usually responsible for these checks, and the routine tasks are administered by the maintenance control center. The PP&C unit merely monitors this activity. Additional tasks, whose intervals are less than the "A" check, are usually added to these checks or performed concurrently by a separate work crew. Occasionally, SBs and other modifications, if simple and involving small amounts of time, will be included (by EO)

TABLE 9-1 Aircraft Maintenance Check Schedule (Typical A/L Example)

	747-400	747-200/300	DC-10-30	A300B4	F50
Transit check	At each stop whenever aircraft is in transit				
Daily check	Before first flight or whenever aircraft is on ground more than 4 hours				
"A" check	Every 600 FH	Every 500 FH or 7 Weeks	In 3 parts A1, A2, A3 465 FH or 9 weeks	In 4 parts A1, A2, A3, A4 Every 385 FH or 11 weeks	Every 650 FH or 4 months
"B" check	In 2 parts B1, B2 Every 1200 FH	In 2 parts B1, B2 Every 1000 FH	None	None	Every 1300 FH or 8 months
"C" check	In 2 parts C1, C2 Every 5000 FH or 18 months	Every 4650 FH or 24 months	In 2 parts C1, C2 Every 4500 FH or 20 months	In 2 parts C1, C2 Every 3000 FH or 18 months	In 2 parts C1, C2 Every 4000 FH or 25 months
"D/HMV" check	First check done between 25K & 27.5K FH Subsequent every 25K FH or 6 years	First check at 25K FH or 6 years Subsequent every 20K FH or 5 years	Every 20K FH or 6 years	Every 12K FH or 4 years	In 2 parts H1, H2 Every 12K FH or 6 years

FH: flight hours; HMV: heavy maintenance visit.

NOTE: Some maintenance planning documents from the manufacturer do not have specified "B" checks. Airlines, however, can identify their own checks or identify existing checks by any name or letter they choose.

The schedule above was taken from an international airline with a fleet of 30–40 A/C. It has been modified slightly for illustration.

When FH and calendar times are both given, the check will be performed at whichever comes first.

Where checks are split into parts, e.g., 'B1, B2 every 1000 FH,' B1 will be done at 1000 FH and B2 at 2000 FH. This pattern is repeated so that each part is done at 2000 FH intervals.

TABLE 9-2 Average Check Package Man-hours (Example)

A/C type	Check type	Routine	Variable routine	Nonroutine	Total
747-400	A	100	–	–	100
	B	300	300	600	1200
	C	900	810	1710	3420
	D (HMV)	4000	20,000	36,000	60,000
747-200/300	A	300	150	450	900
DC-10-30	A	410	369	467	1246
	C	1800	1260	2142	5202
	HMV				65000
A300B4	A	550	220	539	1309
	C	1600	1120	2176	4896
	D (HMV)				
F50	A	71	71	142	284
	B	300	90	234	624
	C	930	465	1116	2511
	D (HMV)	2119	1060	2861	6039

Some checks are not done by the airline. The checks are either contracted out or the airplanes are leased and the owner does the checks. Also, aircraft may be fairly new and no D or HMV checks are due at this time.

Times required will vary from check to check depending on many factors as discussed in the text.

in the line checks. This planning and scheduling would be done by PP&C with cooperation from MCC and line maintenance for implementation.

All “A” checks and higher are planned, scheduled, and coordinated by PP&C, and their content varies from check to check. These activities are more involved than the 48-hour and transit checks so the planning is started well in advance of the actual check. For “A” checks, planning begins 1 to 2 weeks prior to the scheduled check. For “C” checks, the planning begins about 4 weeks in advance. In certain cases, such as the incorporation of SBs or ADs, the lead time on parts availability may require that the planning for those items be started even earlier. We will discuss these items as they arise. We will first look at the planning of the tasks scheduled at intervals less than the “A” check and say a word about multiple checks before addressing the “A” and “C” checks themselves.

Maintenance tasks at less than “A” check interval

Certain maintenance items in the MRB report are designated for time and cycles that are less than the “A” check cycle. The PP&C unit is responsible for issuing weekly, biweekly, or daily schedules for these items to the line maintenance organization for timely accomplishment. These tasks can be scheduled at specific times on overnight checks; at certain turnaround times, if time permits; or included in “A” checks if time permits. These items can be accomplished by line maintenance personnel assigned to meet aircraft on normal turnaround or they can be assigned to a special crew of line maintenance people who are separate from the turnaround crew. The method is up to the airline and is usually

determined by local conditions and manpower availability. Regardless of how these tasks are accomplished, it is PP&C's responsibility to schedule them and follow up on them in order to ensure that they are completed within the scheduled interval.

There is one problem that airlines sometimes get into concerning these less than "A" check tasks. That is to defer these tasks day after day, due to pressing work by the turnaround crew. If these tasks are habitually put off to a more convenient time, the deadline for completion gets nearer and nearer. Finally, the airline has to take the aircraft out of service for several hours in order to complete the maintenance so as not to exceed the FAA time limits. Such delays can be costly.

Multiple checks

You will recall from Chap. 2, that some MRB items are done at intervals that place them on every other, every third, etc. check. This is true for "A" checks as well as "C" checks. What this means is that each "A" check or "C" check performed, depending on where the aircraft is in the maintenance cycle, will have a different set of tasks to perform and thus will require different amounts of time, manpower, etc. This is just one more of PP&C's responsibilities: to ensure that parts and supplies, manpower, facilities, and time are available for this variance in the check schedule. Table 9-3 shows a typical pattern for multiple "A" checks. These cycles are carried out until changed by FAA approval.

It should also be noted that every "C" check includes all the "A" check items required by the table. In some instances, this means that task cards may need to be combined. For instance, an "A" check may require an operational test of a system while the "C" check will require a functional test of the same system. The maintenance manual (and subsequently the task cards) would give complete test instructions for each individual test. Doing both, however, may involve a duplication of certain unnecessary steps. These task cards, then, must be modified by engineering or by standing orders given to avoid the unnecessary action. The "C" check items can also be originally scheduled for longer intervals designated as 2C (every second), 3C (every third), and so forth. A chart similar to Table 9-3 can be drawn for multiple "C" checks to aid planners.

TABLE 9-3 Typical Aircraft "A" Check* and "C" Check† Schedule

Check	300	600	900	1200	1500	1800	2100	2400	2700	3000	3300
1A	X	X	X	X	X	X	X	X	X	X	X
2A		X		X		X		X		X	
3A			X			X			X		
4A				X				X			
5A					X					X	
C										X	

*"A" check = 300 hours.
†"C" check = 3000 hours

Phased checks

Phase checks are different from multiple checks and, therefore, have a different (but not too different) numbering scheme. An "A" check may be split into two phases, each one performed on successive nights to minimize aircraft downtime and maintenance crew needs. This type of check is broken into zonal type maintenance (discussed in Chap. 2) task cards. In this case, the different zones are inspected and maintenance is performed as per the task card requirement. For example, the left and right wings and aileron system and the tail section are inspected as an A1 check, and later on the remaining airframe structure is inspected as A2. These checks can be broken down into different parts depending on the maintenance interval provided by the aircraft manufacturer, tailored by the airlines, and approved by the FAA.

Each airline has a different way of performing phase checks, A checks, B checks, or C checks. Depending on the size of their fleet and approved methods, some airlines have broken "C" checks into four parts (C1, C2, C3, and C4) that are performed once every 3 months, and some airlines have broken "C" checks into 12 parts, in which case one "C" check is required every month.

"A" check planning

"A" checks are usually routine. The tasks required are defined by engineering using the MRB or Ops Specs document. The time, manpower, and parts and supplies needed are generally fixed (see Chap. 2 for discussion of adjustment of MRB task time estimates). There are variations, however, that must be addressed. When there is a write-up in the aircraft maintenance log that cannot be addressed at turnaround or on daily or overnight checks, it may be deferred until a later time. The deferral may be a result of a lack of parts, a temporary lack of skilled labor, or lack of sufficient time required (at the time of occurrence) to effect resolution. In these cases, the deferred maintenance is scheduled by PP&C for the next "A" check. The necessary parts, supplies, and personnel should be available at that time.

Performance of an "A" check may also include, because of time and parts constraints, some "less than "A" check" items (100 hours, 250 cycles, etc.). These may be near the time or cycle interval and so are placed with the "A" check for convenience. If there are SBs or SLs that do not require extensive time or parts to complete, these may also be scheduled for the "A" check.

Thus, even though an "A" check is relatively simple and straightforward, there is still some planning required. Since PP&C is responsible for that planning and scheduling, they will develop the work package and send it to the applicable work centers for review a few days before the scheduled date of the check. This allows adjustment for changes in circumstances. (This is the beginning of the "control" portion of PP&C.)

The "B" checks, if they are used, are often similar to "A" checks but involve different tasks, usually at intervals which fall between consecutive "A" checks. The planning for these is essentially the same as for "A" checks.

"C" check planning

The "C" check is usually done about once a year (12 to 18 months on the newer model aircraft), depending on the airline flight schedule. The planning effort is more detailed and more elaborate than for the "A" check. Normally, a "C" check will take 4 to 7 days to complete, depending upon the model and the circumstances. The number of shifts worked, the availability of manpower and parts, and the skill requirements for the work will affect the length of time involved. The check will consist of three categories of tasks: routine, variable routine, and nonroutine.

Routine tasks are those tasks identified in the MRB document. These are items that must be performed at the specified interval. Since some of these items are performed every "C" check and others are performed every second, third, or fourth check (2C, 3C, or 4C), the amount of time required to perform each scheduled check will vary from check to check. This scheduling and variation in time requirements are PP&C's concern.

Variable routine tasks are those tasks which vary from one check to another and from one aircraft to another. These tasks include incorporation of service bulletins and airworthiness directives, as well as fleet campaigns, items deferred from previous maintenance checks, and any other one-time maintenance actions required for a particular aircraft. The time required to accomplish these tasks is generally fixed, so these items are similar to the routine tasks for planning purposes.

Nonroutine tasks are those work items that are generated by the accomplishment of other, routine tasks. For example, if a routine task says to inspect the wheel-well area for hydraulic leaks, the task will take a certain amount of time (scheduled). If a leak is discovered, however, it must be addressed. This constitutes the production of a nonroutine maintenance task and subsequently a nonroutine task card. Since the number of nonroutines can only be estimated and the amount of time required to complete the nonroutine item varies with many factors, it becomes an interesting task for PP&C to properly estimate the time needed to complete these nonroutine items and the entire check.

Below is a list of items that might be included in a "C" check. Not all of these would be included each time, however.

1. "C" check items from the approved maintenance program (routine)
2. Deferred maintenance from line or other check packages (variable routine)
3. Incorporation of SBs, SLs, ADs (variable routine)
4. Incorporation of airline mods and fleet campaigns (variable routine)
5. Cleaning, painting of aircraft (variable routine)
6. Work generated by inspections and routine items (nonroutine).

It is the job of PP&C to collect and schedule these items using accurate estimates of the time required for routine and variable routine items and predicting a reasonable amount of time for nonroutines and other delays. Once the package is set and the time estimated, PP&C must arrange for and schedule all the necessary elements for proper execution of the package. That would include the following:

1. Locate and secure hangar space for the duration of the check
2. Obtain a release of the airplane from operations for maintenance purposes (this may be accomplished by MCC)
3. Arrange for and schedule the washing of the aircraft
4. Secure tow vehicles and manpower needed to move the airplane to the wash rack and then into the hangar
5. Ensure all parts and supplies needed to carry out the check will be on hand
6. Ensure delivery of those parts and supplies to the hangar at the time needed
7. Identify manpower and skills needed for the check

Table 9-4 shows our typical airline's estimate for the man-hours planned for a "C" check on the Airbus A300B4.

As with the "A" check, the "C" check package must be developed and distributed to the applicable work centers prior to the start of the activity. The package would be sent out 1 to 2 weeks before the scheduled date of the check. A meeting of all involved units will then be held to discuss and finalize this into a workable plan. This will allow for any last-minute changes needed because of circumstances that PP&C was unaware of at the time of plan origination. Such circumstances would be as follows: certain items may need more time to complete than has been scheduled; recently deferred items may have priority; required parts not received; or manpower may not be available due to illness, vacations, etc. The check package would be adjusted as necessary. In rare cases, the time for the check might be extended 1 day or one shift as needed. This, of course, would have to be coordinated with operations and the business office to accommodate rescheduling the aircraft for service.

The final effort of PP&C will be to produce the check package from the computer database (or by hand) and issue work cards for use by the AMTs and quality inspectors during the check. On the date scheduled, the aircraft will be washed[3] and rolled into the hangar and the check will begin. (How this check is carried out is detailed in Chap. 14.)

Production Control

The plan produced by PP&C allows a certain amount of time for the performance work based on past knowledge of the work to be done and also based on the assumption that parts, supplies, manpower, and facilities will be available when needed. The plan also assumes that there is no variation in the flow of work activity. The PP&C planners can only estimate the amount of time required for nonroutine items, and this can be less than accurate. Take, for instance, a

[3]Washing of aircraft at "C"check is at the operator's discretion and subject to airport regulations due to environmental issues. Some aircraft are washed following a wash schedule separate from any phase check.

TABLE 9-4 Summary of Aircraft Check Package Man-Hours (Example B1 Check for A330 Aircraft)

	On-aircraft work														Off A/C	
	Hangar										Shops					
Work type	AF	ENG	ELEC	INST	RADIO	AIM	LUB	UTIL	TOTAL	%	NDT	ASM	PS/FG	Total	All Wk Ctrs	Grand Total
Routine*	71	28	19	3	3	62	7	115	308	37.71						308
Variable routine†																
SIP	18	18	2		14		15		67	7.99						67
SSI																
Component change	3					6			9	1.07						9
Eng change																
APU change																
LDG change																
SI	33	48	6	9	9	6			111	13.23	5			5		116
Modifications	23	7	32			2			64	7.63		15		15		79
EN	10	15		2					27	3.22	5			5		32
MARF																
Other	20	11	5	6	10	1	10	8	71	8.46						71
Nonroutine‡	51	25	17	3	3	46	2	35	182	21.69		14	12	26		208
Total	229	152	81	23	39	123	34	158	839	100	10	29	12	51		890
Man-hours available																
Variance																

*Tasks from the MRB or Ops Specs.
†Routine items that vary with aircraft, check, and other planning decisions.
‡Tasks generated from other tasks.

routine task that says "check the hydraulic line for leaks." If there are no leaks, the inspection task should take a specific amount of time, but since there is no way for the planner to determine if there will be leaks or to know the extent of any leak(s) found, there is no way for him or her to accurately estimate the time required to perform the nonroutine task of repairing the leaks. The time needed to fix a leak still must be estimated and scheduled.

However, through feedback from similar tasks on previous checks, the planner can get some idea of what might be expected. It is important, then, for those doing the work and controlling the check to provide feedback to planning to help them to make more accurate estimates for the next check planning effort. Often this can be adjusted during the planning meeting mentioned above.

A routine task of removing and replacing a hard time item may take 2 hours under normal circumstances. On one particular occasion, suppose a bolt is sheared off during the installation. This will require additional work in extracting the broken bolt. The tools to do this may not be readily available at the site, and the process of removing the bolt and redressing the threads may take a considerable amount of time. There probably would be an inspection or investigation to determine why this occurred (improper use of tools by mechanic, weakened part, out-of-calibration torque wrench). The time elapsed may be significant and it may, due to the location of the activity, cause another mechanic delay in working another task within that same area.

All of this is "business as usual" in the real world of maintenance. It is important, then, for maintenance to keep track of the time spent on each task. Although mechanics, and their unions, don't like the idea of being timed, it is important for scheduling and planning purposes to know how long a given job should take, the kinds of things that might go wrong when performing that job, and the time required to rectify the problems that do occur. It should be understood by management and mechanics alike, that some people will take longer than others to do a job and that the same person will take longer on some days than on other days. This is not unusual, this is a fact of life—so tracking the time to do a task is not to be used for disciplinary purposes; it is to be used only for practical planning purposes. Managers, engineers, and mechanics all have need, from time to time, to adjust the plan's schedule for numerous good reasons, and this must be respected and planned for.

Other Scheduled Work

The planning department issues a daily work plan for all maintenance operations that include line maintenance checks. These checks contain all safety items; inspection inside the aircraft cabin and flight deck; service of engine oil; hydraulic oil service; crew and passenger oxygen check; inspection of brakes and tires, wing, and fuselage; and any navigation system updates, such as GPS and T2CAS systems. The planning department also monitors all MEL, CDL, and NEF items and engine oil consumption trends. The engine oil consumption monitoring program requires an aircraft to have an oil level check done prior to daily departure. Planning is responsible for monitoring work performed and updating maintenance stations as required.

Feedback for Planning

An aircraft does not generate any revenue while on the ground; taking all the time you need for maintenance is not usually an option. It is important, therefore, for maintenance and planners to know how much time is needed to perform the tasks and the overall checks so that planning can be done accurately and the maintenance checks can be completed within a reasonable amount of time.

The letter checks plan is developed with the best information possible on hand. The plan is then reviewed by all the work centers involved to head off any obvious problems such as manpower, logistics, and specialized tooling. Other factors come into play that may require some changes. It is very important that these changes are communicated to the PP&C planner so that future efforts can take these requirements into account.

What the planner needs to know to adjust future plans are:

1. The exact amount of time required to perform each task.
2. The amount of time lost in waiting for parts delivery, supplies, tooling, etc.
3. The downtime for unusual circumstances.
4. The exact additional time spent on nonroutine findings.
5. The variation in manpower availability (i.e., sick calls, vacation etc.).
6. Lost time due to parts robbing for other jobs.

This information is used in many ways. Scheduling of tasks can be more accurate if the actual time requirements are known instead of the estimated or calculated time requirements from the maintenance planning data. If time is being lost because parts or supplies are not at the work place when needed, arrangements must be made for more timely delivery for the next scheduled check. And if there is going to be a change in available personnel (due to vacations, etc.) for the next check, this may also have an effect on the accomplishment of the work and should be included in the plan.

Parts robbing at airlines is an age-old problem. Those working on the flight line have an obligation to return aircraft to service as quickly as possible. If parts are required to do that and the parts are not available in stock, the most likely source would be any airplane that is not currently scheduled for flight. That makes the one setting in the hangar for "C" check a prime source. Presumably, the part can be ordered and, hopefully, arrive before the "C" check is done. Unfortunately, for those doing the "C" check, this often requires the same work to be done twice, and the result is more time than necessary taken to finish the check.

Although parts robbing has a detrimental effect on the scheduled check, it is not just a problem for planning. It is really a problem for the whole M&E organization. One that should be resolved by someone other than (higher than) PP&C. Its effect, however, until resolved, still must be included in check planning efforts. Parts robbing is discussed further in Chap. 14.

Chapter

10

Technical Publications

Introduction

In Chap. 5, we discussed the numerous documents needed to address the maintenance activities of a modern commercial airline. It should be immediately apparent that producing, distributing, and updating these documents is a considerable task. For that reason, we have established the technical publications department within the technical services directorate of our typical midsized airline. The technical publication department is vital to aircraft maintenance operations, since this entity is solely responsible for receiving and distributing publications throughout the airline maintenance bases, hubs, and smaller stations.

In smaller airlines, a different arrangement may be more effective. In these small airlines, the typical publication unit could be part of the engineering organization or possibly quality assurance. Larger airlines may require an extended publication unit. In any case, the functions and requirements discussed in this chapter will apply to all airlines no matter how they are organized.

Functions of Technical Publications

The technical publication organization essentially has three functions:

1. To receive and distribute, within the airline, all those publications issued by outside sources
2. To print and distribute the publications generated by the various organizations within the airlines
3. To establish and maintain a complete, up-to-date library system for all such documents needed for M&E operations.

Outside sources of documents would include airframe and engine manufacturers, vendors and manufacturers of equipment installed on the aircraft, and

manufacturers of special tools and test equipment used in the maintenance effort. These documents may consist of initial issue of maintenance manuals and other such documents as well as any periodic or occasional revisions to those manuals. This would also include service letters (SLs), service bulletins (SBs), or maintenance tips issued by these manufacturers or vendors. Federal Aviation Regulations (FARs), airworthiness directives (ADs), advisory circulars (ACs), and other official publications from the airline's regulatory authority would also be included here.

Internal airline documents consist of the airline technical policies and procedures manual (TPPM), the reliability program manual, and any other maintenance and inspection documents generated by the airline itself (see Chap. 5 for a detailed list). Many of the documents produced by other M&E units, such as engineering, QA, etc., may be created by the unit having primary responsibility but will usually be reproduced and distributed by technical publications simply because the process and facility for doing so is already in place. This could include such documents as monthly reliability reports, engineering orders, work packages for line or hangar maintenance checks, tool and equipment calibration schedules, and other such documents.

Airline Libraries

The primary reason for having a technical publications organization is to ensure that all applicable publications related to the airline operation are available to the users and are up to date with the latest changes. The most common way to accomplish this is to establish a main library for the M&E organization. If the M&E organization is of any appreciable size, the location of a single library would be inconvenient for many users and the number of copies of each document might be limited. For that reason, the technical publications organization at most airlines maintains, in addition to the main library, one or more satellite libraries strategically located to minimize travel times to access the information needed. While the main M&E library will contain all publications related to maintenance, engineering, and inspection activities, the documents on hand at any satellite library will usually be limited to copies of only those documents relating to the particular function served. Each library—main and satellite—should contain the necessary tables, chairs, shelves, microfilm readers and printers, computer terminals, and copy machines as needed to serve the users and the document formats (paper, microfilm, electronic) which will be available there. Table 10-1 is a list of some of the possible locations of satellite libraries.

Control of Publications

Maintenance-related documents are classified as either "uncontrolled" or "controlled" documents. *Uncontrolled documents* are issued for general information only and are not used to certify airworthiness. They do not require any of the tracking system requirements discussed below for controlled documents.

TABLE 10-1 Satellite Libraries

Maintenance control center (flight line)
Line stations (1 or more)
Hangar dock
Overhaul shops in hangar
Engineering
Maintenance training
Production planning
Quality assurance
Reliability (may be colocated with engineering or QA)
Material

Controlled documents are used to certify airworthiness of the aircraft, engines, and components. Each controlled document will contain a list of effective pages (LEP) and a record of revisions to the document identifying the revision number or letter and the date of that revision. The LEP will also reflect the active page numbers of the latest revision. Table 10-2 is a typical list of controlled documents.

Since the introduction of electronics, Internet, storage of data, online manuals, and Web retrieval systems, the airlines have created domains or internal Web sites for aircraft maintenance and other departments. The airline maintenance manuals are now commonly located on the airline's server and are updated frequently. This ensures that all manuals are controlled and updated, alleviating the problem of manuals being out of date. In the past, every M&E station received updates via the postal service. The latest version and the revision date normally indicate when the last time the manual was updated online. Prior to online domains, the AMT would have had to look for any kind of manual reference or parts in big binders. The entire process was time consuming.

There still are some hard-copy manuals required. Emergency manuals and emergency contact information must be kept in a hard binder, which is updated by the technical publication personnel. The master copy of each of the control documents is also printed and kept in the M&E library. The list contains all manuals and their latest revisions in an version online and in hard copy. This type of action keeps the M&E department, the technical publication department, and the airline in compliance with the FAA and in-house QC/QA audits.

TABLE 10-2 Controlled Documents Listing

Operations specifications
Technical policies and procedures manual*
Manufacturer and vendor manuals (see Table 5-1)
Regulatory authority documents (see Table 5-2)
Applicable airworthiness directives
Applicable aircraft type data sheets
Applicable aircraft supplemental type certificate

*If the airline chooses to publish the inspection and reliability program manuals separately from the TPPM, they will also be controlled documents.

Manufacturer's documents usually have standard revision cycles (e.g., 3 months, 4 months, yearly), but some are revised on an "as needed" basis. Regulatory authorities also have some regular and some irregular revision cycles for their publications. While the airline can set revision cycles of its internal documents as it chooses, it is often necessary to make revisions to these internal documents in accordance with the changes made by the other documents (manufacturers, FAA, etc.); therefore, local revision cycles would be in line with these changes.

It is the airline's responsibility to address these changes as quickly as possible. The technical publications organization has the responsibility of issuing revisions—whether separate pages or whole documents—to the appropriate work centers as soon as they are received. For this reason, they need to determine how many copies are needed and in what format (paper, microfilm, electronic) so that this distribution can be done efficiently without the need for making or ordering additional copies. This information can be kept on paper, 3 × 5-in file cards, or on the computer system.

Document Distribution

Technical publications will package documents and revisions and send them to the using organizations by the most appropriate means (e.g., hand carried, sent through company mail, shipped on company airplanes, or sent by commercial courier service). This package should be accompanied by a letter or other form from technical publications identifying the material being sent by document number, copy number, and revision date. It should also identify to whom it was sent and the date it was sent. There should also be a space for the recipient to sign (or initial) to verify receipt. The person receiving the documents will check the package for content and applicability and return the signed acknowledgement to Tech Pubs. Verification is returned to the technical publications office by the most convenient means.

This process ensures that these documents have, in fact, been controlled up to the point of delivery and receipt. It is the receiving unit's responsibility to actually make the changes to their documents and to ensure that they are kept up to date at all times. Whether or not this is done can be checked periodically by the technical publications staff, quality control inspectors, or even maintenance management. It will most certainly be an item of concern on the quality assurance or regulatory authority audits.

Chapter

11

Technical Training

Introduction

An airline is responsible for the proper maintenance of its fleet as required by the FARs. The airlines are also responsible for the proper training of all their personnel. This includes flight crews, cabin crews, ground handling crews, aircraft maintenance technicians (AMTs), inspectors, auditors, managers, and computer operations and administrative personnel. A significant portion of their training—especially for flight crews and maintenance personnel—is accomplished prior to their being hired by an airline. This involves formal, specialized training sanctioned by the FAA and the issuance of an FAA license for the particular specialty.

It has been mentioned in Chap. 4 (Aviation Industry Certification Requirements) in detail that to be eligible for an airframe and power plant mechanic license, a student must satisfy the criteria under FAR 65.71, as well as other eligibility requirements. However, having an A&P license does not mean that a mechanic or aviation maintenance technician (AMT) is capable of working on specific equipment or systems at a certain airline. The A&P license signifies that the AMT has completed the basic training of aviation maintenance, but he or she must be trained to perform maintenance and servicing activities on the airline's specified equipment, and the training must be documented. In case of an aviation incident or accident, the FAA investigator often asks, "Was the mechanic properly trained?" The answer given must be backed up with the documentation showing not only the extent of the training but also when and where it was completed. The 14CFR, FAR 121.375 specifies the general requirements; various other FARs provide details on training requirements.

The subject and extent of training required after the employee receives his or her A&P license and is hired by the airline varies throughout the industry, and that variation is based on many things. This chapter will discuss the various types of training requirements an airline must meet.

The airline, having selected those people with proper training and experience as fit their needs, will then place these new hires in orientation classes in order to train them on the airline's specific policies, procedures, paperwork, and equipment. Over time, it will be necessary to provide additional training to various personnel either at the airline or at some outside facility, such as a manufacturer's or a vendor's plant, at another airline, or at special training schools. The training received by each employee must be recorded in his or her training records (or personnel file), and any licenses affected by the training must be monitored and updated accordingly.

Training Organization

Since all airline personnel require training of one sort or another, it is necessary to have a training organization to address these needs. This organization can take various forms. This can be an airline's training organization, training department, or school at the corporate level that is responsible for training of all airline personnel; or there can be a separate organization responsible for maintenance training, flight crews, cabin crews, ground handlers, and management and administrative personnel.

Flight crew training is normally contracted out to various flight academies or the aircraft manufacturer, since they have the classroom facilities, aircraft simulators, and experienced pilots who train the flight crew. This depends on the airline's size and operations. Some airlines do have in-house simulators with a check airman pilot who acts as a flight instructor. Cabin crew are similar to aircraft flight crew in that their training may be performed by the manufacturer or in-house. The cabin crew's training emphasizes safety and evacuation of the aircraft with mock-ups and what to do in the event of an aircraft emergency on land or on water. They learn how to deploy slides and/or rafts.

The ground handling crews have a separate training department and normally are trained in-house due to aircraft availability. They learn how to operate cargo doors (open-close), plug in outside DC-ground power units (GPUs), marshal aircraft in and out, and tow aircraft for push back when ready. They know the safety procedures for such equipment as tugs and push back tugs, and they operate GPU and air-start carts. The management and administrative personnel training also depends on their respective departments. Aircraft maintenance management requires the same training as AMTs as per the FAR and company training requirements.

Each department in the airline, as mentioned above, must have a training instructor, coordinator, or training manager. Airlines are required to have fleet qualified and trained personnel. The trainers must be aware of all changes in their departments and the requirements for ongoing and upcoming training, and they must be able to demonstrate, explain what is required from the training, and answer all questions. The airlines normally have a high turnover of personnel. Airlines undergoing a change of fleet size or makeup will have a considerable amount of training activity.

Airline Maintenance Training

An airline maintenance training program is required by the FAA under FAR 121.375, which requires airlines to provide training to their maintenance personnel. The airline's maintenance training department is responsible for having a comprehensive training program that is effective in teaching its employees and contract maintenance workers how to service and maintain aircraft and their systems.

In a commercial airline, the training department is led by the training manager, who is responsible for accuracy, functionality, training strategies, and the quality of the maintenance training program. The director of training normally works with the director of maintenance (DOM) and director of quality control (DQC) for their personnel training. This ensures that employees schedule the required training, refresher training for aircraft and related systems, and company-required training in a timely manner. The DQC normally works with the training department to comply with any airworthiness training, required inspection authorization (RII), and various other QA and QC training.

For aircraft maintenance personnel, there are several kinds of required training activities. The training listed here is given by an airline after hiring an AMT with a valid A&P: (*a*) organizational training; (*b*) manufacturer or vendor training; (*c*) quality training; (*d*) on-the-job training (OJT); (*e*) equipment operation and safety training; and (*f*) refresher training. Each of these types of training will be discussed later in this chapter.

Formal training

This training is usually accomplished before the mechanic is hired. A&P mechanics and technicians can come from FAA-approved A&P schools, from technical/trade schools with appropriate aviation curricula, or from the U.S. military services. The FAA-approved schools usually graduate students with the appropriate license (airframe/power plant or avionics). The other two sources of training require that the applicant arrange with the FAA to take the necessary tests for attaining the desired license. Some airlines have a special program where they hire mechanic trainees out of high school or other equivalent curricula and train them as aircraft mechanics either at their airline, at contractor airlines, or at special schools that are approved by the regulatory authority. They are airline employees while they study.

Organizational training

This training is developed and conducted by the airline and covers the airline's basic policies and procedures, paperwork, and the specific aviation systems and equipment in use at the airline. These curricula could include the general policy manual or organizational manual; corporate structure; terms and definitions; symbols, rules, and regulations; maintenance practices; full courses for each airframe and its system; minimum equipment list (MEL); deferral program; maintenance duty time limitations; and what is expected from an AMT.

This training may also include how the quality control (QC) and quality assurance (QA) departments function, the internal audit program, the notice of noncompliance, the reliability program, the continuous analysis and surveillance system (CASS), repair and damage tolerance, the aircraft damage reporting system, and aircraft short-term or long-term storage. Depending on the employee's assigned location, he or she must be trained for cold winter operation and deicing of the aircraft, or the operation of aircraft in subtropic conditions of heat and humidity.

Organizational training also addresses the guidelines in place in the event of natural disasters, such as hurricanes, tornadoes, ice storms, and how to prepare a station and aircraft storage during these events.

Manufacturer or vendor training

The manufacturer or vendor training is offered to airline personnel by the aircraft manufacturer/vendor when they purchase an aircraft or system. Manufacturer training covers the aircraft body (airframe). The vendor training covers aircraft systems, such as power plant (aircraft engine), that the aircraft manufacturer purchases from an engine manufacturer, such Pratt & Whitney, General Electric, or Rolls Royce. The vendor provides to the airline additional training on their engine's fleet type. This type of vendor training is also related to an avionics system, such as a terrain warning avoidance system, an aircraft environmental system (air conditioning system), or any other system an airline needs. The airline training department makes all arrangements and monitors all activity.

Quality training

Quality assurance auditors require training in auditing procedures and techniques as well as refresher training on regulations and airline policies; quality control inspectors need to be trained on inspection techniques and on tool and equipment calibration. Mechanics authorized to perform required inspection items (RIIs) must receive special training from the airline or an outside organization in inspection techniques and other details of the units for which they will be responsible.

On-the-job training (OJT)

The on-the-job training involves special procedures that cannot be covered completely or effectively in a classroom and can only be accomplished by hands-on experience on the job. The OJT program is used exclusively in an airline in conjunction with classroom work. This specialized hands-on training is provided by an experienced AMT or a technical crew chief to newly hired AMTs. The training may consist of showing an AMT how to service oil on fleet aircraft; remove and install tires, aircraft engines, engine generators, and wires and wire harnesses. It also includes troubleshooting and familiarizing an AMT with the maintenance manual system, job cards and how to retrieve them, and sign-off

processes which the newly hired AMT will be performing on the job. This OJT process is normally documented for employee training record purposes.

Equipment operation and safety training

Each employee in the maintenance department must attend an equipment operation and safety training class since they will be operating these machines on a daily basis. This includes AMTs, aircraft cleaners, stores and logistics, and all shop personnel. They must learn how to use equipment, how to use safety guards, how to identify the pinch points, how to report broken or out-of-service equipment, and proper tagging. This equipment may include company vehicles, trucks, boom trucks, cherry pickers, forklifts, hydraulically operated work stands, aircraft engine hoists, sheet metal cutting shears, metal-bending machines, grinders, and aircraft tow vehicles. This type of training is also taught by the airline's maintenance training department. They keep a good record of maintenance training and retrain as they see fit.

Refresher training

The airline refresher training is required whenever it is noted that an AMT needs to review or reverify certain skills. This normally occurs in the line maintenance operation when an aircraft is out of service for a length of time and the same problem seems to be repeating itself; it becomes clear that maintenance either has troubleshot the system incorrectly or lacks enough knowledge of it. This may occur because the AMT has had extended periods of time where he or she was not exposed to the equipment or maintenance activities (and this may repeat), and airlines decide they need a refresher training of the system.

This type of training is usually developed and taught by the airline's training department or the component vendor so the AMT better understands the systems and how to troubleshoot them. This training is done on an "as necessary" basis.

Maintenance Resources Management

Considerable interest has developed in recent years in the subject of human factors in maintenance (HFM). Appendix B of this book discusses human factors. The training organization is tasked with the responsibility of developing a basic course in human factors (HF) and in incorporating HF into other training courses as applicable. The FAA has issued Advisory Circular AC 120-72, maintenance resource management (MRM) training to outline the requirements for developing, implementing, reinforcing, and assessing MRM and training programs for improving communication, effectiveness, and safety in maintenance operations. Appendix 1 of AC 120-70 outlines a typical program; paragraph 11 of the document (pages 21–29) provides guidelines for developing such a course. These guidelines can also be used, with some modification, to develop other M&E courses.

Airframe Manufacturer's Training Courses

Whenever an airline buys one or more aircraft from the airframe manufacturer (Boeing, Lockheed, Airbus, etc.) they usually get, as part of the purchase price, a certain number of training slots for the manufacturer's training classes on that model. This would include courses on the airframe, power plant, and avionics equipment installed. Who attends these classes for the airline differs from operator to operator and is often dependent on airline size and management. For small airlines, the mechanics who will be working on the aircraft systems while in service or their supervisors will attend these classes. Very often, both will attend. In larger airlines, some or all of these training slots may be given to the maintenance instructors of the airline's training organization. The choice, of course, is at the airline's discretion. If airline training instructors attend, they will return with the responsibility of creating the airline's version of the course and presenting the material to the airline's mechanics.

In cases where the new equipment is only partially different from equipment currently in use—a 767-300, for instance, going to an airline that already flies 767-200s—only the differences between the two models need be taught to the airline personnel. This airline may already have a 767-200 course established and mechanics will need only to be taught the differences in the 767-300. Meanwhile, the airline's existing course can be modified to include the differences, and subsequent trainees at the airline can get training on either or both as necessary.

On many occasions manufacturers will offer special courses on specific equipment at their plant or at the airline's location. Engine condition monitoring (ECM) courses are offered by all engine manufacturers to train airline people on the use of their special computer programs that monitor engine health. Since only a few people at each airline need this training, there is usually no on-site training. Mechanics, managers, inspectors, or instructors from several airlines may be trained in a single class at the engine manufacturer's facility or some other convenient place.

Airframe, engine, and equipment manufacturers may provide a variety of one-time programs at the airline venue. This might include training on such topics as extended range operations with two-engine airplanes (ETOPS); corrosion protection and control program (CPCP); maintenance error detection aids (MEDA); nondestructive test and inspection techniques (NDT/NDI); aviation safety; reliability programs; and the like. Although these courses are presented by outside sources, the airline training office is involved, since they must provide classroom space and other assistance as necessary and they must update the training records of those in attendance.

Supplemental Training

After completing all aircraft and systems training mentioned in this chapter, the AMT must complete additional company-required training. This training may be in the following areas: (*a*) fleet type and difference; (*b*) environmental or hazardous materials; (*c*) dangerous goods; (*d*) values and ethics; (*e*) fire safety; (*f*) hearing conservation; (*g*) aircraft taxi and towing.

The airline training department uses all sorts of material to help educate an AMT about the company and its policies, procedures, and aircraft fleet maintenance. The media used by the airline training department may include the following:

- Formal instructor, classroom environment training
- Computer-based training (CBT)
- Web-based training (WBT)
- Video, PowerPoint-type training
- On-the-job training (OJT)
- Maintenance workshop-type training

As an airline or a company evolves, there are some changes that are normal to a growing and ever-changing aviation industry. These types of changes must be relayed to the maintenance management and personnel who provide information and as a method of compliance. This type of compliance is known as *refresher training*, which is critical and effective. As needed, the training department distributes bulletins, alerts, CBT, and other types of communication to keep maintenance personnel informed.

Note: It should be understood that training deficiencies among certificated mechanics and technicians can jeopardize their certification and the airline's operations certificate. It should also be understood, however, that not all personnel are perfect. The airline management must always be on alert for any additional training requirements and must ensure that qualified personnel perform and certify all maintenance work done.

There are additional training requirements at an airline that may be necessary from time to time, and they may or may not be available in-house. Nevertheless, the training department will be responsible for arranging for the accomplishment of the training. This would include the specialized training required for quality assurance auditors, quality control inspectors, RII inspectors, NDT/NDI procedures, engine operations (run-up, boroscope inspection, etc.), taxiing, and towing of aircraft. The training organization is required to respond to airline needs by either conducting these classes themselves or by coordinating with other qualified training units.

It should be noted here that any requirement for training of M&E personnel, whether it can be done by the airline staff or not, is the primary responsibility of the training coordinator, the M&E training organization, or the airline training school—whichever is extant at the airline in question. The important thing to remember is that the M&E organization must maintain some sense of control over the training of its own personnel regardless of the airline's organizational structure or management philosophy and must keep adequate records of such training that affects the certification and capabilities of the mechanics and the airline.

Part

III

Aircraft Management, Maintenance, and Material Support

In earlier chapters, we discussed two types of maintenance: scheduled and unscheduled. The working maintenance organization, however, is not divided in that manner. For operational reasons, maintenance activities are divided into the categories of on-aircraft maintenance and off-aircraft maintenance. On-aircraft maintenance is further divided into line and hangar maintenance activities. The unique feature of on-aircraft maintenance is that the effort is performed at or on the aircraft. Components and systems are troubleshot, repaired, and tested in the airplane, and faulty units are removed and replaced with functional units. The aircraft is then returned to service. The units removed are either discarded or sent to the appropriate shop for repair. This shop activity constitutes the bulk of the off-aircraft maintenance activity.

On- and off-aircraft maintenance activities require parts and supplies, which are handled by the materials section. The need for special tooling and equipment is handled by the aircraft tooling department (a part of stores and logistics), normally located at line maintenance stores (parts) area and the maintenance hangar for convenience. There is also a requirement for maintenance work stands, AC/DC power units, heaters, air-conditioning carts, and other items designated as ground support equipment (GSE). The GSE organization is also responsible for maintenance and servicing of this ground support equipment.

Chapter 12 will discuss the aircraft maintenance management, management structure, and front line management. Chapter 13 will

discuss on-aircraft maintenance (line maintenance) activities for all aircraft in scheduled service. Chapter 14 will discuss hangar maintenance, which is also on-aircraft maintenance, as well as maintenance overhaul shops off-aircraft in detail since they are an integral part of hangar maintenance. Chapter 15 will deliberate on the importance of material support and logistics.

Chapter

12

Aircraft Maintenance Management

Introduction

The definition of *management* in any industry is "people who are hired to seek corporation's interest and administer the organization's activities." We will define management in an aviation business organization as "an act of getting people together to accomplish the desired goals and objectives in aircraft maintenance."

Aviation organizations, such as commercial, commuter, and charter airlines, need a management team to be successful. In addition, fixed-base operators and aircraft repair stations also need managers and, depending on their size, a streamlined, multiple-layer approach that may include senior, middle, and supervisory management and different levels of staff for management support.

Managers in the aviation industry consist basically of a director of maintenance (DOM), base or station manager, and the front line supervisors. They are required to go through company-based seminars and training where they learn the techniques for effectively managing people and where the focus is on the general guidelines and principles of the corporation. These seminars can help managers in their everyday work life: investigating infractions, unsatisfactory performance, employee conduct, serious incidents, offenses, attendance, hate-related issues, aircraft accidents, and employee injuries.

All management personnel go through diversity training. This allows all management to understand the topic, to help in overcoming stereotypes, and to deal effectively with individuals with disabilities. To become a successful manager today, one must be agile, highly focused on the organization, flexible, and able to adapt rapidly to changes in the aviation environment. A member of any management team must take appropriate actions against any offensive behavior or misconduct and must conduct an investigation into the offense. Furthermore, a manager must also ensure that no discrimination or unlawful harassment occurs in his or her area and must be able to take immediate action to confirm that the workplace remains free of any type of harassment.

Aircraft Maintenance Management Structure

The organizational structure of aircraft maintenance management in a corporation may vary depending on size and structure of airline.

The typical aviation maintenance structure consists of a vice president (VP) of maintenance and engineering, a DOM, an aircraft maintenance manager, and an aircraft maintenance supervisor. Companies vary in whether they employ a top-down or bottom-up approach to the hierarchy of command. Sometimes companies will structure their departments differently depending on their maintenance base locations and the airport's proximity to other cities. The base station will have a VP and DOM, whereas a substation will only have a maintenance manager and supervisors to fit the needs of the station. Government regulations, especially where international stations are situated, will have to adapt to different rules, customs, and border protection regulations. Some outstations may require international travel to attend to aircraft that are out of service. Domestic flight hub rules are less stringent, but all FAA rules and guidelines must be followed by all stations. The VP and DOM will oversee all stations followed by each hub's maintenance manager and the line supervisors.

Sometimes different departments change their structure, depending on the maintenance base location. Figure 12-1 is a diagram of a typical airline maintenance organization structure. It shows the manager of maintenance position

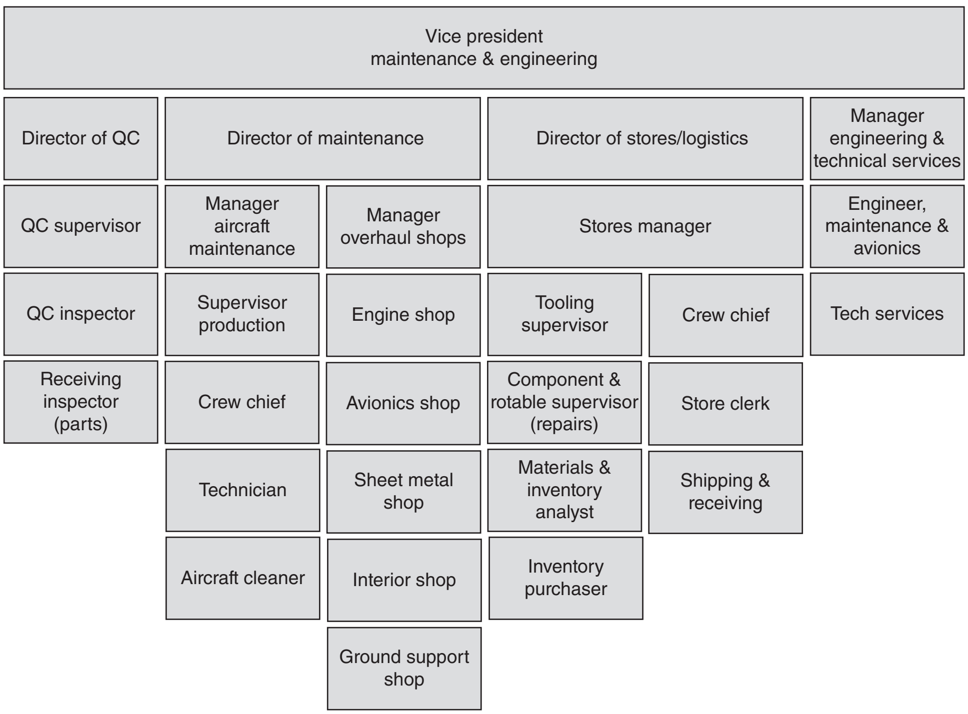

Figure 12-1 Organizational chart for maintenance management and support.

and his or her subordinates. The new or the vacant position in a maintenance structure normally is left blank if not filled, and it shows the director who is responsible. There are mandatory positions, such as VP of maintenance, director of quality control (DQC), and DOM, that are required by the FAA.

The Role of Management in Aviation

A manager directs and coordinates department activities through subordinate supervisors. The manager contributes to and participates in the training and growth of subordinate supervisors. The manager reviews and analyzes reports, records, and directives, and confers with supervisors to obtain data for planning department activities, such as new commitment, status of work in progress, and problems encountered. A manager also assigns or delegates responsibilities for specific work or functional activities, disseminates policy, and sets deadlines to ensure work is completed on time.

Managers also coordinate department activities to ensure efficiency and economy. They monitor costs by preparing budgets, reports, and records on all maintenance departments for upper management. In addition, they evaluate current policies, procedures, and practices, and develop objectives for all departments, and implement and supervise their development. Managers initiate or authorize the hiring, promotion, and discharging of employees, and they must communicate effectively. Effective communication is critical to the success of all managers and their subordinates, especially with regard to communicating the company's objectives. Semantics play a crucial role in this communication. Due to the increase in the use of email, words that have multiple or different meaning may be misunderstood. Sometimes managers use abbreviations that are common in aviation maintenance, and employees must be familiar with the terminology. In short, every message a manager sends must be effectively received.

Managers must learn to develop good listening skills. This is one of the most important skills that can help managers be successful. They have to take time out to listen to their subordinates and other managers/supervisors who can provide them with important feedback about their operations and what changes are needed to make them better. Oral communication plays an important part when managers present their ideas to senior management or hold quarterly staff meetings where they may have to clarify an idea, the company's policy, rules and regulations, or the company's union contracts.

Manager of Aircraft Maintenance

The manager or base manager for aircraft maintenance is in a visionary and challenging position, and it is his or her responsibility to oversee the entire operation of the maintenance base and contract maintenance bases. It is the maintenance manager's responsibility to make sure everything runs smoothly and to amend and remove any policies or procedures as needed.

A manager must have a good work ethic, good communication skills, and a thorough knowledge of aircraft systems. Since the manager is responsible for his organization's structure and development, it is necessary that he or she demonstrate leadership and establish a good relationship with supervisors and workers to achieve desired goals. A manager's communication skills and his peers' ability to organize and inspire high and positive performance in the maintenance department can lead to an efficient and effective department.

Managers face a variety of tasks and problems with aircraft on ground (AOG): damage, lack of parts, union strikes or other union issues, employees calling in sick, or problems with the regulating agencies, top management, or aircraft maintenance planning issues.

Aircraft maintenance managers play a very important role in aviation maintenance. They know how to deal with this organized chaos, and good managers build their airline or maintenance department and their maintenance base into a very successful team that can tackle any obstacle with total confidence.

Front Line Supervisor/Management

Front line supervisors, also known as front line managers, are responsible for carrying out day-to-day managerial duties. They delegate their work through the maintenance crew chief or a maintenance lead mechanic who distributes work as required for the operation. Front line supervisors are result oriented and must make sound decisions about the aircraft and the mechanics working on them. They are safety conscious, and it is their job to keep upper management well informed about an out-of-service aircraft, emergencies, and other unexpected occurrences.

Front line supervisors work well under the stress and pressure of this job environment. They can handle multiple tasks and are very competitive. They are able to meet the demands of their position due to their leadership qualities of integrity, self-management, and experience; knowledge of aircraft maintenance; and effective communication skills. They are innovators, and when they see opportunity for any improvement, they take chances. Their optimistic and flexible approach to any kind of problem conveys a clear direction for their organization. They keep abreast of industry trends and new developments in aviation, maintenance, safety, system upgrade, and modifications to existing systems.

Management Areas of Concern in an Airline

As a maintenance manager or upper, middle, or front line manager, you are constantly bombarded with all kinds of problems and issues, such as aircraft that are out of service, aircraft parts availability, production, subordinate behavior, deadlines for audits, emails, upper managers' odd requests, and other challenges on a daily basis. The airlines are a service industry, and all aircraft must be available

and in good flying condition. Unavailability of an aircraft means that the aircraft is not going to make the flight it has been scheduled for; thus, the manager has to do everything possible to correct the problem. This also happens when weather turns hazardous due to snow, hail, or hurricanes, and an aircraft cannot be flown to another city, where it was scheduled to fly.

As noted, aircraft being out of service for parts and damage is the biggest concern for managers. Since parts are normally obtained from a different city, there is always a chance the part may not make its intended flight or may be lost. The damaged part of the aircraft must be mapped and inspected to understand the severity of the damage and what parts and repairs will be required, and sometimes there are no quick fixes.

The challenging and demanding work of aircraft maintenance management and its concerns are very complex, and the work requires an individual with great focus, diligence, and effective organizational skills. Daily challenges must be prioritized based on available flying aircraft and time, and managers must have creative decision-making abilities to overcome obstacles and achieve their goals.

Manager of Overhaul Shops

The manager of overhaul shops is normally responsible for all overhaul shops. Some of these shops, such as sheet metal, avionics, and interior shops, must be synchronized with the hangar "C" check (heavy check) due to time limitations of the aircraft on the ground for maintenance. The sheet metal shop fixes all dents, corrosion, and other maintenance deferred items. The avionics shop performs modification of aircraft. The components and seat shop refurbishes and modifies all passengers' seats and flight crew seats. The manager of overhaul shops must be informed of daily progress and the work start and completion time of all tasks due to the sensitive nature of aircraft scheduling.

The manager of overhaul shops normally has a supervisor or crew chief who directly reports to him or her on the progress of the work and the materials used and needed to complete it. The engine shop normally has aircraft engines ready, since they keep spare engine(s) in stock for emergencies or scheduled engine changes. We will discuss maintenance shops further in Chap. 14, Hangar Maintenance (On-Aircraft).

As mentioned before, managing an airline's maintenance operation requires vision, knowledge, openness to new ideas and suggestions, and a dynamic personality needed to overcome the daily obstacles of aviation maintenance management. Besides the aircraft maintenance department, there are many other departments involved in an airline's daily operation. The flight department, in-flight department, catering services, ramp (baggage) handlers, aircraft cleaning, base operations, aircraft dispatch, and others play key roles in running a successful airline. The maintenance manager must work closely with all these departments to understand their functions and how they interact with aircraft maintenance on a daily basis.

Note: The management structures and details may be different in other airlines, aircraft carriers, repair stations, and facilities. Since each airline's operation differs due to fleet size, flying schedule, number of employees, contract employees, and other factors, the positions and management structures described in this chapter are to be used as suggested guidelines only.

Chapter

13

Line Maintenance (on-Aircraft)

Introduction

The makeup of the line maintenance depends on the size of the airline. The line maintenance organization may take a different structure, but a commercial midsize airline is normally organized according to the aircraft it operates, the number of daily flights, and the maintenance personnel required to run a good operation. The maintenance control center (MCC) coordinates all maintenance activity on the flight line at the home base, and all outstations. Due to aircraft turnaround times, flight line maintenance is a fast-paced maintenance environment, consisting of scheduled and unscheduled maintenance. The work done by line maintenance is any maintenance that can be done on the aircraft in service without disturbing the flight schedule. These maintenance tasks may include everything from daily oil checks, to 48-hour check, and the “A” check items. (The “A” check items are described in Chap. 2.) If an airline has “B” checks (at intervals between “A” and “C” checks), these are usually done by the line maintenance personnel as well. In many airlines the “A” check interval tasks are added or other tasks scheduled such as the daily line maintenance checks. All of this work is defined by the airline’s maintenance program, and scheduled by production planning and control and administered by the maintenance control center.

The crew used for line maintenance, again determined by the size of the organization, may consist of a single crew to perform all of the items mentioned or separate crews for certain tasks. For example, one crew might be assigned exclusively to different checks while another crew handles all servicing and the logbook discrepancies of the scheduled aircraft. The daily servicing and checks are usually performed first thing in the morning or overnight.

The line maintenance crew is normally an experienced crew, with a very good knowledge and understanding of the aircraft that the airline operates and their systems. When a technician receives a maintenance call from an inbound aircraft concerning the discrepancy it is arriving with, the line maintenance technician usually has a good idea how to resolve the discrepancy quickly and return

the aircraft to service in a safe and airworthy condition. The technicians at the flight line often work in adverse conditions: hot weather, rain, and snow. These technicians often must stand, kneel, or bend in awkward positions to remove and install aircraft parts. They have the tremendous burden of maintaining safety standards, and sometimes the tasks they perform to meet those standards can be stressful.

The flight line is normally equipped with an office for the aircraft maintenance supervisor, a technician ready room (break room), a parts and tooling room, and an aircraft maintenance library, where all the aircraft maintenance manuals are readily available for troubleshooting. The line avionics room contains all radio equipment and charging stations for aircraft test equipment, which includes very sensitive equipment.

Functions that Control Maintenance

There are two organizations in M&E responsible for controlling maintenance activities, and these are shown in Fig. 13-1. We have already discussed the primary control function, production planning and control, in Chap. 9. This group requires input from various sources identified on the left of Fig. 13-1.

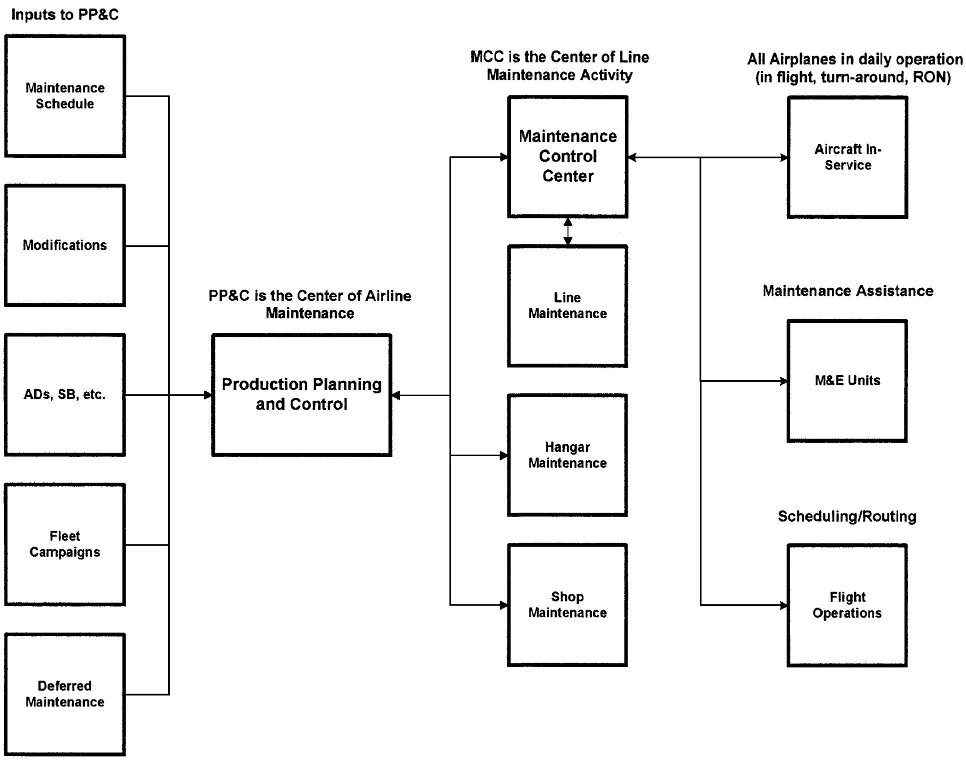

Figure 13-1 Functions controlling maintenance.

Any maintenance that is identified in the airline's maintenance program, plus any additional requirements for modification, upgrade, or maintenance deferred from earlier checks, are controlled (scheduled) by PP&C. This maintenance is directed toward the hangar, the shops, and the flight line as necessary. The PP&C organization interfaces with line maintenance through the second controlling activity, the maintenance control center.

The MCC coordinates all maintenance activity—scheduled or unscheduled—for the aircraft in service with the applicable M&E organization and with the flight operations. Note the double-headed arrows in Fig. 13-1. These indicate a two-way communication. The MCC must deal with all aircraft in the flight schedule, regardless of where they are in the route structure, and must coordinate all maintenance activity whether it is done by the airline or a third party. The MCC also coordinates the contracting of maintenance at units where no previous maintenance agreement exists. The MCC also coordinates with any of the airline's M&E units for support of in-service aircraft discrepancies and the rescheduling of maintenance actions; and with the flight operations organization regarding down times, flight delays, and cancellations.

If maintenance is required by an aircraft in service and such support is not available at the aircraft's current location, maintenance may be deferred—all other requirements being met. This deferral will be handled by the MCC, and they will schedule the work for another outstation or the home base wherever the appropriate time, facilities, and staff exist. If the maintenance must be deferred to a major check ("A" check or higher), then the MCC would coordinate that action with the PP&C, who will then schedule the work for an appropriate down time and ensure that parts, supplies, etc. will be available for that check. These deferrals, of course, must be in accordance with the MEL and CDL requirements.

Maintenance Control Center Responsibilities

The maintenance control center is the heart of line maintenance. Regardless of how large or small an airline is, the MCC functions must be established and must be in control. The purpose of the maintenance control center is to:

1. Complete all daily checks on designated aircraft.
2. Perform transit or turnaround maintenance on aircraft as needed.
3 Coordinate servicing of these aircraft (food, water, fuel, etc.).
4. Troubleshoot maintenance problems and schedule repairs (if possible) in the allotted turnaround time or defer maintenance (MEL, CDL, NEF) until a more appropriate time.
5. Coordinate with various departments—stores/material, engineering, inspection, planning, and other M&E organizations—for assistance in resolving maintenance problems at the home base or outstation.

6. Coordinate with flight operations for the maintenance, deferral of maintenance, functional check flight (FCF), aircraft ferry permits, whenever the schedule may be impacted.
7. Track all aircraft during flight to determine their location, maintenance requirements, and status.
8. Coordinate maintenance at outstations with other airlines or approved third-party contractors as necessary.
9. Collect log pages of any in-flight engine shutdown (IFSD), bird strikes, lighting strikes, or any emergencies that require an aircraft to return from flight and or any ground interruptions.

Needless to say, the personnel in the MCC have quite a large job to perform. To do this, they need the right facilities to aid them in the performance of the job. First, they need a centrally located room near the main flight line operations where they can have close contact with all of the activity.

Second, the MCC should have sufficient tally boards or computer displays of all aircraft (by aircraft type and tail number) to identify flight schedules, flight durations, current location of aircraft, and maintenance needs, if any. These boards should also display the status of that maintenance and the due date of the next scheduled maintenance checks (A, B, C, etc.). If these checks are performed only at certain bases, it is the MCC's responsibility to coordinate with flight operations and scheduling to see to it that the aircraft is in the proper place for that check when it comes due. The MCC should be "on top" of everything that is happening to all aircraft in service.

Third, the MCC must have sufficient communications devices to carry out all the requirements stated above. That means telephones for internal and external conversations with anyone related to a given problem; radios for communications with aircraft; hand-held radios (or cell phones) for communication with maintenance crews on the line and in the field not accessible by other communications devices; and teletype, facsimile machines, and/or computer terminals for the transfer of data and forms between the various units.

To carry out many of the tasks assigned to it, the MCC must have access to maintenance manuals and other technical documents. The fourth requirement for the MCC, then, is to have within the facility an extensive technical library (see Chap. 10). Since the MCC is first to be notified of any maintenance problems, they are the first line of defense and are the ones responsible for effecting a speedy solution. They must coordinate with other M&E units to reach that successful completion. The MCC is in charge and is responsible for returning the aircraft to service.

Finally, the MCC must have sufficient, qualified staff to carry out these activities and the ability to manage quick and accurate responses to any and all problems relating to maintenance of in-service aircraft. All MCC staff should be licensed mechanics. The MCC plays a very significant role in the effort to meet the goals and objectives of the maintenance and engineering organization, as well as those of the airline.

The MCC department's primary function, as mentioned previously is to ensure that all aircraft are available for daily flying. The MCC also supports the airline's reliability program. The MCC is responsible for identifying and reporting all delays and cancellations of aircraft and must provide the details of all incidents. Since the line maintenance department and its procedures are integral to these delays and cancellations, the MCC is a key player in the investigation and solving of these problems. (Reliability and repeat items, see Chap. 18). The MCC also coordinates, issues, controls, and reviews all maintenance deferred items under the MEL, CDL, and NEF systems. The MCC has the authority to deny or defer any item due to its condition, penalty restriction, or the number of time discrepancy has been repeated. For some airlines, repeat discrepancies are categorized in their Ops Spec. Some may specify that the discrepancy or write-up has occurred more than three times in 5 days; other airlines may specify 7 days. If the repeat rates are not specified as part of the Ops Spec, they should be clearly stated in the airline's reliability program document.

If the problem persists, there must be an error. The error could be procedural, mechanical, operational, or pertaining to the maintenance manuals, environmental conditions, or faulty parts from stock. Whatever the reason, the MCC does an immediate investigation to determine the problem and solve it. This is an effort to identify and contain the problem without waiting until reliability data confirms it. In all likelihood, a repeat discrepancy will not even show up in the reliability data because if addressed quickly, it will not recur in sufficient numbers to cause a reliability alert.

Line Maintenance Operation—General

Figure 13-2 shows the typical flight line activities for a given flight.

An aircraft may or may not experience any faults or discrepancies during the flight. When the aircraft arrives at the gate, normal services (fuel, food, etc.) will be provided, as well as the exchange of passengers, their baggage, and any cargo. If a failure or discrepancy did occur in flight, there are two possible scenarios. Normally the problem is written up in the aircraft maintenance logbook and addressed by the ground crew upon flight arrival. Maintenance actions would be as indicated by the center column blocks of Fig. 13-2. To minimize delay on the ground, however, it is recommended that advance warning be given to the maintenance personnel by the flight crew through flight operations and the MCC. This allows maintenance to spend time before the aircraft arrives to review past records and troubleshoot the problem. Thus, the actions shown in the left hand column of Fig. 13-2 are employed. In many cases, the maintenance crew can meet the aircraft with a solution in hand thus minimizing maintenance downtime and delays. This may be accomplished by a separate team or the same team that handles any other logbook items. Note that both sign-off of all discrepancies (or deferrals) and servicing of the aircraft must be completed prior to returning the aircraft to flight service.

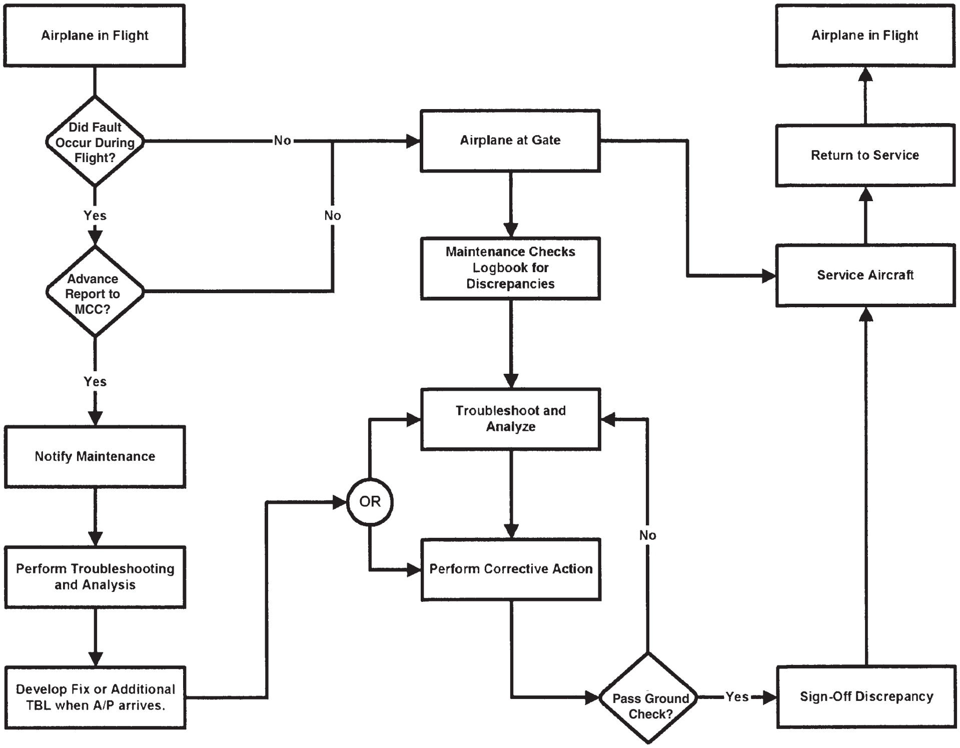

Figure 13-2 Line maintenance operations—turnaround.

Aircraft Logbook

The aircraft logbook is a type of document that is required by the FAA and the airline to document any maintenance discrepancies. An aircraft cannot fly to any destination without its logbook neither can an aircraft be taxied to any other location without having the logbook on board. The logbook shows if there are any open maintenance discrepancies, and if by moving or starting an aircraft, someone may damage the aircraft or its systems.

The aircraft maintenance department is responsible for keeping the logbook up to date, which includes recording of such information as total flight hours and cycles when fixing an aircraft's maintenance discrepancy. The pilot in command must write such basic information as the names of the flight crew and the flight number, and must sign the logbook accepting the aircraft. The logbook contains a section that allows the flight crew to write any maintenance discrepancies found during the preflight check, encounter any maintenance problems while in the air, or discovered during the postflight check. The flight crew must write the maintenance discrepancy in the logbook and notify the MCC, so maintenance personnel can address the problem. Depending on the maintenance discrepancy, it may be fixed quickly or it may be deferred under the MEL program.

Once the MCC and AMT have agreed of the deferral item, the AMT enters the appropriate information in the corrective action box adjacent to the mechanical discrepancy box and signs off with the information and authorization number of the MEL, which was obtained from the MCC.

When maintenance is completed on the aircraft and the discrepancy is signed off, the AMT will remove the log page copy and forward it to the MCC. Some airlines collect log copies at the end of each flight day. The logbook pages are normally duplicate copies but may be in triplicate. Only copies of a logbook page are removed. The original log page always stays with the aircraft until the logbook is full and a new book is installed. The completed logbook is forwarded to the aircraft records department. The log pages sent to the MCC are entered into the M&E maintenance database, and the information is used by M&E, QA, QC, and the reliability department for various other actions, ATA verifications, and future references.

The modern aircraft have superseded or have improved the logbook with electronic logbook. The ACARS (ARINC communication and reporting system) is used to transmit data to the airline home base. The ACARS system is a digital datalink used by the flight crew to transmit messages between the aircraft and the maintenance base while in flight. This helps the MCC to evaluate discrepancies and the time needed for repairs. The ACARS system is also used to sign off maintenance discrepancy (used as an electronic logbook) depending on the aircraft used and its capabilities. Once the AMT signs off the discrepancy in the ACARS system, it will record it in the MCC or the aircraft record system database. The ACARS system is also used in preflight communication and other integral systems, to calculate the weight and balance of aircraft, and to monitor engine trends.

Ramp and Terminal Operations

Transiting aircraft are the subject of a lot of attention at any airport, and that attention is usually concentrated in a short (often 30-minute) time span called the *turnaround*. During this turnaround, flight handling, servicing, and maintenance chores must be accomplished. Although not all these actions would be required at every turnaround, the following sections provide an overview of what might be done.

Flight handling

The main purpose of flight handling is to move passengers, their baggage, and/or any carried cargo off and on the aircraft as necessary. This begins with parking the aircraft at the gate and positioning the air stairs or the gateway ramp and opening the aircraft doors. This is a joint effort involving maintenance, ground handling crews, the flight and cabin crews, airline terminal personnel, and the FAA tower personnel responsible for ground control. Watching this activity from the passenger lounge, one sees a well-coordinated ballet of workers and machines.

The baggage and cargo loading equipment and crews form a second wave of activity followed by servicing and maintenance activities. Servicing consists of refueling, adding potable water, and all the food and beverages for the next flight, as well as removing the trash and other waste materials of the previous one.

In the meantime (it is difficult to separate one activity from another from your vantage point in the passenger lounge), the maintenance crew has entered the airplane, checked the logbooks and, if possible, talked to the crew about any problems they may be having with the equipment. Maintenance will check out and troubleshoot the problems and initiate repairs. In some cases (recommended whenever possible), advance warning of problems has allowed maintenance to troubleshoot a problem ("on paper") prior to aircraft arrival, using the fault isolation manual (FIM) and the airplane maintenance manual (AMM), and they can meet the airplane with a possible solution already in hand. If maintenance is completed, it is so noted in the logbook. If not, it is deferred according to predetermined procedures and that action is noted in the logbook. The flight crew is also notified of this condition prior to the next flight.

These deferrals must be handled in accordance with MEL requirements (see Chap.1) and with the pilot in command (PIC), who has final say on whether or not to dispatch the aircraft in such condition. If the deferral is not allowed, maintenance must effect repairs at once and, in some cases, take responsibility for a flight delay or cancellation (see Chap. 18). If a delay or cancellation does occur, the MCC must coordinate with flight operations and with the airline's terminal personnel to handle the passengers and, if required, their baggage.

So, you see, although maintenance is our main concern in this book, line maintenance is only a part of the activity on the line at any aircraft turnaround. Their efforts are extremely important and must be completed within a matrix of activity and a narrow window of opportunity. But transit maintenance is not all the line maintenance organization has to do. In some airlines, their line maintenance crews also perform some or all of the above functions under contract for other airlines landing at this station that do not have their own maintenance people assigned. This contract work is coordinated through the MCC.

Flight line (preflight and postflight)

The preflight inspection must be accomplished on the aircraft's first flight of the day. Preflight normally contains the recommended sequence and expanded procedures. The preflight inspection is normally accomplished by the first officer (copilot) and does not require the presence of both crew members.

Preflight for winter operating conditions are different, and require basic precautions, compliance with special procedures, and attention to detail. Airline pilots are provided specific aircraft winter operating policies and procedures in their flight manuals, which include ground deicing and anti-icing programs.

The following is an example of the recommended preflight sequence:

- Exterior safety
- Exterior preflight inspection

- Cabin safety inspection
- Flight deck equipment location
- Flight deck safety scan

The exterior, cabin, and flight deck scans are performed in detail with an overall visual observation. While performing walk around, the first office pays particular attention to all aircraft surfaces, such as windows, antennas, engine, cowlings, access panels, and emergency exits. The equipment hatches not in use are properly closed and secured. If any abnormalities or maintenance discrepancies are noted during the preflight check, the flight crew will send a message via ACARS or the aircraft radio using a preset maintenance frequency and request maintenance via the MCC.

The postflight inspection must be accomplished after each flight. This is intended to detect obvious discrepancies and consists of less tedious check than a preflight inspection. In the event the outbound crew meets the incoming crew at the aircraft, the postflight check is not required, since a preflight check will be accomplished by the next outbound crew. If there are any maintenance discrepancies found during the postflight check, the crew will report discrepancies to the MCC. Also, it is the departing crew's responsibility to shut off all power, batteries, external power, and oxygen supply after all passengers have been deplaned.

Other Line Maintenance Activities

After the excitement, fervor, and expedience of the turnaround effort has subsided, the line maintenance organization attends to numerous other tasks. One of these is the performance of the daily or 48-hour check (see Chap. 2) on all assigned aircraft. These checks are usually done before the first flight each day (overnight or morning). The daily or 48-hour check consists of specific items outlined in the maintenance program identified in the unit's Ops Specs. The airline may add other items as necessary. Table 13-1 shows a typical 48-hour check for a twin-engine jet; Table 13-2 is a typical transit check for the same airplane.

TABLE 13-1 Typical 48-Hour Check (Twin-Engine Jet)

- Check brakes for condition
- Check oil levels for IDGs and APU
- Check main and nose landing gear tires for wear
- Check main and nose landing gear tires for inflation pressure
- Check main and nose landing gear assemblies for condition
- Check tail skid shock popup indicator
- Operational check of standby power
- Test engine, APU, cargo squibs on squib test panel
- Test escape slide squib on test panel (passenger aircraft)
- Apply brakes and check landing gear brakes for engagement and wear
- Operational check of interior emergency lights
- Operational check of fire/overheat systems
- Operational check of TCAS (if installed)
- Visually check cargo door seals for condition (ETOPS)

TABLE 13-2 Typical Transit Check (Twin-Engine Jet)

- Service engine oil as required
- Check RAM air inlet/exhaust doors and cabin pressure outflow valve for condition and obstructions
- Check positive pressure relief valves for indication that valves have opened
- Check all movable flight control surfaces for condition, obstructions, and locks
- Make sure that the fueling station door is closed
- Check nose and main landing gear tires and wheels for obvious damage
- Check navigation and communication antennas for condition
- Check static ports, TAT probe, pitot static probes, and AOA vanes for condition
- Check crew oxygen discharge disc for presence
- Check drain mast areas and drains for leakage of fuel and/or hydraulic fluid
- Check vertical fin and rudder, horizontal stabilizers and elevators for obvious damage, evidence of fluid leakage, and missing or damaged static dischargers
- Check lower wing surfaces and wing tips for obvious damage and fuel leakage
- Check engine cowlings for obvious damage; check that blowout door is not open and latches are secure; check for signs of fluid leakage
- Check inlet cowl, fan rotor spinner, and fan rotor blades (both engines)

These will differ somewhat for passenger and cargo aircraft and for an airline's specific equipment.

In addition to the daily and 48-hour checks, those items in the maintenance program that are scheduled at times less than the "A" check interval are performed by line maintenance personnel either during the turnaround (if time permits) or whenever the aircraft is on the ground for a sufficient amount of time, such as overnight or wide gaps in the daily flight schedule. This downtime is also utilized by production planning and control (see Chap. 9) for scheduling the "A" check itself. Usually, this check can be done overnight with sufficient crew or it can be split into two phases and performed on consecutive nights by a smaller crew (left side of aircraft one night, right side the next).

The line maintenance crews may also be required to perform special inspections or even simple modifications to or inspections of equipment during the turnaround or overnight periods as time and conditions permit. These mods or inspections may be suggested by manufacturers, dictated by regulatory authorities, or imposed by the airline QA/QC units. They may be required on a single aircraft or the entire fleet. If the checks are simple or involve short time expenditure, line maintenance crews are capable of carrying out the tasks. However, if the time requirements are longer, these tasks can be allotted to a longer maintenance visit such as the daily, 48-hour, or an overnight; or if the task requires opening of panels, tearing down or removal of components, or other extensive maintenance activities, the tasks might be relegated to hangar or shop maintenance (see Chap. 14).

Line Station Activities

Two terms have been used, somewhat interchangeably, in reference to maintenance activities at stations that are not the home base of the airline. These terms

are *line station* and *outstation*. These terms are usually considered synonymous. For the most part, line station activity is a smaller version of the home station activity. The same type of activities take place relative to transiting aircraft. However, the line station may have limited personnel and skills; limited availability of parts and supplies; and limited facilities (stands, hangar space, GSE) for the performance of maintenance.

One of the consequences of this arrangement is that a greater number of deferred maintenance actions will be taken at line stations than at the home base. In some cases, the repair can be done at the next stop, at some other stop along the route, or deferred until arrival at the home base. These deferral actions must be coordinated with the MCC.

The airline's MCC at the home base must provide or arrange for the parts, supplies, and maintenance personnel required for the resolution of any problems that occur when there are limitations in any of these areas at that station. This is also true for stations where the airline has no permanent activity. Crews and supplies must be obtained on site from other airlines or flown to the site by the operator. As a last resort, the aircraft may have to be flown home or ferried to another suitable site for repairs. Of course, arrangements for disposition of the passengers must also be made with the business office and flight operations. In all of these situations, the MCC is responsible for making all the arrangements and for coordinating with all parties concerned.

Other concerns at outstations include the contracting of maintenance personnel on site for effecting repairs and for servicing the aircraft. Unless the airline has made previous contractual arrangements with the station, arrangements for maintenance are handled by the MCC. At some airlines, however, the pilot in command has the authority to contract for any services needed, but this must also be coordinated with the MCC. No matter how the problem is handled, it should be spelled out in the airline's TPPM, and all activity should be reported through the airline's MCC for coordination and execution within the airline.

Maintenance Crew Skill Requirements

It is often thought that, because of the simple nature of the work—turnaround maintenance and servicing—the line maintenance unit can be manned by the newer, less experienced personnel. Nothing could be further from the truth. The work done by line maintenance covers a broad scope of activity. While the shops and hangar can employ specialists who work essentially on one or a few items repeatedly, line personnel need to know the entire aircraft: all of its systems and their interactions. Line mechanics have to deal with a different problem, often on a different type of aircraft, each time they are called upon to meet an incoming flight.

The crews assigned to line maintenance must be well qualified in their profession. They should be certified mechanics approved by the regulatory authority and the airline to work on airframe, power plant, and aircraft systems, and they must be certified to sign off maintenance tasks and authorize an aircraft

to “return to service.” The line maintenance crew may also include unlicensed helpers and trainee personnel, but they must work under the supervision of qualified personnel. Dedicated QC inspectors may be assigned to the line crews (larger airlines), or line maintenance personnel can be appointed as designated inspectors to address the quality issues as they arise (see Chap. 17). The QC inspectors of either type can also be part of the MCC staff depending on the requirements and size of the operation.

The skills required by the line maintenance crews are just as broad-based as the work effort. Crews must be familiar with all aircraft types within the airline’s fleet. They must be familiar with applicable FAA rules and regulations, as well as the airline’s policies and procedures that relate to the line maintenance activities. Although these line crews will ordinarily be supervised and supported by the MCC, there are times (overnight) when the line crew is performing the duties of the MCC in addition to their normal duties.

General maintenance skills and techniques are a must, but the line maintenance crews must also know what specialists, if any, will be needed to complete a particular job if they cannot handle it themselves. Much of this effort, of course, would be handled by the line maintenance supervisor or by the MCC. But keep in mind that in small airlines, these functions may all fuse together into one crew—or into one or two people. Since the line maintenance crew is responsible for whatever arises, they need to have the necessary skills to perform scheduled and unscheduled maintenance, to troubleshoot the problems, to perform required inspections (RIIs) and conditional inspections (hard landings, bird strikes, etc.), and to do all the required paperwork.

The paperwork includes logbook handling (pilot reports, or PIREPS); task card handling (“A” check and below); engineering orders (see Chap. 8); repeat items (with MCC); incoming and outgoing deferred maintenance items (DMIs); and any other reports or MCC actions that may occur.

The makeup of the line crews, the number of shifts, shift length, and scheduling of personnel is dependent on several factors: the size of the airline, the flight schedule, types of aircraft flown (different types often require different skills), and type and amount of work performed. Each airline must decide the most appropriate approach to meet their own needs.

One last point of line maintenance activity must be stressed. If any maintenance work is being done that requires it to be spread across two (or more) shifts, there must be procedures written on the manner in which job information is transferred from one work crew to the next to ensure proper completion of the work. Some airlines accomplish this by requiring the original crew to continue past their normal duty hours until the job is completed. Thus, no changeover procedures are required. Other airlines, however, prefer to pass the job (maintenance as well as inspection and paperwork) to the crew on the next shift. Whichever way it is done, the procedures for the transfer of work and inspection activities must be spelled out in the TPPM (see Chap. 5).

Chapter 14

Hangar Maintenance (on-Aircraft)

Introduction

Hangar maintenance, whether or not the airline actually has a hangar for such activity, refers to that maintenance which is done on an out-of-service (OTS) aircraft. This includes any major maintenance or modification on aircraft that have been temporarily removed from the flight schedule, usually for that express purpose. The following types of activities are addressed in hangar maintenance:

1. Schedule checks ("C" check, "D" check, heavy maintenance visit)
2. Modification of aircraft airframe or aircraft systems according to service bulletins, airworthiness directives, or engineering orders
3. Fleet campaign directives
4. Aircraft engine removal and installation
5. Aircraft painting
6. Aircraft interior modifications
7. Special inspection required by the FAA (i.e., corrosion program)

Any hangar visit can include various combinations of the preceding activities in order to achieve maintenance objectives and to minimize maintenance downtime. Scheduling of these activities is done by the production planning and control organization with coordination of all involved units. This planning process was discussed in Chap. 9.

Washing of aircraft can be done outside on the ramp or in a special apron rear, but the painting of the aircraft is normally done inside a dedicated paint hangar. The main hangar (the only hangar for some airlines) is usually dedicated to maintenance. This facility must be large enough, with hangar doors closed, to house the largest aircraft in the airline's fleet that will be serviced. This hangar should include height for the vertical tail section, as well as space around the

aircraft to accommodate maintenance stands and other work units necessary for the maintenance work. On occasion, airlines are required to work on aircraft with the vertical tail section sticking out of the hangar with hangar doors not fully closed. This is an acceptable procedure when the only alternative is modifying the hangar or building a new one.

The hangar building itself also provides space for numerous support shops, the overhaul shop (discussed later in this chapter), and ground support equipment, as well as office space for the hangar maintenance management, PP&C, stores and logistics, and administration staff. A dock area should be provided to serve as the control center of the hangar maintenance check-in progress. This includes the space where work cards and nonroutine work cards are kept for the purpose of assigning work and signing off various maintenance job tasks. This area is also the central point of hangar supervisory and inspection personnel. This dock area is to hangar maintenance what the MCC is to line maintenance: the center of activity and control. The parts and supplies needed for maintenance being performed in the hangar should be stored in a dedicated area as near the aircraft as possible. Separate space should be provided for the items removed from the aircraft and for new items to be installed. All items should be properly tagged.

Hangar floor layouts and dock spacing are planned according to the fleet type, which may include aircraft with four engines, aircraft with two engines, wide-body aircraft, narrow-body aircraft, and aircraft with differing engine locations. The hangar is to accommodate maintenance simultaneously on different types of aircraft. The hangar floor maps and layouts are normally identified in the airline's TPPM. Depending on the airline's operation and the work performed, it may require a separate dock and a separate crew to perform different tasks. The hangar capabilities and needs from those mentioned are essentially the same: (*a*) hangar space must be adequate for the work performed, and (*b*) hangar maintenance must be planned, scheduled, and controlled to ensure that the required work is completed on time. A typical hangar visit, a "C" check, will be discussed at the end of the chapter.

Organization of Hangar Maintenance

Hangar maintenance is a manager-level position under the director of aircraft maintenance (DOM). Under the DOM is a typical organizational structure with managerial and supervisory positions: aircraft maintenance, GSE, facilities, and support shops. The supervisor of aircraft maintenance is responsible for all the hangar maintenance activities. He or she controls the flow of aircraft into and out of the check, as well as the maintenance crews working the checks. The supervisor of aircraft maintenance coordinates with the overhaul and support shops, materials, production planning and control, flight line maintenance, and flight operations regarding the aircraft in the hangar. The supervisor of GSE and facilities are responsible for all ground support equipment used to support the hangar maintenance personnel, as well as the flight line maintenance activity and the building and facilities used by maintenance. The supervisor of support

shops is responsible for all support activities for aircraft service and maintenance that is not designated as overhaul shops. The support shops include those in support of welding, composite material, sheet metal, upholstery, seats, and interior. The following sections of this chapter will discuss hangar maintenance, support shops, and overhaul shops.

Problem Areas in Hangar Maintenance

There are several areas within the hangar maintenance activity that, at times, may cause some problems. These are discussed below to prepare the reader for the real world of maintenance.

Nonroutine items

The basic maintenance checks have task requirements for various inspections, functional checks, and operational checks of the aircraft equipment. These are known as routine maintenance items, and they require a fixed amount of time to be accomplished. The time requirements are identified in the MPD/OAMP and the estimated items required for completing the job, assuming that all parts, supplies, tooling, equipment, and personnel are available at the aircraft. The requirements assume that all work will go smoothly and without any delays or interruptions and that the mechanics will know exactly what to do and how to do it. The airlines usually multiply the estimated time by two or three (more for older aircraft) in order to be more realistic. This is usually done by engineering when the maintenance program is developed or by PP&C when the planning is done.

If things always went according to plan, all the work needed for most checks would be straightforward and maintenance activities would require a fixed amount of time. Nevertheless, many of these routine tasks will reveal problems that must be addressed. The requirements in skills, parts, supplies, and time can vary considerably depending on the nature of the discrepancy found. These are called *nonroutine items* and, by their nature, they can extend the aircraft downtime needed to accomplish the hangar check. It is the responsibility of the hangar maintenance or dock supervisor to adequately estimate the time required for these nonroutine items. It is an ongoing effort for the maintenance crew and management to ensure that these nonroutine items do not cause undue delays. While no mechanic likes to have his or her work timed, it is important for planning purposes to know how long it takes (on average) to perform these nonroutine jobs so that proper planning can be done in the future. It is information that is gathered over a period of several check cycles.

Parts availability

One activity that affects maintenance downtime is the time mechanics spend "chasing parts." Again, it is a function of PP&C to determine what parts and supplies will be needed for routine and nonroutine work, as well as for items

deferred from other maintenance checks and those parts required by service bulletins, airworthiness directives, and any other work to be incorporated in the scheduled check. Material (Chap. 15) is responsible for the delivery of parts and supplies to the hangar just-in-time (JIT) for maintenance to use them. The hangar management, in turn, must provide a parts staging area in the hangar near the aircraft dock for these parts and supplies to be delivered and stored. This area must be accessible to the work force and at the same time protected from parts robbing or pilferage. This area should also provide space for mechanics to drop off any parts removed from the aircraft that are to be repaired or discarded, so that material may properly process them. It is the responsibility of maintenance to ensure that these items are properly tagged. The establishment of this parts staging area and the delivery of parts when needed allows maintenance people to exert their time and effort on the job they were hired to do—maintenance—rather than spend it traipsing around the airport gathering the parts and supplies they need.

The saga of parts robbing

Parts robbing or *cannibalization*, as it called in aircraft maintenance, is a necessary evil. We are primarily against the practice but understand its necessity at times. This is particularly true if you want to meet the deadlines and goals established for the airline maintenance programs: To deliver an airworthy vehicle to the flight department in time to maintain the flight schedule and to deliver the aircraft with all required maintenance accomplished. The quick return of an airplane to service by line maintenance is an admirable achievement, but robbing a part from another aircraft in order to do so often results in the delay of that second aircraft being returned to service. A typical scenario goes something like this:

Aircraft tail number (TN) 317 is in transit (30-minute turnaround) and will require a part that is not available in stores due to a maintenance discrepancy. To avoid the delay or cancellation of TN 317's scheduled flight, the needed part is taken from TN 324, which is in the hangar undergoing a "C" check. Thus, TN 317 is returned to service without incurring a delay and flight operations, line maintenance, the airline business office, and the passengers are all happy, but what about hangar maintenance?

First, did hangar maintenance order the part as an aircraft on ground (AOG) for TN 324? If the hangar maintenance personnel had completed the necessary maintenance (routine and nonroutine, modification, etc.) on the system from which the part is cannibalized, the work must be repeated in whole or in part.

This may also cause delay in the "C" check release if the part is not available. If any case, the part is not available and the aircraft is ready to come out of the "C" check except that the robbed part has not arrived. In respect to our goals, the part must be robbed from another incoming "C" check aircraft and the cycle of cannibalization continues from aircraft to aircraft until the part ordered

arrives. Hangar maintenance normally fills out cannibalization paperwork, which is a written explanation of where the part was robbed from (if there is more than one part on the aircraft); part description, serial number, and, location; and what aircraft the robbed part is installed on.

The rules regarding parts robbing are established in the aircraft TPPM or an airline's aircraft operations manual. The policies do specify (*a*) cannibalization of parts should only be practiced in absolute necessity, (*b*) parts must be ordered through stores and material, and (*c*) robbing parts should only be done with the consent of management. The entire intent of cannibalization is to enable the aircraft to return to service promptly, to ensure that the required part is on order, and to ensure that all M&E units concerned are aware of the situation and its status. It is in keeping with the objective of maintenance to avoid unnecessary repetition of work. If it is necessary to increase the stock level of the subject part in order to avoid parts robbing, this should be determined and addressed early in the process, thus avoiding similar problems in the future.

Hangar Maintenance Activity—A Typical "C" Check

The content of a "C" check will vary from one airline to another, from one aircraft to another, and even from one check to another for the same aircraft or type. The discussion that follows is typical and, for convenience, is divided into several stages, which, in reality, may overlap or even fuse together. For this illustration, we will break the typical check into five sections: (1) preparation; (2) preliminary activities; (3) conduct of the check; (4) completion and sign-off; and (5) return to service.

Preparation for "C" check

We have already discussed the preliminary activities of engineering (Chap. 8), production planning and control (Chap. 9), and the M&E planning meeting (also Chap. 9) so these will not be repeated here. To begin the actual check, the hangar maintenance organization must prepare for receipt of the aircraft and for the logistics and management of the check. The hangar is cleaned; space is cleared for the aircraft; stands, scaffolding, and other equipment needed are brought into the hangar for immediate use or made available for later use. The parts storage area is stocked with parts and supplies needed for the work to be performed. This, of course, is an ongoing process throughout the check. The parts and supplies will be delivered "as needed" or just-in-time.

In the dock area, where administration and management of the check takes place, a large wall rack with pockets is populated with all routine task cards as required by the maintenance program and the particular check to be performed. There is a row for the cards of each work center (avionics, hydraulics, etc.) and two marked-off areas to separate the completed cards from those still to be worked. Work crews are available or on standby waiting for the arrival of the aircraft.

Preliminary "C" check activities

The first order of business, usually, is to wash the aircraft. The vehicle is towed by ground crews, with appropriate "wing walkers" and communications gear for safety, to the wash rack area for a thorough cleaning. After washing is done, the aircraft is towed to the hangar where it is parked and chocked; now the work begins. Panels and cowlings are opened and visual inspections are conducted. Any discrepancies found at this time will require nonroutine work cards. These cards are generated by QC and are placed in the card rack for later accomplishment with other work cards. Next, or in conjunction with the inspections, the stands and scaffolding (as needed) will be placed around the aircraft to allow access to work areas during the check. Any ground power, pneumatic, or hydraulic carts, as well as any special tools and test equipment needed for the scheduled tasks, will also be put into place.

Conduction of the "C" check

Mechanics are assigned to tasks according to the check schedule produced by PP&C in an efficient manner. The work to be done in any given area by more than one work center is scheduled in sequence to avoid congestion in the work area and to minimize the opening and closing of panels, cowlings, etc. Any nonroutine items generated during normal work will be written on nonroutine cards and worked or scheduled for work at a later time. Most units produce a PERT chart or some other form of visual aid showing the planned work schedule. This chart is updated, or annotated, as necessary during the check to accommodate the nonroutine work or any other delays or schedule adjustments that may be encountered.

Requests for additional parts and/or supplies not in the original plan, or for parts and supplies not yet delivered to the work site, will be relayed to material by the dock staff. Material will deliver these items to the parts staging area to eliminate parts chasing by mechanics.

Quality control inspectors will reinspect any items previously rejected and approve the work (buyback, see Chap. 17). Any delays in the check schedule, especially those affecting return to service, will be coordinated with the MCC and flight operations by the dock manager. If all goes well, the "C" check will be completed on time and the aircraft will come out of check "clean," i.e., all required tasks completed with no deferred maintenance items.

Completion and sign-off of the "C" check

Although the maintenance work is the key part of the effort, the check is not really complete until it has been assured that all task cards—routine and nonroutine—have been completed, signed off, and where required, inspected, stamped, and approved by quality control. That includes all rejected work and the subsequent rework and buyback actions. The person responsible for this activity is the senior QC inspector assigned to the check. He or she must review

every work card for mechanics' signatures or initials as required, indicating accomplishment and completion of the task and for QC stamps (and initials) for any work where QC inspection is required. Any discrepancies noted at this time must be corrected even if it requires further work and inspection. When all work cards have been completed, signed off, and accepted, QC signs off the check as complete and releases the aircraft out of check, ready for service.

Return to service

Once QC has signed off the check, the dock manager notifies MCC and flight operations of the availability of the aircraft. The aircraft is then towed from the hangar to the ramp by maintenance, and Flight Ops returns the aircraft to the active flight schedule. Ground crews service the vehicle (fuel, food, etc.), and cabin crews ready the aircraft for passengers.

Meanwhile …

Once the check is completed and the aircraft has been moved out of the hangar, there is a requirement for a clean-up effort in the hangar and the dock area. First, all completed task cards must be collected and sent to other M&E units (PP&C, engineering, and reliability as required) for analysis and recording of significant items. This will aid PP&C in planning future checks and will permit engineering and reliability to tally the information on check findings to aid in future problem investigations and for possible adjustment (escalation) of task or check intervals. Any unused, repairable, or discarded items remaining in the parts staging area will be removed by material and processed as necessary. Hangar and dock areas will be cleaned and put in order for the next activity when the whole process is repeated for the next aircraft, which may be the same model with similar check requirements, or a different model aircraft with completely different requirements. The size of the airline and its fleet makeup will vary hangar activities for specific checks, but the process is essentially the same for all of them.

Morning Meetings

One of the most important activities of the M&E operation is the morning meeting. This is held first thing each morning and is conducted by maintenance control center (MCC) to address current maintenance status:

1. Aircraft out of service with maintenance status throughout airline's system (hangar and line maintenance)
2. Aircraft AOG situation and resolutions
3. The day's flight schedule
4. Any significant issues or changes in maintenance that may affect the day's flight and maintenance work schedule

During this morning meeting, maintenance personnel may also discuss (or there may be a separate meeting on) upcoming hangar and shop maintenance activities and problems. There is another meeting following the morning MCC aircraft maintenance situation meeting, where daily maintenance planning is discussed, including the aircraft routing due to required maintenance and requirements for logistics and tooling which may be needed. The purpose of these meetings is to enable M&E managers and supervisors to keep abreast of everything that is going on in the maintenance area and quickly address any problems that may arise.

Hangar maintenance support and overhaul shops (off-aircraft)

Hangar maintenance and overhaul shops are a vital part of the hangar operation. These shops are designed to help and support heavy aircraft maintenance checks ("C" and "D" checks) and consist of various specialties. The employees in these support shops require special skills for the work they perform. They do not require an FAA license as do those who work in the overhaul shops, who are required to have either an A&P license or an FAA repairman certificate. The support shop work can be performed on the aircraft or off the aircraft, depending on the work discrepancy. Due to the nature of some repairs, these heavy tasks are done while the aircraft is out of service for a length of time. Thus, support and overhaul shops are part of the hangar maintenance function.

Hangar support and overhaul shops consist of various specialties. They perform work to refurbish or repair aircraft panels, surfaces, and aircraft engine cowlings (sheet metal or composite) material. They also have an interior shop for repair, modification, and refurbishment of aircraft interiors; repair and modification of passenger and crew seats; and aircraft painting. The shops associated with hangar activity would be those working in welding (gas, electric, and heliarc).

The work performed by these shops is not directly a part of the scheduled maintenance program, and it is not specified in the MRB document or the airline Ops Spec as routine or nonroutine maintenance, but work will be required on the various components mentioned above from time to time, either by nonroutine work card or by SB, AD, or an EO. Some airlines may also perform work in these support shops for other airlines or fixed-base operators to generate revenue.

Support and Overhaul Shops Organization

The manager of the overhaul shop is responsible for overall management and administration of maintenance support and overhaul shops. With the aid of shop supervisors, managers oversee and manage overhaul, repair, and maintenance of components and equipment removed from the aircraft for maintenance. This maintenance can be anything from simple cleaning and adjustment to complete overhaul.

Shop maintenance is normally done on an out-of-service basis: equipment is removed from the aircraft and replaced with a serviceable unit by the line or hangar maintenance personnel. The removed unit, properly tagged as to maintenance status, is then sent to stores and material, where it is either discarded according to standard maintenance procedures or routed to the appropriate shop for repair. This would include the airline's shop or an approved component repair contractor. Units under warranty would be sent to the manufacturer or to the designated warranty repair facility by material. Upon completion of such repair, the unit is returned to material with a serviceable tag then returned to stores for future use as required. On certain occasions, determined by the airline and the circumstances, a unit may be removed from an aircraft by the line or hangar maintenance personnel, sent to the appropriate shop for repair, and returned to the aircraft for reinstallation.

Types of Shops

There are two types of shop maintenance activities in an airline maintenance organization. One type is the shop function that is related to hangar maintenance on aircraft in heavy check. These support shops include such special skills and activities as working with sheet metal, composite material, and aircraft interiors. The work they do is primarily in support of out of service aircraft, although some support is given to line maintenance as needed.

The other types of maintenance support and overhaul shops involve support for the specialized equipment on the aircraft, such as engines, avionics, and hydraulic and pneumatic systems. The work performed in these shops is on equipment that has been removed from the aircraft during line or hangar maintenance operations.

Sheet metal shop

The shop normally handles all types of sheet metal work, which can include working with aluminum, steel, composites, honeycomb, and other material as needed. The sheet metal shop repairs any kind of damage to the aircraft skin, structures, fuselage, and wings.

While an aircraft is in "C" or "D" check, the sheet metal shop normally works on modifications, corrosion problems, and previously deferred maintenance items requiring sheet metal or composite type work, such as minor damages, scratches, and repairs using the structure repair manual (SRM). The PP&C normally assigns all work prior to aircraft arriving for its "C" check, and under the PP&C, the sheet metal shop performs ADs, SBs, and EOs, as well as addressing discrepancies found during routine, nonroutine, and schedule work. This shop also supports any unscheduled maintenance needed for line operation.

During downtime, the sheet metal shop works on making the complex templates that will be needed later for repairs and overhauls. They also repair

composite panels that have been removed from previous aircraft for repair due to cracking or minor damages and that will be ready to be placed in the next aircraft if needed.

Aircraft interior shop

The aircraft interior shop repairs, fabricates, and overhauls anything that is inside the aircraft. This includes removing and overhauling passenger and flight crew seats; removing and overhauling aircraft galley and gallery areas, and beverage serving carts; and overhauling the entire aircraft lavatories. They install new wall covering, wall bumpers, side panels, and overhead panels.

The interior shop removes and replaces cabin windows due to scratches and dents and the cockpit windshield and side windows. Special attention is required while removing and installing cockpit windows due to the torque requirements of the nuts and bolts and sealants. After window installations, the aircraft must be pressurized to make sure there are no pressure leaks. The interior shop also paints aircraft inside and out. Interior paint is applied to overhead panels and overhead bins. Painting the aircraft exterior is a very big and difficult task, and there is no room for error.

Engine shop

The engine shop is the largest shop in terms of space requirements. Besides the shop area for working on small parts (bench work), the engine shop also needs an area for engine buildup (EBU) activities. This is where certain components, such as the fuel pump, fuel lines, generators, ignition igniters, engine mounts, and other components, are added to a basic engine to configure it for a given model aircraft for a specific position on the airplane (i.e., right, left, center, or wing position 1, 2, 3, or 4). This effort requires a suitable engine work stand for holding the engine while the EBU process is underway. The EBU activity is done off-aircraft, minimizing the time required for an engine change, and it results in shorter downtime for the aircraft. This is known as the quick engine change (QEC) process.

The engine shop also performs work and inspection on turbine accessories and any auxiliary power units (APU). APUs are small engines normally located at the tail end of aircraft, providing power while the aircraft is parked.

It is also the engine shop's function to remove oil and fuel lines and generator sensors, and perform boroscope inspection of engines removed from aircraft prior to sending them to overhaul. The engine shop normally follows the engine removal and installation parts inventory checklist, which shows a detailed list of part numbers and serial numbers of on and off parts and serviceable tags information. This includes the aircraft "N" registration number for tracking purposes due to the service life of the part(s) installed.

The engine shop also requires an engine run-up area situated away from the main facility (for noise reasons) to allow ground testing of engines mounted on

the aircraft before or after maintenance. A large sound barrier (baffle) structure is part of this engine run-up area. For airlines with a mixed fleet, there may be separate engine shops within the engine facility for different models; however, some facilities may be combined.

Not all airlines have engine shops like the ones previously mentioned; depending on the airlines and their lesser agreements with the aircraft owner or the aircraft engine manufacturers, the airline may remove and install pre-QEC engines. The off engine from the aircraft is sent back to an aircraft leasing company or the engine manufacturer for overhaul.

Avionics shop

Avionics refers to a wide assortment of systems used in aviation that include both electrical and electronics systems. The avionics shops can take on a variety of configurations depending on many factors. There may be a separate electrical shop that addresses electrical system components only, such as motors, generators, power distribution systems, or power buses. The electronics systems, which include radios, navigation system, computers, inside telephone (PA announcement system), media, flight deck instruments, and control units of all types, will be handled by various specialty shops in a large airline. Avionics repair shops will have similar mockups of aircraft systems, and after a repair, a part can be tested prior to being installed on aircraft. Avionics personnel also repair engine harnesses, which can be very tedious due to the number of wires located in a bundle.

If there are any new modifications, new avionics systems to install, or a need for wires to be run within the aircraft structures, “C” and “D” checks are the best time to do so, since all the aircraft side panels, ceiling panels, flight deck computer racks, and instrument panels are removed for inspection and repairs. Avionics technicians must be sophisticated troubleshooters due to the complexity of the equipment they use to diagnose navigations and radio communications errors, and it is their job to find the problem that is causing a system to malfunction.

Instruments, both conventional electromechanical instruments and electronic or *glass cockpit* displays, will be handled by the appropriately skilled technicians either in a single instrument shop or in separate shops for each of the two types mentioned. Conventional instruments would be flap position indicators, aircraft attitude indicators, magnetic compasses, and any other galvanometer-type instruments. The glass cockpit instruments, more correctly referred to as *displays*, include CRT versions of the above instruments. In modern airliners, the same display units can sometimes be used for an attitude display indicator (ADI), as well as the horizontal situation indicator (HSI), which shows a map of the flight plan with waypoints and other information. Other displays may use liquid crystal display (LCD) panels. These electronic displays are more the domain of the electronics shop than the instruments shop, however.

Ground Support Equipment Shop (GSE)

The ground support equipment shop is one of the busiest shops because modern commercial aircraft require a considerable amount of tooling and equipment to support maintenance operation activities.

Support shop work, while in support of all aircraft, can be done on or off the aircraft; but since it is usually extensive in nature, it is normally done while the aircraft is out of service. Thus, support shops normally are part of the hangar maintenance function.

Hangar support shops consist of various specialties. They perform work to refurbish or repair aircraft panels, surfaces, and cowlings made of sheet metal and composite materials. There will also be a fabrics and interiors shop for the repair and refurbishment of aircraft interiors. Aircraft seats, both passenger and crew, will be removed, installed, and repaired by a seat shop which may be part of or separate from the interiors shop. Other shops associated with the hangar activity would be those doing work in welding (gas, electric, and heliarc).

The work performed by these shops is not directly a part of the scheduled maintenance program and is not specified in the MRB document or the airline's Ops Specs as routine or nonroutine maintenance but work will be required on the various components mentioned above from time to time either by nonroutine work card or by SB, AD, or EO. Additional work for these shops may come from the GSE and facilities requirements whenever such special skills are needed to repair these units. Airlines may also perform work in these support shops for other airlines or fixed-base operators.

Ground Support Equipment

Modern commercial aircraft require a considerable amount of tools and equipment to support the maintenance and operations activities. In addition to the tools and test sets used by mechanics and technicians for normal maintenance, there is a vast array of equipment that comes under the special heading of ground support equipment. There are also special tools and jigs for maintenance activities that are designed for one type of aircraft only; other special tools and jigs are usable on several types of aircraft.

Ground support equipment is defined as "that equipment required to support the operation and maintenance of the aircraft and all its airborne equipment."[1] This GSE includes an extensive variety of equipment ranging from simple jacks and stands to million dollar towbarless towing vehicles. For the sake of discussion, we can divide GSE into two broad categories: (*a*) equipment to support the servicing and handling of operational aircraft while engaged in flight turnaround and ground movement activities; and (*b*) equipment used to facilitate maintenance whether at turnaround or during scheduled or unscheduled downtime.

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[1]Air Transport Association of America (ATA); *Common Support Data Dictionary* (CSDD); revision 2001.1.

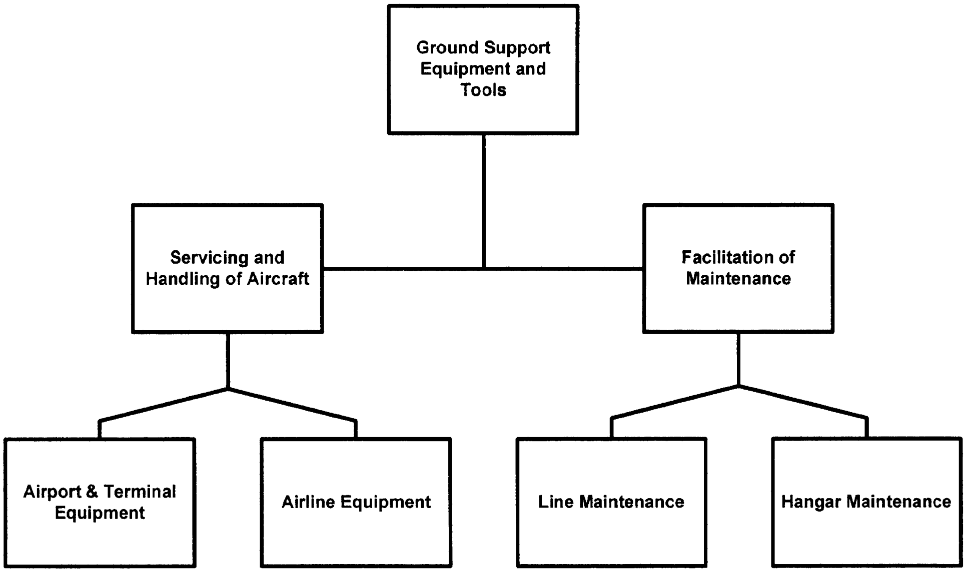

Figure 14-1 Ground support equipment categories.

The first category, servicing and handling equipment, can be further divided into GSE that is owned and operated by the airport authority or terminal operator and that owned by the airline itself. The second category, maintenance equipment, includes equipment that may be used on the flight line, in the hangar, or shared by both activities. This breakdown is shown in Fig. 14-1. Table 14-1 is a list of typical ground support equipment used for handling, servicing, and maintaining aircraft. The table identifies typical ownership and usage of the GSE.[2]

To maximize in-service reliability and profitability, operators must procure GSE and tooling appropriate for their aircraft when a new model is being incorporated into the fleet. Tugs, tows, towbars, and other special tools and fixtures are sometimes mated to specific aircraft models. Other GSE and tooling can be used on more than one type of aircraft. The GSE and facilities organization must work with engineering at the outset, whenever the purchase or lease of new aircraft is considered, to determine what existing equipment and tools (if any) can be used with the new model and to determine what additional equipment and tools must be ordered specifically for the new model. This activity should be done at least 9 to 12 months prior to delivery of the first aircraft so that these tools and equipment will be available when the aircraft arrives.

[2]This discussion, as well as Fig. 14-1 and Table 14-1, are based on the assumption that all maintenance is done by the airline. If any maintenance is outsourced to a third party, some of the GSE listed may belong to that third-party organization.

TABLE 14-1 List of Ground Support Equipment (GSE) Items

Name of GSE item	Airport owned	Airline owned	Usage (L, H, B)*	Handling & servicing	Maintenance
Air start units	X	L	X		
APU cradles	X	B		X	
Axle jacks	X	B		X	
Baggage carts	X	L	X		
Baggage loaders (at A/C)		X	L	X	
Battery charging equipment		X	B		X
Boarding wheelchairs		X	L	X	
Cargo container/pallet handling		X	L	X	
Cargo trailers	X	L	X		
Communications equipment		X	B	X	X
Deicing equipment (motorized & stationary)	X		L	X	
Diesel powered ground power units		X	B	X	X
Fixed jacks	X	B		X	
Hydraulic oil fill carts & couplings		X	B		X
Hydraulic test carts		X	B		X
Lavatory service components		X	B	X	
Lifting equipment: cranes & platforms		X	B		X
Nitrogen servicing equipment		X	B		X
Oxygen servicing equipment		X	B		X
Passenger loading bridges	X		L	X	
Passenger loading stairs (powered & unpowered)	X	X	L	X	
Pneumatic air start units, couplings & accessories		X	B	X	X
Potable water service components		X	B	X	
Power supplies: 28 vdc & 400 Hertz		X	B	X	X
Recovery jacks	X	L		X	
Refueling trucks X	X	L	X		
Snow removal equipment (ramp & runway)	X		L	X	
Specialized maintenance tools		X	B		X
Stands and scaffolding (many variations)		X	B	X	X
Thrust reverser dollies		X	B		X
Towbarless A/C handling tractors	X	X	L	X	X
Towbars	X	L	X	X	
Towing tractors (gas, diesel, electric)	X	X	B	X	X
Variable jacks	X	B		X	
Weigh systems	X	L		X	
Wheel and tire build-up fixtures		X	B		X
Wheel and tire dollies		X	B		X
Wheel chocks	X	B	X	X	

*L: line; H: hangar; B: both line and hangar.

Selection of GSE and tooling is related to a number of variables: (*a*) the type and level of maintenance to be performed by the airline; (*b*) the number of line stations to be supported (multiple units may be required); (*c*) the number of ramp operations to be accommodated (individual or simultaneous use requirements); (*d*) the extent of overhaul work to be done by the operator; and (*e*) coordination with other units for borrowed equipment or contract work to be done (by or for your airline).

Because of the complexity and variety of this equipment, it is usually handled by a separate maintenance activity within the airline. For small to midsized airlines, the GSE is handled by a group attached to the hangar maintenance organization and is often housed in the same hangar as other overhaul and support shops. In larger airlines, GSE may have a separate manager or director under M&E and may be housed in its own hangar. Either way it may be organized, its job is to support maintenance both on the flight line and in the hangar.

Because of the size and quantity of ground support equipment, it is often stored outside the hangar in a designated area on the ramp near the operator's facilities. Some smaller equipment would be stored in the hangar. Special tools and fixtures may be stored in the hangar tool shed.

The GSE and facilities group in our typical midsized airline is also responsible for general maintenance and upkeep of all GSE, as well as the general maintenance and upkeep of all buildings and facilities used by the M&E organization.

Mechanical shops

The mechanical component shop can also be separated or combined depending upon airline size and requirements. These shops would include hydraulic systems and components, pneumatic systems and components (heat, air), oxygen systems, and flight control surfaces. The battery shop is also part of the mechanical shop, where maintenance personnel repair, store, and charge aircraft batteries. The wheel, tire, and brake shop has responsibility for various actions relating to the aircraft: (*a*) the repair, assembly, and disassembly of aircraft wheels; (*b*) the repair, servicing, and retreading of aircraft tires; and (*c*) adjustment and placement of aircraft brakes. Again, these activities may be performed in one or several shops depending on the amount of work and the complexity of the fleet.

Outsourcing of Shop Maintenance Work

As with line and hangar maintenance, some or all of the shop maintenance at a given airline can be outsourced to other airlines or to third-party maintenance organizations. In the case of partial outsourcing, the director of overhaul shops is responsible for coordinating these activities into the overall airline maintenance plan. If all shop maintenance is done by outside contractors, the overhaul shops directorate would not exist at the airline.

However, to ensure that work is done within the airline's schedule and maintenance plan, someone in the aircraft maintenance directorate of the M&E organization must be designated as the overhaul shop maintenance coordinator. Quality assurance identifies the standards to which these outside contractors will be held (see Chap. 16).

Operation of Overhaul Shops

Work on a flight line is hectic at times and subject to flight schedules, maintenance emergencies, foul weather, and the ever-irritating "time limitations."

Hangar work may be less hectic with more time to accomplish each job, but there is still a time limitation and other pressures. In shop maintenance, however, the pressures of time and schedule are somewhat lessened by the nature of the shop operation.

Items come in for servicing, repair, or overhaul and are addressed, usually by specialists in the type of equipment or system involved. Some of the basic troubleshooting has already been done to indicate such-and-such a unit is bad and has to be replaced. This done, the mechanic turns the errant item into material and draws a good one for installation. Material, then, sends the properly tagged incoming unit to the appropriate shop. The shop mechanic or technician then uses his or her standard bench check procedures to determine the problem, make the necessary repairs, and perform some check to ensure that the job has been completed successfully. Once maintenance is completed and the proper paperwork filled out and attached, the serviceable unit is sent back to material for placement in stores for reissue when needed.

Each maintenance shop will have a work area and a storage area with adequate separation of serviceable, unserviceable, and discarded units. Usually there will be a spare parts area, maintained by material, for the small parts needed for work. Again, proximity of these areas to the work area minimizes the time a mechanic spends in "parts chasing." Of course, each shop will be equipped with the necessary tools, work benches, test stands, and test equipment for the type of equipment to be worked on. Appropriate safety equipment for the work performed and hazardous materials handled (if any) should be readily available and accessible to the employees. Suitable office space will be provided for administrative and management functions.

The overhaul shops generally work a standard shift, with or without overtime; night shift and weekend work depends on the airline and its workload. The pace may be slower than on line or in hangar, but short turnaround for maintenance or mean time to repair (MTTR), is still important. The number of items held in stock (see Chap. 15) is based not only on the failure rate for the fleet, but also on the amount of time it takes to pass the repairable item through maintenance. The sequence goes like this: (*a*) remove unit from the aircraft; (*b*) send the unit to material for replacement; (*c*) route unit to the repair facility (in-house or third party); (*d*) return serviceable unit to stores for reissue.

Shop Data Collection

The airline's maintenance reliability program, discussed in detail in Chap. 18, involves many data collection tasks throughout the M&E activity. One very important source of such data is the overhaul shops. While flight line and hangar reports provide information on systems and components, the shop data provide useful information on internal components of equipment and subsystems that contribute to the on-aircraft failures and write-ups. These shop data collection efforts are submitted through shop tear-down reports that identify servicing, repair, and overhaul actions taken, as well as the parts and supplies used in that maintenance work. These components are then tracked by reliability to determine if there is an unnecessarily high failure rate that should be of concern to the airline or the equipment manufacturer.

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Chapter 15

Material Support

Organization and Function of Material

Material is one of the key units within an airline's maintenance and engineering organization. It is the one that spends the most money and is, therefore, under scrutiny by the airline's higher management as well as the M&E management. The high-level concern for operating costs is at the root of one rather prominent controversy in the M&E area. That controversy is "who should have control of material: maintenance or finance?"

Our recommendation, and one that has proven to be quite successful in a great many airlines throughout the world, both large and small, is that material should be part of the M&E organization. If finance, accounting, or any other unit outside maintenance is in control, there is a fear that the lack of (or at least a lessened) knowledge of maintenance and its idiosyncrasies could result in poor decisions—such things as how much to spend; what parts to buy and how much to stock; determining what constitutes a suitable substitute part; and so forth—that affect the quality of maintenance.

The other side of the argument is that maintenance would not have a full understanding of budgets and costs and would spend too much money on parts or have too many assets tied up in "rainy day" stock levels. Unfortunately, both situations are possible and both situations do exist in today's airlines, both foreign and domestic. And the discussion goes on without resolution. What we need to emphasize here, however, is that both of these extremes should be avoided.

People in the performing arts (symphonies, ballet companies, acting groups, etc.) have an adage that they give as a guideline to their boards of directors: "Artistic decisions should not be made by nonartistic people." In other words, the board's job is to take care of the business end, not the artistic end, of the activity. We need only modify this slightly for aviation: "Technical decisions should not be made by nontechnical people." This is the philosophy behind the need for management with technical backgrounds in the M&E field that we discussed

in Chap. 7. Mechanics, engineers, and technical management in M&E are aware of the changing requirements of aging equipment and the increasing need for spare parts with age. These working experts are also aware, from experience, of what constitutes a reasonable substitute for a given part and what does not, even though the specifications for both units are within limits. The past experiences of these people are more conducive to addressing the goals of M&E than the experience of the finance and administration people.

Our recommendation, then, is that the material support effort be an integral part of the maintenance and engineering organization with oversight by accounting and finance for expenditures. With that said, we move on to the functions of material. Briefly, these are (*a*) to provide parts and supplies for all aspects of the M&E operation; (*b*) to maintain adequate supplies of these items on hand and in convenient locations for quick access by maintenance; and (*c*) to provide adequate support to the maintenance organization within reasonable budget constraints.

Material Management

Material, inventory, stores, and logistics management's primary function is to understand the logistics and scope of aviation inventory management. These responsibilities include concerns about replenishment of stored parts, cost of inventory, forecasting of new and in-house available inventory, realistic and physical space of the inventory, replenishment of minimum and maximum, repair parts, returns and defective parts, bogus parts, knowing the supply network and its demands, and the ongoing process of utilizing aircraft parts. Material and other items needed on a daily basis require a sophisticated maintenance support operation.

Stores management has continuous contact with the aircraft manufacturer, parts overhaul vendors, aircraft part suppliers, and vendors of hardware and software. They determine the inventory needed based on fleet size, parts utilization, parts reliability, and a vendor's repair capability and turnaround time. The managers set targets and goals that are normally achievable to balance the need for product availability. Material management positions may vary depending on the airline's operations. We will briefly describe the areas of inventory control, stores, purchasing, and shipping and receiving.

Inventory control

Inventory control refers to a continual effort to supervise the supply, storage, and accessibility of aircraft parts. It is the inventory control's responsibility to ensure that all necessary parts and supplies are on hand and available at selected locations throughout M&E. Their purpose is to support all maintenance activities by having an adequate supply of parts and parts storage, not being over- or undersupplied, and avoiding any aircraft on the ground (AOG). Inventory control also monitors raw stock material, monitors components repair orders in

progress, keeps an accurate count of stock onsite, and assures the availability of airworthy parts. The monitoring of the inventory system helps to keep costs low, which means that when the supply of a part goes to its minimum target the part is ordered before it drops to a critical level if AOG will cost more than the normal price of the part.

The airline's logistic management and inventory control strives very hard to maintain a good balance since aircraft parts are expensive. By executing a strategy of a fully automated integrated software system to have real-time inventory availability, and with lean inventory control and management, an airline can reach its goal of saving money by renegotiating vendor, supplier, and AOG contracts by having minimum stock, the shortest turnaround time for repaired components, a vendor stocking system, purchasing solutions, a new generation of inventory reorder and supply processes, and minimal or no AOG fees.

Stores

Stores is responsible for issuing parts to and exchanging parts with the mechanics. Stores is also responsible for delivering parts to the work centers as necessary and ensuring that parts and supplies that require special storage and handling are properly managed. Stores also routes repairable units to the appropriate maintenance shop.

Purchasing

Purchasing is responsible for the procurement of all parts and supplies used by M&E. They deal mainly with suppliers and manufacturers, attending to such things as specifications, costs, delivery, etc. Essentially, purchasing has primary budget control in material and works closely with finance on expenditures and budget matters.

Purchasing and inventory control work together to avoid AOG situations because the part(s) purchased in the AOG situation will be expensive. The purchasing and stores departments work together on aircraft parts purchases, warranty, and modifications (discussed later in this chapter) due to cost and budgets.

Shipping and receiving

The shipping and receiving area is one of the busiest places in aviation stores and logistics; not only do stores receive parts for themselves and for maintenance, they also receive courier deliveries for the entire airline operation located at a main hub. Shipping and receiving normally handle all packing and unpacking of parts and supplies coming into and out of the airline. They also maintain the ability to handle any inspections that might be needed relative to the shipment or receipt of goods.

Shipping and receiving require qualified personnel and management since they also send and receive dangerous goods. It is their responsibility to make sure that the container in which dangerous goods will be shipped is sufficient

and the paperwork is filled out correctly according to the company's dangerous goods policy. They must know the segregation process for items such as flammable, corrosive, and temperature-sensitive items as required by the manufacturer's material safety data sheet (MSDS).

The material organization varies depending on the airline's structure, size, and the availability of qualified personnel. Some activities may be combined for departmental convenience. In the following sections, we will discuss various functions of the material organization.

Support Functions of Material

These support functions can be stated briefly as (*a*) ordering; (*b*) storing; (*c*) issuing; (*d*) controlling; and (*e*) handling of parts and supplies. The first four involve mainly parts and supplies, while the last (handling) involves the movement of parts between the various facilities concerned. We will address these items separately.

Parts ordering

Ordering of parts includes the initial provisioning when new equipment and systems become part of the fleet. It also includes reordering whenever supplies on hand drop below a certain level (more on this later). The initial provisioning is established at the outset by a recommended spare parts list prepared by the airframe manufacturer. This list is based on the manufacturer's recommendations and on fleet-wide experience of those airlines already using the equipment in similar operations.

Based on initial provisioning and on the airline's ongoing experience after entering service with the model, changes in the stock levels and quantities held will be inevitable. The components on hand and the quantity needed for day-to-day operation is determined by a number of variables, and these will differ from one operation to the next. The flight schedule—number of hours and cycles flown, stage length, flight environment—as well as the number of aircraft in the fleet, affect the usage rate of components and thus the number of parts needed in stock to support the maintenance and operations. The location of where maintenance is done may also affect stock levels in that extra parts and supplies may be needed at several line stations to facilitate maintenance.

Also, the quality of maintenance—the abilities and skills of the maintenance staff—may also affect the need for spare parts and assemblies. A continual perusal of stock usage by the material section is necessary to optimize the stock levels on hand. This usage rate, of course, affects the frequency at which parts are purchased; that is, the reorder point. This requires the establishment of usage rate and reorder point data for all parts and supplies used. For repairable items, the lead time for repair action (i.e., the time required to send the item to the maintenance shop, repair it, and return it to stores for reissue) could affect both the required stock levels and the reorder point, since available stock would be subject to use in other aircraft maintenance actions during this repair cycle.

Finally, the effect of quantity discounts from certain suppliers on specific items may determine a more economical reorder point for those items. This, however, must be reconciled with the costs of storage of the additional material purchased.

Parts storage

Storing of parts is the next material function to consider. There are two concepts here: (*a*) putting every part where it can readily be located and issued when needed; and (*b*) storing certain parts under specified conditions. The latter category includes proper storage of fuels, lubricants, paints, oils, and other flammable or perishable items. Oxygen bottles and the tools used on oxygen systems require special handling and storage. All of this proper storage is a material function.

The basic or standard storage arrangement is the traditional array of storage shelves or bins, marked by a coordinate system so that every part has a location and each location is easily found. This, most often, is a "row-shelf-bin" locator grid of the operator's choosing. For example, part number 1234-5678-C could be located in D-2-14; i.e., row D, shelf 2, bin number 14. Here the rows of shelves are lettered: "A, B, C ...." The shelves, numbered from top to bottom, are "1, 2, 3 ...." And finally, each bin (on each shelf) is numbered consecutively from left to right: "1, 2, 3 ...." Any similar system can be used.

This location system might be further stratified by aircraft model. While many components, subassemblies, and units may be used on several model aircraft, many are unique to one model. Most airlines with mixed fleets have separate parts bins for each model to allow separate cost information to be kept by model. Any need to issue a part from one model's stores for use on another model will be handled through the paperwork process by material personnel. This would include computer records to show availability and location of parts.

Additional storage facilities would be necessary for specific operations. To facilitate maintenance and minimize the time required by maintenance for parts chasing, for example, spare parts could be available at line stations to support limited maintenance in addition to the normal turnaround maintenance.

Stores facilities and storage must be thought out and must function as required. The stores facility is required to handle expensive and delicate parts, and proper storage must be available due to the sensitive nature of some parts, some of which need a refrigerated or air-conditioned environment. The stores department requires lots of space and volume due to the amount of shelving and bins needed to keep parts organized and within easy reach when they are needed by AMT. Stores facility areas are subdivided into sections for the convenience of stores personnel:

- Quarantine area
- Flammable, hazmat, and refrigeration area
- Serviceable, nonserviceable, and red-tag parts area
- Parts issue and return area
- Parts receiving inspection area

Parts issue

Issuing parts to mechanics is another major function of material. Items such as bolts, nuts, and other common hardware are better stored in open, accessible bins near the work location so that the mechanics have easy access. For other items, such as black boxes, assemblies, and other major items, it is better for all concerned to have “parts windows” or other facilities where material personnel can issue parts to mechanics, as needed, and attend to the proper handling of the parts tags and other important paper and computer work.

Some of these parts, of course, are repairable and the mechanic is required to “give one to get one.” This exchange is handled by the material control clerk who also ensures that the maintenance tags on both units are properly filled out (by the mechanic) and that the unit turned in is routed to the appropriate repair facility for rework. For those items that are not repairable, material is responsible for discarding the unit.

This parts issue window should be as close to the work center as possible to minimize parts chasing time for mechanics. In some airlines, the necessary parts can be ordered through a computer terminal at the work site and delivered to the mechanic by material (see Controlling Parts later in this chapter). No matter what method of issue is used, it is the responsibility of material to update the computer “quantity on hand” information each time a part is drawn or exchanged. In the case of repairable parts, material (through the computer) must also keep track of where the part is at all times (shop, stores, in transit, on aircraft).

Another useful service offered by material is the buildup of kits for certain maintenance actions. To remove and replace some items, certain hardware is needed in addition to the primary unit and its accessories. Very often removed hardware, “O” rings, gaskets, and the like, are not reusable. For certain SB or AD actions, additional components (harnesses, brackets, hardware) are needed for completion. It is a boon to maintenance when material can develop kits of all these necessary parts and issue them together as a package. These kits can be developed with the assistance of maintenance or engineering personnel. Very often, SB and AD modifications are available to the airline in kit form supplied by the airframe manufacturer or component vendor.

Some airlines aid their line station maintenance activities by maintaining flyaway kits (FAKs) on board the aircraft. These kits contain items that might likely be needed for turnaround maintenance and servicing at stations where maintenance crews are available but such supplies are not. Items such as tires, engine oil, and other common components may be included.

The purpose of the FAK is to provide these items when needed, but the extra weight on board the aircraft may be a limiting factor on how much is carried. The units carried in the FAK should be based on past experience of the aircraft’s out-of-service history and some of minimum equipment list (MEL) parts requirements due to maintenance. The FAK content list documents the parts inside the FAK and is monitored by the aircraft maintenance department. In addition to monitoring the content of the FAK, material must be replaced to ensure

that a complete kit is always on board the aircraft. Monitoring the FAK should be part of the task card bundle when the aircraft is sent for an “A” check and for every subsequent “A” check afterward. There should be a log associated with the FAK to identify missing content or pending orders and usage of the part.

Some airlines use FAKs and some do not. It is a matter of individual preference. Often, however, airlines flying ETOPS will use FAKs to facilitate maintenance activities to avoid downgrading an ETOPS flight to a lesser diversion time (180 to 120 minutes) or to a non-ETOPS flight. Such downgrades usually mean longer flight lengths and subsequently generate problems with flight connections for the passengers. The FAK becomes quite important in these situations.

Parts control

Controlling parts cover a variety of activities. We have already mentioned identification of storage locations for all parts and the need for tracking certain components such as repairables through their processing. We have also mentioned the need for material to deliver parts and supplies to maintenance work centers to minimize or eliminate the time spent by maintenance personnel in parts chasing. Additional personnel in material for this purpose are a great help to the maintenance effort.

It is also necessary to track flight hours, flight cycles, calendar time, and location of parts that are designated as “time-limited” parts. These are serial-numbered parts that require removal from service before a specified interval has elapsed. These parts accrue time or cycles only while in service. Therefore, the aircraft on which they are mounted must be known, and its time and/or cycles must be tallied against the part. If the component is removed before its time limit is reached, it can be repaired, restored, or completely overhauled as necessary with or without zeroing out the time (details on zeroing out time-limited items are discussed in Chap. 17). If the item is placed in stores for reuse on another aircraft after this action has been completed, its time and cycle tally will begin again (at the previous level or at zero) as soon as it is reinstalled on an aircraft. Material, through the computer system, will be responsible for tracking time-limited parts.

This controlling of parts going to and from internal maintenance organizations, vendors, or outside repair contractors and warranty holders is the primary control function of material, but there is an additional control requirement. Parts are occasionally removed from larger assemblies (officially authorized or not) to facilitate line or hangar maintenance efforts and to quickly return an operating aircraft to service. While this expedites the maintenance and minimizes the effect on flight schedules, the negative side is an adverse effect on maintenance and material costs and efforts later on.

This cannibalization renders the major assembly (the one robbed) unusable or requiring maintenance. If material authorizes this cannibalization to expedite line or hangar maintenance, it must initiate reorder and subsequent repair of the robbed unit. If such cannibalization is not authorized by material, then

maintenance is responsible for the robbing and thus for the reordering and subsequent maintenance action on the robbed assembly.

One of the parts control processes employed by many airlines is the "parts quarantine" area. This area is used to separate parts removed from aircraft until it can be determined if repair is necessary or if a unit can be returned to stores for reissue. If the replacement part fixes the problem, it is assumed that the part in quarantine is in need of repair and material routes it to the appropriate repair facility. If the replacement unit does not resolve the problem, then the one in quarantine is assumed to be okay and is returned to stores. This is not always the best approach, however. Some airlines will return the quarantined part to the shop for checkout before returning it to stores to ensure serviceability.

This quarantine activity is an integral part of troubleshooting and should be monitored by QA and reliability to determine if the troubleshooting skills of maintenance personnel are in question. See the no fault found (NFF) process discussed in Appendix C.

Parts handling

Handling of parts and supplies is sometimes referred to as "shipping and receiving." However, this latter term does not tell the whole story. Handling begins with receipt of parts and supplies and involves, in some cases, an incoming inspection by quality control to ensure that the part is the correct one: part number, serial number if applicable, modification status, serviceability, expiration date (if applicable), and so forth. Physical condition is also examined. This can be done by QC or by someone in material designated by QC to perform such inspections (see Chap. 17). After receipt and incoming inspection, the parts are distributed to the proper place—stores, hangar, line, shops, etc.—and computer records are updated accordingly.

During day-to-day operations, material is issuing parts to mechanics and, in some cases, accepting an exchange part. This exchange requires that material, upon checking for proper tagging by the mechanic, route the part to the appropriate shop, vendor, or contractor for repairs. Upon return of the repaired part, material will check the tag for correctness, update the computer record, and route the part to stores.

One function that comes under this topic of handling of parts, a rather important financial consideration that airlines sometimes overlook, is the handling of warranty repairs. It is a fact that many aircraft components are expensive and that maintenance costs are also high. It is very important, then, for an airline to take advantage of any warranty claims it may have to avoid unnecessary costs (see objective 5 in Chap. 3).

Whenever a part is turned in to material in exchange for a serviceable one, material's first responsibility is to check the warranty status of the incoming part. If it is still under warranty, it is processed and shipped to the warranty holder (or designated repair facility) for repairs. If the part is no longer covered by warranty, then it will be sent to the appropriate in-house or third-party facility for repair.

If parts are shipped out for warranty repair, they sometimes incur longer lead times before being returned to stores. In this case, the airline has two options. The usual one is to increase the stock level or reorder point in order to accommodate this extension. In some cases, however, airlines that have the capability to do the repair work, enter into a contract with the warranty holder to perform the repair work themselves. This not only reduces the processing time, but it also provides the airline with additional revenue for the contract work.

Other Material Functions

The five functions previously described are basic material department functions that directly affect the maintenance department. There are some other functions and activities in stores and material's day-to-day operation for their own support or maintenance support activity. These items are briefly discussed in the following sections.

Obsolete parts

Obsolete parts are parts that are no longer wanted or required due to component upgrade or change. This also occurs when an airline upgrades its fleet and renders parts useless. These now obsolete parts are still good and can be sold to another airline or facility, which may be able to upgrade these parts or components. Inventory management must find buyers for obsolete parts in a timely manner to secure funds to purchase new parts and to make necessary space in parts storage. These obsolete parts must be scrapped if a buyer cannot be found in a prescribed period of time.

Parts receiving—quality control

Quality control (QC) plays a crucial role in the inspection process, especially when receiving parts that are newly purchased, returning from repair, or loaned by another airline. It is QC's function to review new parts and paperwork to make sure they are good. A repaired part normally comes from a company-approved vendor who has been selected to repair parts. When the part returns from the vendor, the QC inspector inspects the part and the accompanying paperwork, which gives a complete tear-down report describing the problem, what was done to fix it, and what kind of test was performed to determine its airworthiness so it can be reinstalled. After reviewing all information, the receiving inspector signs or stamps the paperwork, which means the part can be placed on a shelf for immediate or later use.

Loaner parts—bogus parts

Airlines that have the same type of fleet aircraft sometimes have loaner parts contracts or agreements with one another. When one of the airlines is in need of a part that the other airline has, it can borrow the part for its own aircraft. These types of parts are known as *loaner parts*. The airline in possession of the

needed part sends it to the needy airline. When the other airline receives the part, it generates its own paperwork indicating that the part is a loaner and that it is good enough to be used on its fleet. This paperwork helps the AMT and the stores departments of both airlines to keep track of the loaned part. When the borrowing airline receives its own part, they will remove the loaned part from their aircraft and return it to the airline from whom they borrowed it.

Bogus parts have been circulating in aviation and have been estimated to cost millions of dollars. *Bogus parts* are unapproved parts which could be counterfeit, stolen, production overruns sold unauthorized, parts which may have exceeded their time limits, or fraudulently marked parts which are untraceable and lack any type of paperwork, and thus do not have adequate credentials. For example, engine mount bolts are made of a special material to hold an aircraft engine. Bogus parts are often made of some lesser material which can fail and damage an aircraft. When an aircraft manufacturer makes an aircraft or the parts needed for an aircraft system, their engineers spend time examining and testing the materials used for parts to be certain that they will withstand the stresses caused by an aircraft in motion. The bogus parts, which could have been manufactured by anyone with cheap materials of inferior quality, can cause harm to an aircraft or its components which may fail and require replacement more often than legitimate parts. It takes a trained eye to catch these types of parts. The FAA Web site for identifying bogus parts contains the following information on how to identify an unqualified supplier:

- Lowball prices
- Suspiciously fast service
- Lack of data
- Lack of a paper trail

If any one of these situations arises, you should inspect the product, check parts tracking, and inspect the part for visual defects. The penalties for bogus parts in the United States and other countries may include criminal charges and very hefty fines depending on the seriousness of the case.

Once you decide the part is bogus, you must fill out FAA Form 820-11, Suspected Unapproved Parts Notification and send it to your local FAA branch. There is also a hotline created by the FAA for reporting suspected unapproved parts.

Stores—tool calibration program

The tool calibration program is required by the FAA. The FAA requires that the specialized tooling used by aircraft maintenance, such as torque wrenches, multimeters, pitot static boxes, and other specialized tooling items, must go out to be calibrated and tested periodically, depending on the airline's repair station tooling manuals. Specialized tooling is sent out for calibration, and upon their

return, these tools are received and inspected for proper calibration and certification paperwork showing that all the material sent out has been calibrated according to FAA regulations and the company policy.

Stock level adjustments

The initial provisioning of an airline is similar to the initial maintenance program developed for a new aircraft and a new operator (see Chap. 2). Experience of the operator will indicate the need to change this "starting point" over time. The parts required, the quantity needed in stock, and the reorder points will be determined by the actual maintenance activity, and this will vary from airline to airline as well as from route to route within an airline. It could also vary with the seasons and with the quality of maintenance available. None of these variants can be totally controlled by management, but they must be monitored regularly and appropriately addressed. Therefore, it is necessary to have a continual surveillance of parts usage, and adjustments need to be made as necessary. This is a joint effort of the maintenance and material sections and is commensurate with the cost control and budgeting activities.

Shelf life

The shelf life program is monitored by the logistics/stores management and personnel, which defines how long an item may be retained in an airline's stores inventory due to limits based on deterioration and chemical changes. These shelf life dates are also recommended by the manufacturers. It is the responsibility of an airline's stores department to make sure any item does not surpass its intended date and is not used in any aircraft. The company must have a plan for how to dispose off items with expired shelf life, which normally fall under the regulatory requirements of OSHA and the EPA.

There are some storage requirements for shelf life parts, which were discussed previously due to their sensitivity to high temperatures or exposure to the environment and their tendency to combust and corrode so that they must be kept in metal cabinets and be labeled as hazardous material, refrigerant, etc.

Examples of shelf life items follow:

- "O"rings
- Aviation grease
- Paint and paint-related items
- Penetrating oil
- Antiseize products
- Insulating compounds
- Aviation sealants
- Dry-film lubricants

The stores department must perform an inspection monthly or semimonthly to remove any shelf life item(s) that are coming due. The stores department must seek component recertification, and if consumable, they must be scrapped following the company's guidelines. Quality control management and QC inspectors play an important role in the stores department's shelf life program by performing spot audits to determine shelf life items' storage conditions; by reviewing shelf life policy and procedures; and by monitoring stores management's infrastructure, facility, and system for disposing off shelf life items when expired.

Exchanges, warranty, and modification of parts

Part exchanges and warranty work can be very tedious. This activity normally is the responsibility of the purchasing department of stores and logistics. Parts often are exchanged with a vendor to avoid an AOG situation. Stores must be sure that the exchanged part will perform the same as the old part which was sent out and that the integrity of the aircraft system will not be compromised due to part status upgrade or modification. The exchange of parts is common in the aviation industry.

Warranty work will need help from aviation maintenance personnel. Since these AMTs have rejected a part for its intended purpose, it will have a green tag attached to it defining the problem that caused it to be rejected. The airline's stores department must work diligently to avoid any delays in warranty work. This is where the airline's reliability department comes in handy since they monitor all aircraft rotable premature removal of part and system failures, which helps stores explain the malfunction of the part to its repair vendor.

Aircraft parts are modified due to system integration, airworthiness directives (AD), and constant failures, which lead to revisiting the design and its components. Once it is confirmed that a part or component must be modified, the vendor immediately starts the process with the components on hand and repair orders. The airline's parts department starts to send out components for modification or upgrade purposes. Since the installation of an incorrect modification could cause a risk to flight safety, these types of modifications need constant monitoring and communication between the vendor, stores management, and the engineering department. The upgraded or modified part will have the same part number as the old part, but it may have a higher dash number, or an alphabet letter may be added to the end of the part number. Take as an example the modification of a starter generator bearing with the old part number 8260121-2. The new updated part number would be either 8260121-3 or 8260121-2A, which indicates modification being completed as per AD or any other scenario with the proper documentation accompanying the part. Also, the stores department will show an updated or alternate superseded part number as well in their system to avoid giving out an old nonmodified part.

Budgeting efforts

The modern approach to management requires each and every manager to be cognizant of the cost requirements of the organization that he or she commands. If M&E wants full control of material as we suggested in the beginning of this chapter, then M&E must take full responsibility for the costs incurred and the budgeting of the whole activity. This is primarily the responsibility of the director of material, but he or she will (undoubtedly) delegate to each manager the responsibility for his or her own activities. Of course, in the final analysis, accounting and finance at corporate level will maintain oversight of the effort and make the final determination as to budget allocations. After all, accounting and finance also has a boss—the CEO of the airline.

One of the major problems in establishing stock levels is the cost of the items stocked. Some airlines overstock to hedge against running out of an item when it is sorely needed. The result of this overstocking may be to minimize maintenance downtime and subsequent delays and cancellations, but the penalty is having too much money tied up in supplies that are not used, not needed, or in some cases, become out of date or obsolete while sitting on the shelf.

The other extreme embraced by some airlines is to invest very little in spare parts, thus minimizing the amount of money needed to start up and run the airline. The downside here is that the maintenance downtime, as well as the delays and cancellations, tend to increase to the detriment of the flight schedule, passenger satisfaction, and even the quality of maintenance.

Like so many things in the airline industry, budgeting and stock levels both become precarious juggling acts that require skill, dexterity, and perhaps a little luck to carry them off.

Part

IV

Oversight Functions

In Chap. 6, we discussed the CASS requirement of FAA AC 120-16E. The FAA Advisory Circular AC 120-79A provides further details on CASS including various ways to organize the function. In this book, we address the CASS requirement through four oversight organizations. Each function encompasses specific areas of interest that assist the director of maintenance program evaluation (MPE) in these oversight efforts (Fig. IV-1). These units are called (in our structure) quality assurance, quality control, reliability, and safety and are each addressed in a separate chapter (Chaps. 16 through 19).

Quality assurance (QA) is the organization responsible for carrying out certain administrative actions for the director of MPE and for conducting annual audits of all M&E organizations, including those outside the airline that provide work or other assistance to the airline. Quality control (QC) looks specifically at maintenance practices and the actual conduct of the maintenance work. They are also responsible for special inspections and the calibration of tools and test equipment. The reliability organization has the responsibility of monitoring failure rates, removals, etc. of aircraft systems and components to measure the effectiveness of the overall maintenance program. If any deficiencies are noted, reliability turns the problem over to engineering for investigation and development of an adequate solution. The remaining oversight function is safety. The safety organization looks specifically at the health and safety issues involved in the M&E activities. This means establishing the health and safety program and overseeing its implementation.

Each chapter in Part IV is written to discuss a particular oversight function independently. The airline's CASS, however, should integrate the activities on all the oversight units to fully monitor the airline maintenance and inspection program. An airline with an FAA-approved reliability program will usually have a board established to address problems uncovered during these activities. This board, made

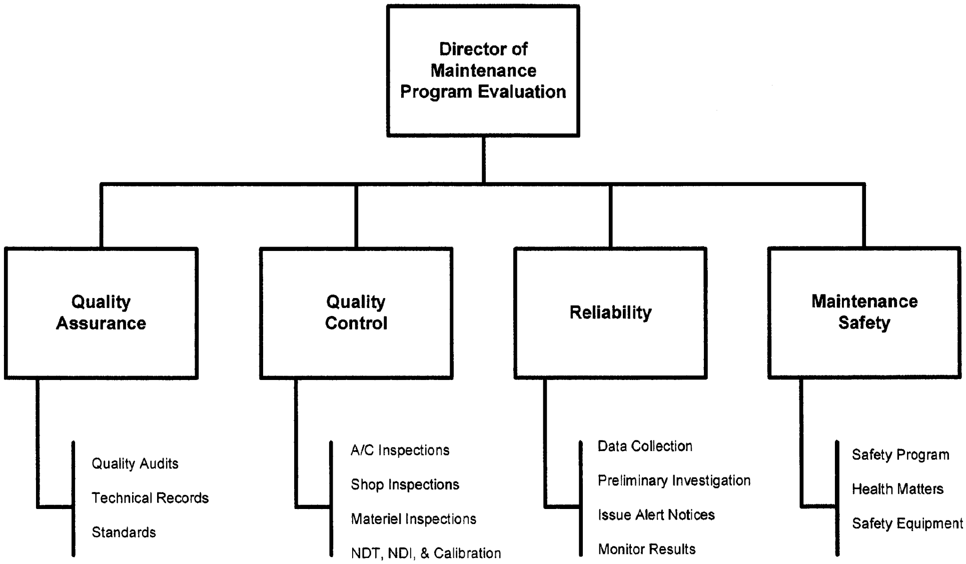

Figure IV-1 Organizational chart for maintenance program evaluation.

up of representatives of all the M&E units, reviews the program, as well as the problem analysis and solution for problems detected through the reliability program and is usually called the Reliability Control Board (RCB).

To address and subsequently resolve any problems or issues related to findings of any of the other oversight activities, the airline should establish a Maintenance Program Review Board (MPRB). This board replaces the RCB mentioned above. Since the oversight functions vary in scope, the actions of the MPRB will also vary. For example, write-ups resulting from the QA audits will primarily be infractions of the airline or FAA rules and regulations and thus corrective action will be to bring the unit into compliance. If, on occasion, the QA write-up requires a change in rules or procedures, the MPRB will be enlisted to discuss the matter and determine the necessary approach. If FAA regulations are involved, the director of MPE will coordinate MPRB action with the FAA. For QC, reliability, and safety issues, the analysis and corrective action will vary with the type of problem and the units involved. Likewise, the MPRB involvement will vary.

The MPRB is defined in Chap. 18, since its major efforts will be with reliability issues.

Chapter 16

Quality Assurance

Requirement for Quality Assurance (QA)

For each type of aircraft flown, the airline must generate the operations specifications (Ops Specs) that establish, among other things, the maintenance and inspection programs to be used to keep the aircraft in an airworthy condition. This is referred to as the continuous airworthiness maintenance program or CAMP and is defined in the operator's Ops Specs. The Ops Specs is approved by the FAA, but it is not enough to ensure that such programs are effective. Federal Aviation Regulation (FAR) 121.373 (Continuing Analysis and Surveillance) provides an additional requirement. Paragraph (a) of 121.373 reads as follows:

> Each certificate holder shall establish and maintain a system for the continuing analysis and surveillance of the performance and effectiveness of its inspection program and the program covering other maintenance, preventive maintenance, and alterations and for the correction of any deficiency in those programs, regardless of whether those programs are carried out by the certificate holder or another person.

What this means is that, although the airline has an FAA-approved maintenance and inspection program in place, they must monitor these programs to determine their effectiveness and implement appropriate corrective action whenever any portion of such programs proves to be ineffective. This requirement of the operating airline covers not only the work they perform themselves but also any work performed for them by third-party organizations including other airlines. This review of the airline maintenance and inspection programs is further addressed in FAA Advisory Circular AC 120-79A.

In this chapter, we will discuss quality assurance activities only. Other CASS requirements are discussed in subsequent chapters. The functions of QA are (*a*) the administration and management of QA and CASS activities; (*b*) the conduction of QA audits of all M&E organizations; (*c*) the maintenance of technical records; and (*d*) liaison with the regulatory authority for all M&E functions.

Quality Audits

In support of the FAR 121.373 requirements (i.e., CASS), a quality audit should be performed on each and every unit within the M&E organization. Generally, this would be done on a yearly basis, but other schedules (more or less often) may be appropriate for certain areas. This audit should be a detailed, fact-finding effort designed to look at all aspects of the operation, determine any discrepancies, and establish a corrective action with a finite time for correction of each such discrepancy. This means the auditor, or audit team if one is required, will look at administrative and supervisory aspects of the operation being audited as well as the performance of work. In relation to work performance, they will look at (*a*) the adequacy of tools, test equipment, and facilities; (*b*) the competency of assigned personnel (licenses, training, skills, and skill levels, etc.); (*c*) shop and office orderliness; and (*d*) the use and handling of tools, parts, supplies, and paperwork. The following is a sample, but not exhaustive, list of airline activities that should be audited.

1. Processes and procedures related to line, hangar, and shop maintenance: logbooks; completed checks; conduct of transit, daily, and 48-hour maintenance checks; handling of deferred maintenance; fueling activities; quality control inspections; procedures related to work transfer at shift change; and procurement of parts and supplies.
2. Processes and procedures related to material: receiving, storing, labeling, and handling of parts and supplies, including high-value, time-limited, and flammable items; tracking of time-limited parts; processing of warranty claims; establishment and replenishing of fly-away kits; hangar, line, and outstation parts allocations.
3. Processes and procedures related to engineering: development of maintenance program; investigation of problem areas; establishment of policies and procedures; procedures for the evaluation of service bulletins, service letters, and airworthiness directives.
4. Processes and procedures related to training of maintenance and inspection personnel in the use of computing systems, manuals, documentation, technical libraries, and safety equipment.

Table 16-1 shows the units of M&E and various areas of interest to those performing the quality audits.

These quality audits should be performed on each M&E organization by the supervisor of quality audits and his or her staff once per year. A schedule should be prepared in advance of each calendar year showing approximate dates and subject of each audit. This is not an attempt to “catch” someone doing wrong. The purpose is to review current operations and ensure that deficiencies are corrected. However, spot checks or surprise audits could be implemented if the situation

TABLE 16-1 Quality Audits

Audit Subjects	Hangar	Line	Shops	Contractors	Vendors	Fuel	Tech. Lib.	Logbooks	Checks	Material	Tools & Eq	Deferrals	Oxygen	Training	Safety
1. Adequacy & Upkeep of Facilities	x	x	x	x		x				x	x		x	x	
2. Adequacy and Serviceability of GSE	x	x													
3. Serviceability & Calibration: Tools & Test Eq.	x	x	x	x							x				
4. Use of Technical Manuals	x	x	x	x											
5. Availability of Skilled & Qualified Personnel	x	x	x	x					x					x	
6. Paperwork Handling	x	x	x	x	x				x						
7. Required Inspection Items Handling	x	x		x											
8. Personnel Records	x	x	x	x											
9. Parts: Availability, Handling, Control	x	x	x	x						x					
10. Fuel & Oil: Dispensing & Storage		x				x									
11. Deicing Chemicals: Dispersing & Storage		x													
12. Compliance with Airline Requirements				x	x										
13. Capabilities				x											
14. Cleanliness & Quality of Fuel						x									
15. Periodic Test & Inspection of Fuel Facilities						x									
16. Fuel Handling Equipment						x									
17. Fueling Procedures		x				x									
18. Revision Status of Manuals							x								
19. Distribution Procedures for Manuals							x								
20. Proper Revision Sign Off							x								
21. Currency & Completeness of Manuals	x	x	x	x			x								
22. Completeness of Logbooks								x							
23. Proper Sign Off of Discrepancies								x	x						
24. Transfer of Data to Tracking System								x							
25. Handling of Deferred Maintenance		x						x							
26. Improper Maintenance Write-ups in Logbook		x						x							
27. Completeness of Check Packages									x						
28. Inspection Stamp Usage	x	x							x						

(Continued)

TABLE 16-1 Quality Audits (*Continued*)

Audit Subjects	Hangar	Line	Shops	Contractors	Vendors	Fuel	Tech. Lib.	Logbooks	Checks	Material	Tools & Eq	Deferrals	Oxygen	Training	Safety
29. Airplanes Identified									x						
30. Handling Items Deferred out of Check									x						
31. Receiving Inspections										x					
32. Serviceable Tag Sign Off										x					
33. Shop Finding Reports			x	x	x					x					
34. Quarantine Areas										x					
35. Shelf Life Control (Stores)										x					
36. Separation of Serviceable from Unserviceable										x					
37. Currency of Calibration Stickers											x				
38. Re-Calibration Control System											x				
39. Traceability of Standards (NIST)											x				
40. Reporting & Rectification of Deferred Items	x	x										x			
41. Reasons for Deferrals												x			
42. Proper Control of Deferrals												x			
43. Cleanliness of Tools, Work Areas, Parts													x		
44. Proper Storage of Oxygen Bottles													x		
45. Quality of Oxygen													x		
46. Availability of Safety Equipment	x	x	x												x
47. Safety Training														x	x
48. Accident/Incident Reporting	x	x	x												x
49. Identification of 'No Smoking' Areas	x	x	x			x									x
50. Hazardous Materials Labeling & Handling	x	x	x												x
51. Training Course Syllabus														x	
52. Maintenance of Training Records														x	
53. Processing Warranty Claims										x					

calls for it.[1] It is important that each aspect of the M&E operation be audited yearly to ensure compliance with regulatory and airline requirements. It is equally important that these audits be taken seriously. Any discrepancies must be addressed and corrective action implemented in a timely manner.

Audits should be standardized. Although specific areas of investigation would vary from one audit to another, as can be seen in Table 16-1, there are certain items that are common to many organizations. Standard forms should be developed with specific areas of interest noted for each unit audited.

The supervisor of quality audits is also responsible for auditing all outside organizations that have dealings with M&E. This includes parts suppliers, parts pools, third-party maintenance organizations, and other contractors. This is not just a cursory approval of an organization that has already received approval by its own regulatory authority or that airline's QA department. The quality audits performed by your airline must ensure that the work performed by these contractors is in compliance with your airline and your regulatory requirements, no matter how similar or different they may be from the contractor's. Remember, FAR 121.373 says that an airline is responsible for monitoring all maintenance on its aircraft regardless of who performs that maintenance.

Certain other types of audits can be performed either on a yearly or on an as necessary basis. These are audits of certain processes, procedures, or functions, which may span two or more organizations or activities within M&E. Each organization involved would be audited for their part in the larger process, procedure, or function without a full audit of their organization (unless that is deemed necessary due to these or other findings). These audits include the following:

1. *Ramp operations.* All line maintenance and support functions related to activities in the airport ramp and gate areas. This would include parking, taxiing, refueling, aircraft servicing, loading and unloading (passengers, cargo, etc.), and turnaround maintenance. Such an audit might be performed in conjunction with a problem concerning delays and cancellations or with terminal operations in general.
2. *Airplane tire pressures.* The process for checking and adjusting tire pressures (inspection techniques, use of nitrogen, etc.) throughout the fleet might be audited. This would include all model aircraft, all stations where such work is likely to be done, and the crews involved.
3. *Shop records.* Although this subject would normally be part of a standard audit for any unit where records are kept, situations may arise that require an audit of the record keeping process airline-wide. New procedures, new computer processes, or reliability program findings, for example, could necessitate such an audit.

[1]Most airlines find the scheduled audits to be quite a sufficient workload for the QA audits section.

4. *Required inspection items (RIIs).* Again, this would be included in the standard audit each time any unit involved with RIIs is audited. But it may be necessary to check the RII process itself, as well as to review the authorization of those mechanics performing RIIs.
5. *AD and SB compliance.* All ADs are required to be implemented within some specified time limit and often apply to specific aircraft (by tail number, model, or dash number, etc.). Service bulletins, although optional, must be reviewed for proper compliance if incorporated. Sometimes an AD is generated for an already released SB. Even if the airline rejected the SB (for whatever reason) as an AD it must be incorporated. This audit would look at engineering for the handling of ADs and SBs and the subsequent generation of EOs and other work orders; it will also look at appropriate units involved in the incorporation of these modifications (maintenance, material, training, etc.).
6. *Major repairs and alterations.* These audits are usually performed to ensure compliance with requirements whenever major aircraft repairs or alterations are done. These modifications would be performed on a fleet of aircraft, but the audit would normally be done only once.
7. *Safety equipment.* Availability and accessibility of safety equipment in the various work centers may be part of the center's normal audit, but a special audit of all safety equipment may be desirable at times. This may include an audit of the safety organization itself.
8. *Safety training.* Training in the location and use of safety items and the proper employment of safety measures is also done in conjunction with work center audits, but again, a special audit of the entire safety program may be in order.
9. *Accident/incident reporting.* These processes and procedures would be addressed in an audit of the safety organization, but an audit may be necessary of the total program, including other work centers.
10. *Fire protection/prevention.* All systems, equipment, and procedures related to fire protection and fire prevention may be the subject of a one-time audit.
11. *Hazardous materials handling.* The proper handling of these materials requires training of personnel who have contact with such materials. The overall program, spanning several work centers, may be audited.

ISO 9000 Quality Standard

There has been much interest lately in quality: quality of workmanship, quality of service, quality of life. Most of industry throughout the world is adopting the international standard of quality, known as ISO 9000 (ISO, International Standards Organization). This standard establishes the requirement for a

TABLE 16-2 ISO 9000 Requirements for Quality Organizations

ISO 9000 requirement	9001	9002	9003	Maintenance
1. Management responsibility	X	X	X	X
2. Documented quality system	X	X	X	X
3. Review of customer contracts	X	X		
4. Implement process controls	X			X
5. Document control	X	X	X	X
6. Purchasing control	X	X		X
7. Supplier controls	X	X		X
8. Product traceability	X	X	X	X
9. Documented processes	X	X		X
10. Inspection and testing	X	X	X	X
11. Calibration of tools and test equipment	X	X	X	X
12. Inspection and test of products	X	X	X	X
13. Control of nonconforming products	X	X	X	
14. Document corrective action	X	X		X
15. Protect parts, etc. from damage, theft, etc.	X	X	X	
16. Quality records required	X	X	X	X
17. Internal quality audits	X	X		X
18. Document training	X	X	X	X
19. Track servicing	X			X
20. Use statistical techniques to track quality	X	X	X	X

Source: Adapted from Levitt, Joel: *The Handbook of Maintenance Management*; Industrial Press, Inc., New York, 1997, Chap. 18. Reprinted with permission.

quality system in organizations performing design and/or manufacturing or providing technical service to others. It identifies three types of organizations, with the ISO 9000 specification tailored to each one. The following information comes from *The Handbook of Maintenance Management* by Joel Levitt.[2]

ISO 9001 is for facilities that design/develop, produce, install, and service products or provide services to customers who specify how the product or service is to perform.

ISO 9002 is for facilities that provide goods or services to the customer's design specifications.

ISO 9003 is for those doing final inspection and testing.

Each facility must be certified to the applicable ISO 900X program based on the type of work performed. Maintenance (aircraft or other) is not specifically addressed in any of these ISO standards, but many aviation regulatory authorities outside the United States require commercial airline operators to develop a quality standard using ISO 9000. Table 16-2 outlines the requirements for each type of ISO 9000 organization. The far right column (added by this author) identifies those items that would relate to aviation maintenance.

[2]Levitt, Joel: *The Handbook of Maintenance Management*; Industrial Press, Inc., New York, 1997, Chap. 18. Reprinted with permission.

Technical Records

In Chap. 6, we identified the FAA requirement for an operator to maintain certain records on the status of the operating aircraft. This requirement is to ensure that aircraft are maintained in airworthy condition and in accordance with certification requirements. These records allow FAA or other regulatory authorities to see that this is being done. It shows the current status of the aircraft and that the status is up to date. It also allows a new operator, if the aircraft is sold, leased, or returned to a lessor, to know the exact status of the aircraft with respect to ADs, SBs, and other modifications and major repairs. It also lets the new operator know what the maintenance schedule is for that aircraft and where it stands in the progression of letter checks at the time of transfer; i.e., how long until the next "A" check or "C" check and what multiple checks (3A, 4C, etc.) might be due.

There are four classifications of records an operator must keep: continuous, routine, repetitive, and permanent.

Continuous records, listed in Table 16-3, are continuously updated to reflect the status of the airline's operation at any point in time. Routine records, in Table 16-4, are usually maintained for a period of 15 months. Some routine records may be transferred to permanent status as noted in the table.

Repetitive records, shown in Table 16-5, identify all work that is repeated at regular intervals, such as daily, transit, and letter checks. Normally, the letter

TABLE 16-3 Continuous Records

General records (aircraft, engines, components, appliances)
Time in service records
Time limits
Time since last overhaul
Time since last inspection
Life-limited parts
Operating limits
Accumulated hours and cycles
Modifications per SB and/or AD
Product improvement by manufacturer or operator
AD status
List of applicable ADs
Date and time in service
Methods of compliance (AD, SB, EO, etc.)
Time to next action for recurring ADs
Aircraft records
Current inspection status
Time in service since last inspection
Routine tasks performed during last inspection
Nonroutine tasks performed during last inspection
Component records
Overhaul list (FAR 121.380)
Time since last overhaul
Time remaining to next overhaul
Component history cards

TABLE 16-4 Routine Records

General records (aircraft, engines, components, appliances)
Fleet campaigns (may be transferred to permanent)
Completed checklists
Maintenance ferry checklist
Engine-out ferry checklist
Test flight checklist
Aircraft records
Logbooks
Flight logbook
Maintenance logbook
Cabin logbook
Engine and APU records
Logbooks
Maintenance training records

TABLE 16-5 Repetitive Records

Aircraft records
Maintenance/inspection checks (daily, 48-hour, transit, letter checks)
Signed-off routine task cards
Signed-off nonroutine task cards
Package closeout records
Maintenance/inspection checks (4C, D, structural—all aircraft)
Signed-off routine task cards (may be transferred to permanent)
Signed-off nonroutine task cards (may be transferred to permanent)
Package closeout records
Weight and balance
Engine and APU records
Overhaul, check, and hot section inspections

TABLE 16-6 Permanent Records

General records (aircraft, engines, components, appliances)
AD compliance records
Signed paperwork (task cards, EOs, etc.)
SB/SL compliance records
Signed paperwork (task cards, EOs, etc.)
Major repairs/alterations records
Accident reports
Repair authorizations, sketches, drawings
SBs, STCs, modifications, EOs
Weight/CG change reports
Test flight reports
FAA form 337 (major repairs and alterations)

check records are kept only until completion of the next check. However, information from these checks would be needed for justification of interval adjustment (see Chap. 2). In such cases, the check package data remains on file or the significant items from each check, each aircraft, are summarized and filed for future use and the original check package paper is destroyed.

Permanent records, listed in Table 16-6, identify permanent changes to the configuration of the aircraft, engines, components, and appliances and are retained permanently. If the aircraft is sold, leased, or returned to a lessor, the permanent records must be transferred to the next operator with the aircraft.

Other Functions of QA

The portion of QA that handles records may also be responsible for monitoring the currency of mechanics' licenses and inspectors' qualifications and authorizations (RIIs and conditional inspections). This group would also have administrative control over the development and modification of the TPPM and other documents requiring approval from the director of MPE.

The QA also performs in-house audit and spot checks that are frequently accomplished on various shifts to get an idea of how well the company's maintenance policies and procedures are being followed. These spot checks may be of aircraft being maintained at hangar, line maintenance, safety, maintenance shops, paperwork, tooling, or equipment being used.

Chapter

17

Quality Control

Introduction

The inspection function of an airline M&E organization is part of the basic maintenance program established by the Ops Specs as discussed in Chap. 6. It consists, in part, of inspections performed by the mechanics during routine maintenance work: general visual inspections, detailed inspections, as well as the obvious checking and rechecking of one's own work. Some maintenance actions require a "second pair of eyes" to perform an inspection to ensure that the work was performed correctly or to double-check the work. This includes the required inspection items (RIIs) and also includes oversight checking of newly hired or newly trained personnel to ensure they are performing up to standards. Still another type of inspection, the conditional inspection, is required for special events, such as bird strikes, hard landings, lightning strikes, flights through heavy turbulence, or the accidental dragging of wing tips or engine pods upon landing or taxiing. For these special events, the inspection must be detailed enough to detect possible structural damage and may require special nondestructive techniques for test and inspection (NDT/NDI). For a mechanic to carry out RIIs or conduct conditional inspections, he or she must be properly trained, qualified, and approved to do said inspections by quality assurance as per FAR 121.371.

Quality Control Organization

To carry out all of these inspection requirements, it is necessary to establish a quality control function within the M&E organization. This function can take various forms. In the typical midsized airline, we have included the quality control function within the MPE directorate. This is assuming that the organization is large enough to employ full-time QC inspectors. In smaller organizations, however, the QC inspectors may, by necessity, be located in the work centers. Very often, however, an airline will have both types of inspectors. Full-time inspectors are called "dedicated inspectors" while the part-time inspectors are called "delegated

inspectors" (sometimes called "designated inspectors"). In either case, someone in the MPE organization should have oversight of all QC inspectors. This oversight function is usually given to QA if there is no QC department.

A *dedicated inspector* may be an experienced mechanic, technician, or engineer, must hold a valid A&P license, and must be trained on general inspection techniques, as well as on the special techniques required for the specific areas to which he or she is assigned to inspect. A QC inspector must be approved by the QA organization to conduct such inspections.

A *delegated (or designated) inspector* may be a mechanic or supervisor in a specific work center who is qualified to perform certain inspections. He or she is often limited to perform inspections only in specific areas simply because there is no other expert in the airline qualified to do such inspection or there is not enough of such work to assign anyone to the inspection work full time. In other instances, where workload is insufficient for full-time inspectors, the delegated inspector may be required to perform all QC inspection within a given work center. To maintain the separation of inspectors from the inspected, however, it is considered that during the inspection activities, the delegated inspector is working for QC (or QA) not for the work center.

Internally, QC is divided into four functions, each under its own supervisor. Size of the airline and management preference may suggest other arrangements, but in our typical midsized airline, we have supervisors for aircraft inspections, shop inspections, material inspections, and testing and calibration.

The supervisor of aircraft inspections would oversee all QC inspectors, dedicated or delegated, who are responsible for the inspections performed on the aircraft whether in the hangar or on the line. The supervisor of shop inspections has the same responsibilities for those inspections performed in all support and overhaul shops for off-aircraft maintenance. The material inspections supervisor is responsible for all inspections required on incoming and outgoing components handled by material.

The fourth position on the QC organizational chart is responsible for supervision of all nondestructive test and inspections (NDT/NDI) and for the calibration of tools and test equipment used throughout M&E. This includes electronics test equipment used on the line, in the hangar, and in the shops, as well as special tools, such as torque wrenches, which require regular checks for calibration accuracy. The QC unit is responsible for seeing that all such tools and equipment have valid calibration stickers showing the last calibration date or the date the next calibration is due; i.e., expiration of the current calibration. Quality control is also responsible for sending such equipment to the appropriate calibration laboratory, which may be run by the airline or by a third party.

FAA and JAA Differences

The above discussion covers the approach to QC relative to the U.S. standards. In Europe, airlines under the Joint Aviation Authorities (JAA) have a different setup. Under JAA rules, there is no quality control organization, only quality

assurance. However, all aspects of the QC function discussed above still exist under the JAA but are controlled differently. The JAA is not a regulatory authority.[1] It is an advisory group with the purpose of standardizing aviation regulations throughout Europe. In all cases, the regulatory authority of the airline's own country has the final say in what the airline should do.[2]

The certified and trained mechanic is considered qualified enough to inspect his own work to assure that it has been done properly. If the mechanic is properly trained and is a conscientious worker, this is to be expected. These mechanics, however, must be properly trained in the inspection techniques and must be approved by the QA department to do the inspection. For those inspections (safety or airworthiness related, for example) that require a second pair of eyes, the second person, under JAA rules, must also be properly trained and approved by QA. For the conditional inspection items mentioned above where structural damage might be involved, the inspector or mechanic performing such inspections must also be trained in the proper techniques (i.e., NDT/NDI) for the given inspection and be approved by QA to perform these conditional inspections.

Under JAA rules, where there is no QC, the mechanic does not have "free run" of the situation. The key words used above are "properly trained and approved by QA." This is true for the FAA or the JAA. In other words, the requirements are the same under both FAA and JAA jurisdictions, only the terminology and the titles used are different.

QC Inspector Qualifications

Anyone working as a quality control inspector, whether dedicated or delegated, must possess certain qualifications. The basic qualification for all inspectors is to have a valid mechanic's license and 2 years of work experience under that license without any violations. They must have completed all company-required training and aircraft fleet training and have knowledge of airlines regulations, policies, and procedures; they must know the company's RII program; and they should have completed the QC inspector's course and successfully passed the QC exam conducted by the airline's QC organization.

The inspector's course should cover the duties and responsibilities of QC inspectors and instructions in inspection procedures and techniques. The course should include instruction on corrosion, its detection, and its control. Nondestructive test and inspection techniques should be addressed to the extent that the individual inspector requires for his or her duties. The course should also include a review of regulatory and airline procedures related to the inspector's specialty.

Once trained and approved for QC inspection, the mechanic is required to maintain proficiency in the inspection methods used, the specifications of the

[1]The European Union (EU) is in the process of establishing the European Aviation Safety Agency (EASA) to regulate aviation in the EU.

[2]Joint Aviation Agency Regulation JAR OPS 1.

equipment involved, the methods and procedures for determining quality, and the proper use of inspection aids, tools, and applicable NDT/NDI techniques.

The airline must keep a record of those personnel who are authorized as QC inspectors. Their status, dedicated or delegated, as well as the items they are qualified and authorized to inspect must be recorded and made available to regulatory personnel.

Basic Inspection Policies

The airline should establish the basic inspection policies for all dedicated and delegated inspectors to abide by. The policies most generally accepted by the industry address the following areas: (*a*) use of an inspector's stamp for official acceptance of work; (*b*) the continuity of inspection across shift boundaries; (*c*) the countermand of inspector's decisions; (*d*) reinspection of rejected work (buyback); and (*e*) the inspection of one's own work. Each of these is discussed below.

Inspection stamp

All authorized QC inspectors are issued an inspector's stamp. These stamps are numbered and controlled, and each inspector is responsible for the security of his or her own stamp. When work is done by a mechanic, it is signed off by the mechanic on the appropriate work card or other official paperwork. If a specific task requires QC inspection, the inspector, after reviewing and accepting the work, will approve it by stamping and initialing the work card or task card. The stamp must be surrendered to QA whenever the inspector leaves the company or is no longer in the inspection unit.

Continuity of inspection

Whenever work spans more than one shift, the airline is required to have procedures in place (in the TPPM) to ensure that complete information and status of the work progress is passed on to the next shift. This policy must also include the transfer of inspection authority to the next shift of inspectors. In some airlines, the original work crew remains on the job until the work is completed, even if overtime is involved. In other airlines, crews work 10- to 12-hour shifts, which covers most jobs. But inspectors, often considered as management level, may work only 8-hour shifts. Whatever the shift schedule, the airline procedures must specifically identify how continuity will be maintained to ensure correctness of the work and of the inspection efforts.

Countermand of inspector's decisions

A QC inspector's decision to accept or reject a job, or ask for a rework, cannot be countermanded or overridden by the mechanic or by the mechanic's management. When a delegated QC inspector in any shop or work center is performing an inspection, his or her decisions cannot be overridden by his or her own work center

supervisor since the inspection is done under QC management. The only ones who can override an inspector's decision are the manager of QC, the director of MPE, or the VP of M&E. Where the QC inspectors are directly under QA authority, the director or manager of QA has override authority. In any case where an inspector's decision has been overridden, the responsibility for the action falls upon the airline and not on the inspector or the mechanic.

Buyback policy

Any discrepancy written up by QC during a check (A, C, etc.) or in any spot check and any work rejected by QC during their acceptance inspection, must be reinspected by QC after the rework has been accomplished to gain final approval. This final inspection and approval is called "buyback." For "B" checks and lower, if no QC inspector is available, the supervisor of the mechanic performing the work has buyback authority.

Inspection of one's own work

Neither a mechanic nor an inspector can inspect and approve his or her own work where two signatures are required. It is an accepted fact that a mechanic who is qualified and conscientious will be able to "self-inspect" his or her own work to ensure that it has been done correctly. However, if the work requires a second pair of eyes or a second signature, the second person cannot be the same as the first.

Completion of work

Each work package has a list of tasks that must be completed for the check to be complete. Most tasks require only the mechanic's sign-off to indicate completion. Some tasks require a QC inspector to inspect, approve, and sign off the task also. In addition to this, the senior QC inspector assigned to the check has the responsibility of checking to see that all tasks have been completed successfully and signed off properly. This involves checking each task card for completion and sign-off, ensuring that all rejected work has been reworked and accepted, and verifying that any QC write-ups generated during the check have been addressed. Any tasks not completed for whatever reason, must be properly deferred. Normally, an airline wants an aircraft to come out of an "A" or "C" check "clean"; i.e., no deferrals, but this is not always possible. Once all the work has been completed and signed off (or deferred), the QC inspector accepts the work package as complete, signs it off, and releases the aircraft out of check.

Other QC Activities

In addition to the inspection activities mentioned above, the QC organization also has responsibility for special nondestructive test and inspection techniques, the calibration of certain tools and test equipment used in maintenance, and a number of special reports to the regulatory authority concerning maintenance problems. We will discuss each of these in turn.

Nondestructive test and inspection

There are a number of special test and inspection activities used in maintenance that require the partial or complete disassembly of components and some that require other means that render the tested unit unserviceable. Although the first type can be tolerated, the second cannot. To avoid the disassembly or destruction of components, several methods of test and inspection have been developed to provide a look at or into certain component and system conditions without permanently destroying the parts. These are called, for obvious reasons, nondestructive test or nondestructive inspection techniques.

The NDT/NDI techniques used in aircraft maintenance include the use of x-rays, ultrasound, dyes, magnetic particle detectors, and boroscopes. Each is unique and each has its particular applications. The QC organization is responsible for conducting these tests and inspections or, in some cases, training the mechanics in the use of these techniques. Table 17-1 lists these NDT/NDI techniques and their applicability.

Calibration of tools and test equipment

Certain measuring tools and test equipment used in maintenance require calibration on a periodic basis. The standards used in the United States are those of the National Institute of Standards and Technology (NIST). The airline must provide for the calibration of tools and test equipment with on-site standards, which can be traced back to the NIST. Maintenance requirements are to use only those tools and test units that have been calibrated and certified as serviceable. Responsibility for this lies with QC, although a dedicated laboratory facility

TABLE 17-1 NDT/NDI Techniques

X-ray	To view internal conditions of certain materials to indicate internal holes, cracks, or other problems.
Ultrasonic	Similar to x-rays but uses high-frequency sound waves. Internal aberrations will conduct the sound differently and thus generate different patterns on the monitor.
Eddy current	Eddy currents set up in various materials exhibit certain patterns. Internal cracks in materials would alter the pattern and thus show areas of weakness.
Dye penetrant	Special dyes are introduced into various flow systems. Leaks in the tubing, gaskets, connectors, etc. will be identified by leakage of the dye at the errant point.
Magnetic particle	Chip detectors strategically placed in engines to detect metal particles in the oil indicating engine wear.
Boroscope	To view the internal condition of the jet engine rotor blades, a special video probe is inserted into an access hole in the engine. The internal section of the engine then can be viewed on an external monitor while the engine fan is rotated to view all blades. *Caution*: The probe must be removed and the access hole secured before running the engine.

is usually established, with specially qualified metrological technicians employed, to accomplish the work.

Properly calibrated tools and test equipment will carry calibration stickers that will identify either the date of last calibration or the date calibration is due. The stickers should also include the initials and stamp of the approving laboratory. Mechanics should use only tools and test equipment that have valid calibration stickers. Compliance will be monitored by QC and QA.

A valid calibration sticker, however, does not guarantee that the tool or test unit is still within calibrated limits. These units malfunction occasionally and a good mechanic should be able to detect such problems. The TPPM should spell out procedures for mechanics and technicians to use in reporting an out-of-calibration tool or instrument to QC. The processing to and from the calibration lab can be through QC or material.

Special reports to the regulatory authority

A mechanical reliability report (MRR)[3] is submitted whenever any malfunction or defect shown in Table 17-2 occurs. The MCC notifies QC whenever an incident occurs, and QC prepares a report to the FAA. Such reports are usually submitted covering a 24-hour period (9:00 AM Monday to 9:00 AM Tuesday, for example) to the certificate-holding office of the airline. The report consists of type and identification number of the aircraft; the airline name; and the date, flight number, and flight stage when the incident occurred. The report would also include the nature of the incident, emergency procedures involved (if any), apparent cause, equipment affected, disposition, and a brief narration of any other pertinent information related to the incident. Information not available at the time of the original submission must be provided to the FAA in a follow-up report when the information becomes available.

A mechanical interruption summary (MIS) will be submitted to the FAA for every flight interruption, unscheduled change of aircraft routing, or any unscheduled stop or diversion caused by mechanical difficulties (known or suspected) that do not fall in the MRR categories of Table 17-2. The MIS report is also the responsibility of QC with information supplied by the MCC.

Required inspection items

Mechanics throughout the M&E organization may be involved with RIIs, but it is a director or manager of QC's responsibility to see that the program is properly administered. The FAA defines an RII as "any item which, if performed improperly or improper parts are used, could endanger the safe operation of the aircraft."[4] This would include such tasks as the following:

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[3]Federal Aviation Regulation 121.703.

[4]Federal Aviation Regulation 121.369

TABLE 17-2 Mechanical Reliability Reports*

A fire or fires during flight
Whether or not the related fire warning system functioned properly
If not protected by a fire warning system

False fire warning

Engine exhaust system that causes damage during flight to
Engine
Adjacent structure
Equipment
Components

Aircraft component that causes accumulation or circulation in crew/passenger cabin of
Smoke
Vapor
Toxic fumes

Engine shutdown due to
Flameout
Foreign object ingestion
Icing

Engine shutdown when external damage to engine or airplane occurs

Shutdown of more than one engine

Fuel or fuel dumping system that
Causes leakage during flight
Affects fuel flow

Landing gear operation during flight
Extension or retraction
Opening or closing of landing gear doors

Braking system components resulting in loss of braking force when A/C is on the ground

Failure of all inertial navigation systems in flight

Any A/C components or systems that cause the crew to take emergency action
Cabin decompression in flight
Evacuation on the ground

Any failure, malfunction, or defect which occurs or is detected at any time if the airline determines that it has or may endanger the safe operation of the aircraft.

* Summarized from the general maintenance manual of a now defunct U.S.-based midsized airline. Also see Federal Aviation Regulation 121.703.

1. Installation, rigging, or adjustment of flight controls
2. Installation and repair of major structural components
3. Installation of engines
4. Overhaul, calibration, or rigging of components, such as engines, transmissions, gear boxes, and navigation equipment

In the case of an RII, the mechanic performing the work must sign off the task when completed. Then a second pair of eyes must review the work and sign off also.

This second pair of eyes should be a mechanic who has been approved by QA to perform such inspections.

The FAA does not specify what items should be identified as RIIs but does require the airline to evaluate their own work program and identify the RIIs applicable to their operation. In addition to identifying RIIs, the airline must also specify who in their organization or any other contract organization is qualified and authorized to perform these inspections. FAR 121.371 is quite specific:

> (*a*) No person may use any person to perform required inspections unless the person performing the inspection is appropriately certificated, properly trained, qualified, and authorized to do so.
>
> (*b*) No person may allow any person to perform a required inspection unless, at that time, the person performing that inspection is under the supervision and control of an inspection unit.
>
> (*c*) No person may perform a required inspection if he or she performed the item of work required to be inspected.
>
> (*d*) Each certificate holder shall maintain, or shall determine that each person with whom it arranges to perform its required inspections maintains, a current listing of persons who have been trained, qualified, and authorized to conduct required inspections. The persons must be identified by name, occupational title, and the inspections that they are authorized to perform. The certificate holder (or person with whom it arranges to perform its required inspections) shall give written information to each person so authorized describing the extent of his responsibilities, authorities, and inspectional limitations. The list shall be made available for inspection by the Administrator upon request.[5]

[5]Federal Aviation Regulation 121.371.

Chapter

18

Reliability

Introduction

Reliability equals consistency. It can be defined as the probability that an item will perform a required function, under specified conditions without failure, for a specified amount of time according to its intended design. The reliability program is a valuable means of achieving better operational performance in an aircraft maintenance environment, and it is designed to decrease maintenance-related issues and increase flight safety. The intent of this program is to deal systematically with problems as they arise instead of trying to cure immediate symptoms. This program is normally customized, depending on the operators, to accurately reflect the specific operation's requirements. Although the word *reliability* has many meanings, in this book we will define the terms that have specialized meanings to aviation maintenance and engineering. In the case of reliability, we first must discuss one important difference in the application of the term.

There are two main approaches to the concept of reliability in the aviation industry. One looks essentially at the whole airline operation or the M&E operation within the whole, and the other looks at the maintenance program in particular. There is nothing wrong with either of these approaches, but they differ somewhat, and that difference must be understood.

The first approach is to look at the overall airline reliability. This is measured essentially by dispatch reliability; that is, by how often the airline achieves an on-time departure[1] of its scheduled flights. Airlines using this approach track delays. Reasons for the delay are categorized as maintenance, flight operations, air traffic control (ATC), etc. and are logged accordingly. The M&E organization is concerned only with those delays caused by maintenance.

[1] On-time departure means that the aircraft has been "pushed back" from the gate within 15 minutes of the scheduled departure time.

Very often, airlines using this approach to reliability overlook any maintenance problems (personnel or equipment related) that do not cause delays, and they track and investigate only those problems that do cause delays. This is only partially effective in establishing a good maintenance program.

The second approach (which we should actually call the primary approach) is to consider reliability as a program specifically designed to address the problems of maintenance—whether or not they cause delays—and provide analysis of and corrective actions for those items to improve the overall reliability of the equipment. This contributes to the dispatch reliability, as well as to the overall operation.

We are not going to overlook the dispatch reliability, however. This is a distinct part of the reliability program we discuss in the following pages. But we must make the distinction and understand the difference. We must also realize that not all delays are caused by maintenance or equipment even though maintenance is the center of attention during such a delay. Nor can we only investigate equipment, maintenance procedures, or personnel for those discrepancies that have caused a delay. As you will see through later discussions, dispatch reliability is a subset of overall reliability.

Types of Reliability

The term *reliability* can be used in various respects. You can talk about the overall reliability of an airline's activity, the reliability of a component or system, or even the reliability of a process, function, or person. Here, however, we will discuss reliability in reference to the maintenance program specifically.

There are four types of reliability one can talk about related to the maintenance activity. They are (*a*) statistical reliability, (*b*) historical reliability, (*c*) event-oriented reliability, and (*d*) dispatch reliability. Although dispatch reliability is a special case of event-oriented reliability, we will discuss it separately due to its significance.

Statistical reliability

Statistical reliability is based upon collection and analysis of failure, removal, and repair rates of systems or components. From this point on, we will refer to these various types of maintenance actions as "events." Event rates are calculated on the basis of events per 1000 flight hours or events per 100 flight cycles. This normalizes the parameter for the purpose of analysis. Other rates may be used as appropriate.

Many airlines use statistical analysis, but some often give the statistics more credence than they deserve. For one example, airlines with 10 or more aircraft tend to use the statistical approach, but most teachers and books on statistics tell us that for any data set with less than about 30 data points the statistical calculations are not very significant. Another case of improper use of statistics was given as an example presented in an aviation industry seminar on reliability.

The airline representative used this as an example of why his airline was going to stop using statistical reliability. Here is his example.

> We use weather radar only 2 months of the year. When we calculate the mean value of failure rates and the alert level in the conventional manner [discussed in detail later in this chapter] we find that we are always on alert. This, of course, is not true.

The gentleman was correct in defining an error in this method, and he was correct in determining that—at least in this one case—statistics was not a valid approach. Figure 18-1 shows why.

The top curve in Fig. 18-1 shows the 2 data points for data collected when the equipment was in service. It also shows 10 zero data points for those months when the equipment was not used and no data were collected (12-month column). These zeros are not valid statistical data points. They do not represent zero failures; they represent "no data" and therefore should not be used in the calculation. Using these data, however, has generated a mean value (lower, dashed line) of 4.8 and an alert level at two standard deviations above the mean (upper, solid line) of 27.6.

One thing to understand about mathematics is that the formulas will work, will produce numerical answers, whether or not the input data are correct. Garbage in, garbage out. The point is, you only have two valid data points here shown in the bottom curve of Fig. 18-1 (2-month data). The only meaningful statistic here is the average of the two numbers, 29 (dashed line). One can calculate a standard deviation (SD) here using the appropriate formula or a calculator, but the parameter has no meaning for just two data points. The alert level set

Data	12 Mos	2 Mos
Jan	0	
Feb	0	
Mar	0	
Apr	0	
May	0	
Jun	0	
Jul	0	
Aug	0	
Sep	26	26
Oct	32	32
Nov	0	
Dec	0	
Sum	58	58
n	12	2
Avg.	4.8	29.0
Std. Dev.	11.4	4.2
A.L.	27.6	37.5

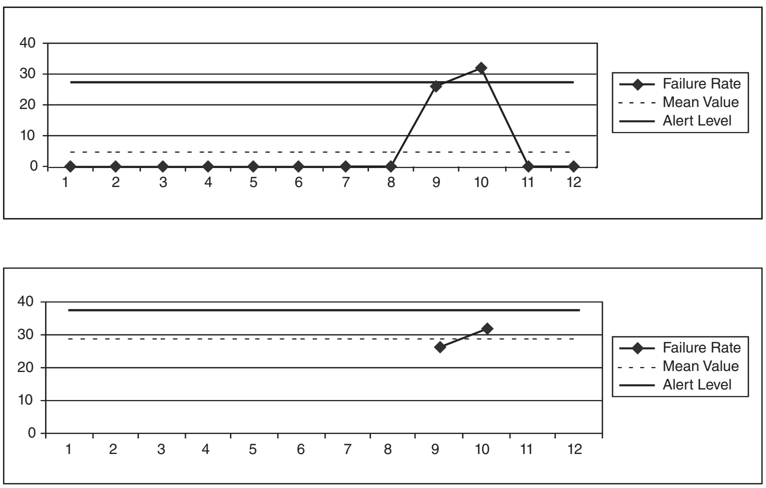

Figure 18-1 Comparison of alert level calculation methods.

by using this calculation is 37.5 (solid line). For this particular example, statistical reliability is not useable, but historical reliability is quite useful. We will discuss that subject in the next section.

Historical reliability

Historical reliability is simply a comparison of current event rates with those of past experience. In the example of Fig. 18-1, the data collected show fleet failures of 26 and 32 for the 2 months the equipment was in service. Is that good or bad? Statistics will not tell you but history will. Look at last year's data for the same equipment, same time period. Use the previous year's data also, if available. If current rates compare favorably with past experience, then everything is okay; if there is a significant difference in the data from one year to the next, that would be an indication of a possible problem. That is what a reliability program is all about: detecting and subsequently resolving problems.

Historical reliability can be used in other instances, also. The most common one is when new equipment is being introduced (components, systems, engines, aircraft) and there is no previous data available on event rates, no information on what sort of rates to expect. What is "normal" and what constitutes "a problem" for this equipment? In historical reliability we merely collect the appropriate data and literally "watch what happens." When sufficient data are collected to determine the "norms," the equipment can be added to the statistical reliability program.

Historical reliability can also be used by airlines wishing to establish a statistically based program. Data on event rates kept for 2 or 3 years can be tallied or plotted graphically and analyzed to determine what the normal or acceptable rates would be (assuming no significant problems were incurred). Guidelines can then be established for use during the next year. This will be covered in more detail in the reliability program section below.

Event-oriented reliability

Event-oriented reliability is concerned with one-time events such as bird strikes, hard landings, overweight landings, in-flight engine shutdowns, lighting strikes, ground or flight interruption, and other accidents or incidents. These are events that do not occur on a daily basis in airline operations and, therefore, produce no usable statistical or historical data. Nevertheless, they do occur from time to time, and each occurrence must be investigated to determine the cause and to prevent or reduce the possibility of recurrence of the problem.

In ETOPS[2] operations, certain events associated with this program differ from conventional reliability programs, and they do rely on historical data and alert levels to determine if an investigation is necessary to establish whether a problem can be reduced or eliminated by changing the maintenance program.

[2] Requirements for extended range operations with two-engine airplanes (ETOPS) are outlined in FAA Advisory Circular AC 120-42B, and also discussed in Appendix E of this book.

Events that are related to ETOPS flights are designated by the FAA as actions to be tracked by an "event-oriented reliability program" in addition to any statistical or historical reliability program. Not all the events are investigated, but everything is continually monitored in case a problem arises.

Dispatch reliability

Dispatch reliability is a measure of the overall effectiveness of the airline operation with respect to on-time departure. It receives considerable attention from regulatory authorities, as well as from airlines and passengers, but it is really just a special form of the event-oriented reliability approach. It is a simple calculation based on 100 flights. This makes it convenient to relate dispatch rate in percent. An example of the dispatch rate calculation follows.

If eight delays and cancellations are experienced in 200 flights, that would mean that there were four delays per 100 flights, or a 4 percent delay rate. A 4 percent delay rate would translate to a 96 percent dispatch rate (100 percent – 4 percent delayed = 96 percent dispatched on time). In other words, the airline dispatched 96 percent of its flights on time.

The use of dispatch reliability at the airlines is, at times, misinterpreted. The passengers are concerned with timely dispatch for obvious reasons. To respond to FAA pressures on dispatch rate, airlines often overreact. Some airline maintenance reliability programs track only dispatch reliability; that is, they only track and investigate problems that resulted in a delay or a cancellation of a flight. But this is only part of an effective program and dispatch reliability involves more than just maintenance. An example will bear this out.

The aircraft pilot in command is 2 hours from his arrival station when he experiences a problem with the rudder controls. He writes up the problem in the aircraft logbook and reports it by radio to the flight following unit at the base. Upon arrival at the base, the maintenance crew meets the plane and checks the log for discrepancies. They find the rudder control write-up and begin troubleshooting and repair actions. The repair takes a little longer than the scheduled turnaround time and, therefore, causes a delay. Since maintenance is at work and the rudder is the problem, the delay is charged to maintenance and the rudder system would be investigated for the cause of the delay.

This is an improper response. Did maintenance cause the delay? Did the rudder equipment cause the delay? Or was the delay caused by poor airline procedures? To put it another way: could a change of airline procedures eliminate the delay? Let us consider the events as they happened and how we might change them for the better.

If the pilot and the flight operations organization knew about the problem 2 hours before landing, why wasn't maintenance informed at the same time? If they had been informed, they could have spent the time prior to landing in studying the problem and performing some troubleshooting analysis. It is quite possible, then, that when the airplane landed, maintenance could have met it with a fix in hand. Thus, this delay could have been prevented by procedural changes. The procedure should be changed to avoid such delays in the future.

While the maintenance organization and the airline could benefit from this advance warning of problems, it will not always eliminate delays. The important thing to remember is that if a delay is caused by procedure, it should be attributed to procedure and it should be avoided in the future by altering the procedure. That is what a reliability program is about: detecting where the problems are and correcting them, regardless of who or what is to blame.

Another fallacy in overemphasizing dispatch delay is that some airlines will investigate each delay (as they should), but if an equipment problem is involved, the investigation may or may not take into account other similar failures that did not cause delays. For example, if you had 12 write-ups of rudder problems during the month and only one of these caused a delay, you actually have two problems to investigate: (*a*) the delay, which could be caused by problems other than the rudder equipment and (*b*) the 12 rudder write-ups that may, in fact, be related to an underlying maintenance problem. One must understand that dispatch delay constitutes one problem and the rudder system malfunction constitutes another. They may indeed overlap but they are two different problems. The delay is an event-oriented reliability problem that must be investigated on its own; the 12 rudder problems (if this constitutes a high failure rate) should be addressed by the statistical (or historical) reliability program. The investigation of the dispatch delays should look at the whole operation. Equipment problems—whether or not they caused delays—should be investigated separately.

A Reliability Program

A reliability program for our purposes is, essentially, a set of rules and practices for managing and controlling a maintenance program. The main function of a reliability program is to monitor the performance of the vehicles and their associated equipment and call attention to any need for corrective action. The program has two additional functions: (*a*) to monitor the effectiveness of those corrective actions and (*b*) to provide data to justify adjusting the maintenance intervals or maintenance program procedures whenever those actions are appropriate.

Elements of a Reliability Program

A good reliability program consists of seven basic elements as well as a number of procedures and administrative functions. The basic elements (discussed in detail below) are (*a*) data collection; (*b*) problem area alerting, (*c*) data display; (*d*) data analysis; (*e*) corrective actions; (*f*) follow-up analysis; and (*g*) a monthly report. We will look at each of these seven program elements in more detail.

Data collection

We will list 10 data types that can be collected, although they may not necessarily be collected by all airlines. Other items may be added at the airline's discretion.

The data collection process gives the reliability department the information needed to observe the effectiveness of the maintenance program. Those items that are doing well might be eliminated from the program simply because the data show that there are no problems. On the other hand, items not being tracked may need to be added to the program because there are serious problems related to those systems. Basically, you collect the data needed to stay on top of your operation. The data types normally collected are as follows:

1. Flight time and cycles for each aircraft
2. Cancellations and delays over 15 minutes
3. Unscheduled component removals
4. Unscheduled engine removals
5. In-flight shutdowns of engines
6. Pilot reports or logbook write-ups
7. Cabin logbook write-ups
8. Component failures (shop maintenance)
9. Maintenance check package findings
10. Critical failures

We will discuss each of these in detail below.

Flight time and flight cycles. Most reliability calculations are "rates" and are based on flight hours or flight cycles; e.g., 0.76 failures per 1000 flight hours or 0.15 removals per 100 flight cycles.

Cancellations and delays over 15 minutes. Some operators collect data on all such events, but maintenance is concerned primarily with those that are maintenance related. The 15-minute time frame is used because that amount of time can usually be made up in flight. Longer delays may cause schedule interruptions or missed connections, thus the need for rebookings. This parameter is usually converted to a "dispatch rate" for the airline as discussed above.

Unscheduled component removals. This is the unscheduled maintenance mentioned earlier and is definitely a concern of the reliability program. The rate at which aircraft components are removed may vary widely depending on the equipment or system involved. If the rate is not acceptable, an investigation should be made and some sort of corrective action must be taken. Components that are removed and replaced on schedule—e.g., HT items and certain OC items—are not included here, but these data may be collected to aid in justifying a change in the HT or OC interval schedule.

Unscheduled removals of engines. This is the same as component removals, but obviously an engine removal constitutes a considerable amount of time and manpower; therefore, these data are tallied separately.

In-flight shutdown (IFSD) of engines. This malfunction is probably one of the most serious in aviation, particularly if the airplane only has two engines (or one).

The FAA requires a report of IFSD within 72 hours.[3] The report must include the cause and the corrective action. The ETOPS operators are required to track IFSDs and respond to excessive rates as part of their authorization to fly ETOPS. However, non-ETOPS operators also have to report shutdowns and should also be tracking and responding to high rates through the reliability program.

Pilot reports or logbook write-ups. These are malfunctions or degradations in airplane systems noted by the flight crew during flight. Tracking is usually by ATA Chapter numbers using two, four, or six digits. This allows pinpointing of the problems to the system, subsystem, or component level as desired. Experience will dictate what levels to track for specific equipment.

Cabin logbook write-ups. These discrepancies may not be as serious as those the flight crew deals with, but passenger comfort and the ability of the cabin crew to perform their duties may be affected. These items may include cabin safety inspection, operational check of cabin emergency lights, first aid kits, and fire extinguishers. If any abnormality is found, these items are written up by the flight crew in the maintenance logbook as a discrepancy item.

Component failures. Any problems found during shop maintenance visits are tallied for the reliability program. This refers to major components within the black boxes (avionics) or parts and components within mechanical systems.

Maintenance check package findings. Systems or components found to be in need of repair or adjustment during normal scheduled maintenance checks (non-routine items) are tracked by the reliability program.

Critical failures. Failures involving a loss of function or secondary damage that could have a direct adverse effect on operating safety.

Problem detection—an alerting system

The data collection system allows the operator to compare present performance with past performance in order to judge the effectiveness of maintenance and the maintenance program. An alerting system should be in place to quickly identify those areas where the performance is significantly different from normal. These are items that might need to be investigated for possible problems. Standards for event rates are set according to analysis of past performances and deviations from these standards.

This alert level is based on a statistical analysis of the event rates of the previous year, offset by 3 months. The mean value of the failure rates and the standard deviation from the mean are calculated, and an alert level is set at one to three standard deviations above that mean rate (more on setting and adjusting alert levels later). This value, the upper control limit (UCL), is commonly referred to as the alert level. However, there is an additional calculation that can be made to smooth the curve and help eliminate “false alerts.” This is the 3-month rolling average, or trend line. The position of these two lines (the monthly rate and the 3-month average) relative to the UCL is used to determine alert status.

[3] See Federal Aviation Regulation 121.703, Mechanical Reliability Report.

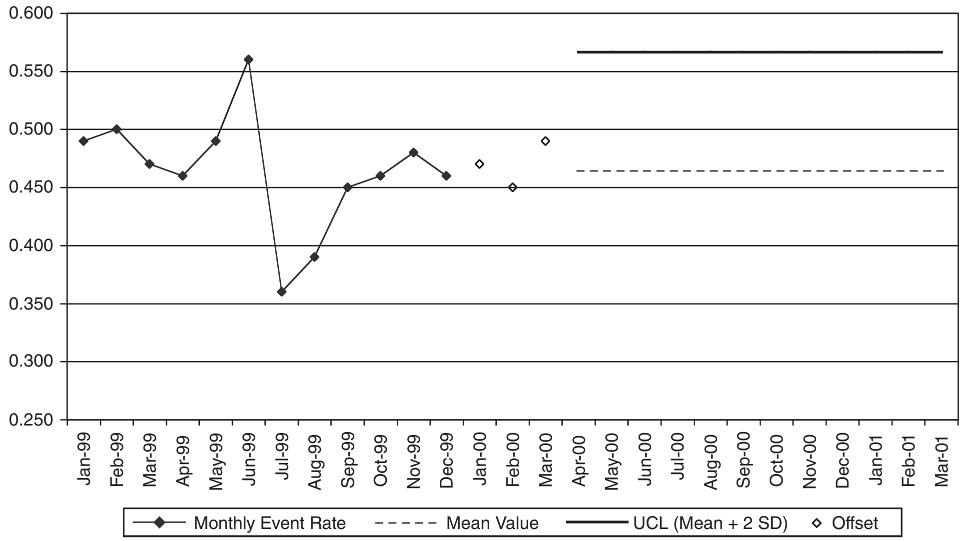

Figure 18-2 Calculation of new alert levels.

Setting and adjusting alert levels

It is recommended that alert levels be recalculated yearly. The data used to determine alert level are the event rates for the previous year offset by 3 months. The reason for this will be explained shortly.

Figure 18-2 shows the data used and the results in graphic form. In this example, we are establishing a new alert level for the year April 2000 through March 2001. This level is represented in Fig. 18-2 as the upper straight line. These data were obtained using the actual event rates for January 1999 through December 1999 shown on the left of the figure. The three data points between (shown as diamonds for January to March 2000 in Fig. 18-2) will be used in calculating a 3-month rolling average to be used during the collection of new data. This will be discussed later.

Basic statistics are used for the calculations. From the original data (January–December 1999) we calculate the mean and the standard deviation of these data points. The mean is used as a baseline for the new data and is shown as the dashed line on the right side of Fig. 18-2. The solid line on the right of Fig. 18-2 is the alert level that we have chosen for these data and is equal to the calculated mean plus two standard deviations. Event rates for the new year, then, will be plotted and measured relative to these guidelines.

Reading alert status

The data shown in Fig. 18-3 show 1 year of event rates (solid jagged line with triangles) along with the mean value (bottom straight line) and the alert level (upper straight line). As you can see, the event rate swings above the alert level several times through the year (February, June, October, and December). Of course,

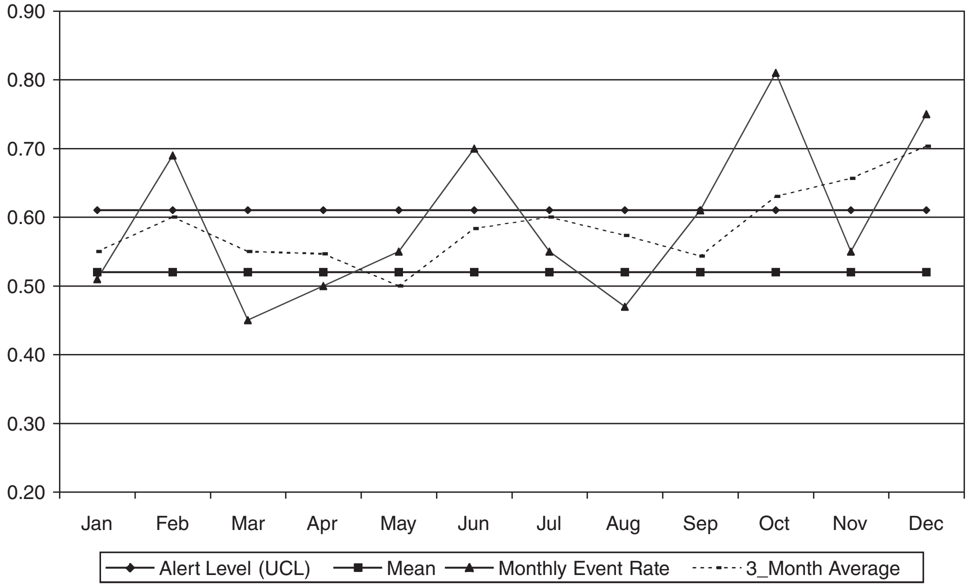

Figure 18-3 Reading alert status.

it is easy to see the pattern as we look at the year's events. But in reality, you will only see 1 month at a time and the preceding months. Information on what is going to happen the next month is not available to you.

When the event rate goes above the alert level (as in February), it is not necessarily a serious matter. But if the rate stays above the alert level for 2 months in succession, then it may warrant an investigation. The preliminary investigation may indicate a seasonal variation or some other one-time cause, or it may suggest the need for a more detailed investigation. More often than not, it can be taken for what it was intended to be—an "alert" to a possible problem. The response would be to wait and see what happens next month. In Fig. 18-3, the data show that, in the following month (March) the rate went below the line; thus, no real problem exists. In other words, when the event rate penetrates the alert level, it is not an indication of a problem; it is merely an "alert" to the possibility of a problem. Reacting too quickly usually results in unnecessary time and effort spent in investigation. This is what we call a "false alert."

If experience shows that the event rate for a given item varies widely from month to month above and below the UCL as in Fig. 18-3—and this is common for some equipment—many operators use a 3-month rolling average. This is shown as the dashed line in Fig. 18-3. For the first month of the new data year, the 3-month average is determined by using the offset data points in Fig. 18-2. (Actually, only 2 months offset is needed, but we like to keep things on a quarterly basis.) The purpose for the offset is to ensure that the plotted data for the new year do not contain any data points that were used to determine the mean and alert levels we use for comparison.

While the event rate swings above and below the alert level, the 3-month rolling average (dashed line) stays below it—until October. This condition—event rate and 3-month average above the UCL—indicates a need to watch the activity more closely. In this example, the event rate went back down below the UCL in November, but the 3-month average stayed above the alert level. This is an indication that the problem should be investigated.

Setting alert levels

These upper control limits, or alert levels, and the mathematics that produced them are not magical by any means. They will not tell you when you have a definite problem nor will they tell you where or what to investigate. What they will do is provide you with intelligent guidelines for making your own decisions about how to proceed. The whole process begins with your intellect and your ability to set these alert levels to an effective level.

Earlier in this chapter, we talked about an airline that was rejecting statistical reliability and gave an example of why. Another of the reasons the gentleman gave for this decision was that "we know we have problems with engines, but engines are never on alert." If you use the UCL concept to alert you to possible problems and you do not get an alert indication when you know you have problems, then it should not take much thought to make you realize that your chosen alert level is wrong. This alert level is a very important parameter and it must be set to a useable level, a level that will indicate to you that a problem exists or may be developing. If not set properly, the alert level is useless. And that is not the fault of statistics.

This use of an alert level is designed to tell you when you have (or may have) a problem developing that requires investigation. But you have to know what conditions constitute a possible problem and set the alert level accordingly. You have to know your equipment and its failure patterns to determine when you should proceed with an investigation and when to refrain from investigating. You have to recognize "false alerts." You also have to know whether or not the event rate data points for a particular item are widely or narrowly distributed; i.e., if it has a large or small standard deviation. This knowledge is vital to setting useable alert levels.

Many airlines erroneously set all alert levels at two standard deviations above the mean. Unfortunately, this is not a good practice. It is a good place to start, but there must be an adjustment in some cases to provide the most useable data and to avoid false alerts.

As we discussed in Chap. 1, not everything fails at the same rate or in the same pattern. Event rates tracked by a reliability program can be quite erratic, as the data in Fig. 18-3 show. For other rates, the numbers can be more stable. This characteristic of the data is depicted by the statistical parameter of standard deviation—the measure of the distribution of data points around the mean. A large standard deviation means wide distribution, a large variation in point values. A small standard deviation means that the points are closer together.

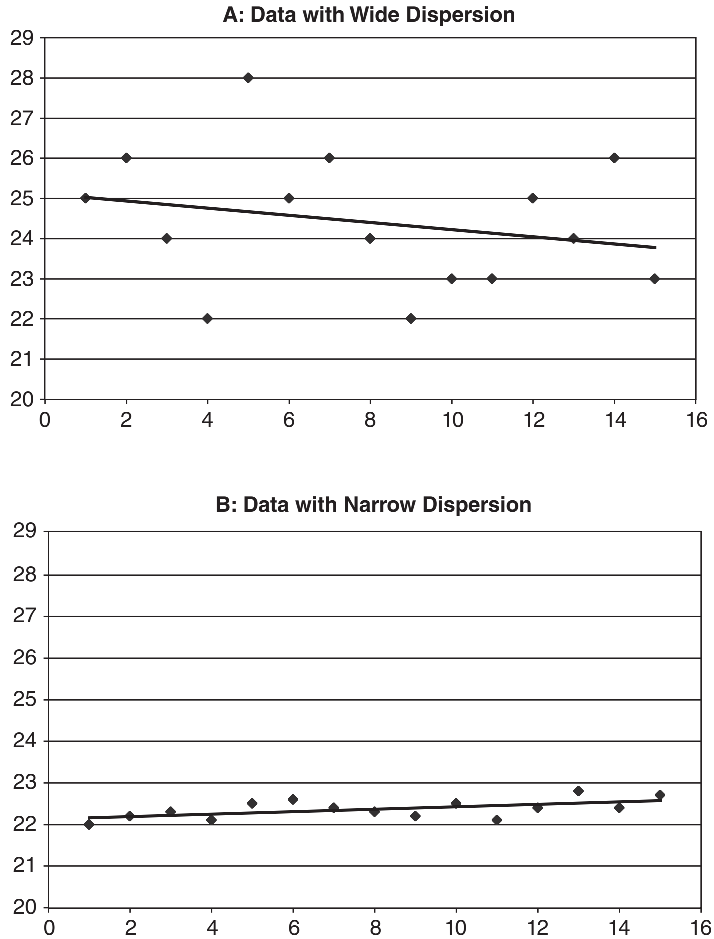

Figure 18-4 Dispersion of data points.

Figure 18-4 shows the difference between two data sets. The data points in (A) are widely scattered or distributed about the mean while those in (B) are all very close together around the mean. Note that the averages of these two data sets are nearly equal but the standard deviations are quite different. Figure 18-5 shows the bell-shaped distribution curve. One, two, and three standard deviations in each case are shown on the graph. You can see here that, at one SD only 68 percent of the valid failure rates are included. At two standard deviations above the mean, you still have not included all the points in the distribution. In fact, two standard deviations above and below the mean encompass only 95.5 percent of the points under the curve; i.e., just over 95 percent of the valid failure rates. This is why we do not consider an event rate in this range a definite problem. If it remains above this level in the following month it may suggest a possible problem.

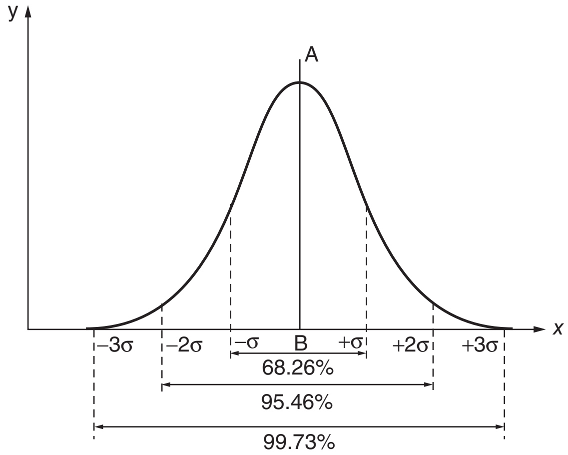

Figure 18-5 Standard bell-shaped curve. (*Source*: *The Standard Handbook for Aeronautical and Astronautical Engineers*, New York, NY: McGraw-Hill, 2003.)

On the other hand, if the event rate data you are working with had a small standard deviation, it would be difficult to distinguish between two and three SDs. In this case, the alert level should be set at three SDs.

This alert level system can be overdone at times. The statistics used are not exact. We are assuming that the event rates will always have a distribution depicted by the bell-shaped curve. We assume that our data are always accurate and that our calculations are always correct. But this may not be true. These alert levels are merely guidelines to identifying what should be investigated and what can be tolerated. Use of the alert level is not rocket science but it helps ease the workload in organizations with large fleets and small reliability staffs. Some airlines, using only event rates, will investigate perhaps the 10 highest rates; but this does not always include the most important or the most significant equipment problems. The alert level approach allows you to prioritize these problems and work the most important ones first.

Data display

Several methods for displaying data are utilized by the reliability department to study and analyze the data they collect. Most operators have personal computers available so that data can easily be displayed in tabular and graphical forms. The data are presented as events per 100 or 1000 flight hours or flight cycles. Some, such as delays and cancellations, are presented as events per 100 departures. The value of 100 allows easy translation of the rate into a percentage.

Tabular data allow the operator to compare event rates with other data on the same sheet. It also allows the comparison of quarterly or yearly data (see Table 18-1). Graphs, on the other hand, allow the operator to view the month-to-month performance and note, more readily, those items that show increasing

TABLE 18-1 Pilot Reports per 100 Landings (by ATA Chapter)

ATA Chapter	System	PIREPS	June-99	July-99	August-99	Three-month average	UCL	Mean	Alert status
21	Air conditioning	114	3.65	3.77	3.80	3.74	3.75	2.70	YE
22	Auto flight	43	1.80	1.48	1.45	1.58	1.39	1.21	WA
23	Communications	69	3.44	2.75	2.33	2.84	2.80	2.30	CL
24	Electrical power	29	1.15	0.87	0.98	1.00	0.94	0.60	AL
25	Equip/furnishings	104	4.17	3.69	3.52	3.79	5.43	4.38	
26	Fire protection	30	1.80	1.30	1.01	1.37	2.19	1.14	
27	Flight controls	48	0.99	3.07	1.62	1.89	1.94	1.26	
28	Fuel	36	0.65	1.16	1.22	1.01	2.32	1.27	
29	Hydraulic power	17	0.73	0.43	0.57	0.58	1.58	0.82	
30	Ice & rain protection	12	0.61	0.65	0.41	0.56	0.72	0.56	
31	Instruments	49	1.76	1.48	1.66	1.63	2.46	1.66	
32	Landing gear	67	2.41	2.06	2.27	2.25	2.72	1.76	
33	Lights	72	3.48	3.15	2.43	3.02	3.32	2.42	
34	Navigation	114	4.81	6.62	3.85	5.09	5.58	4.70	
35	Oxygen	19	0.31	0.67	0.64	0.54	0.41	0.23	YE
36	Pneumatics	25	1.11	0.80	0.85	0.92	1.19	0.77	
38	Water & waste	16	0.42	0.36	0.54	0.44	1.10	0.56	
49	Aux. power	42	1.41	1.48	1.42	1.44	1.63	1.38	
51	Structures	0	0.00	0.00	0.00	0.00	0.16	0.09	
52	Doors	31	1.41	1.05	1.05	1.17	1.62	0.92	
53	Fuselage	0	0.00	0.00	0.00	0.00	0.33	0.02	
54	Nacelles & pylons	1	0.00	0.00	0.08	0.03	0.22	0.10	
55	Stabilizers	0	0.00	0.00	0.00	0.00	0.16	0.09	
56	Windows	0	0.00	0.04	0.00	0.01	0.09	0.06	
57	Wings	0	0.00	0.00	0.00	0.00	0.33	0.15	
71	Power plant	11	0.65	0.54	0.37	0.52	1.30	0.91	
72	Engine	4	0.31	0.29	0.14	0.25	0.47	0.22	
73	Fuel & controls	17	0.96	0.47	0.57	0.67	0.84	0.61	
74	Ignition	11	0.08	0.40	0.37	0.28	0.46	0.30	
75	Air	53	1.52	1.63	1.79	1.65	1.11	0.66	RA
76	Engine control	3	0.23	0.14	0.10	0.16	0.33	0.15	
77	Engine indicating	22	0.53	0.76	0.74	0.68	0.96	0.68	
78	Exhaust	3	0.50	0.43	0.10	0.34	0.90	0.64	
79	Oil	5	0.19	0.22	0.17	0.19	0.83	0.48	
80	Starting	3	0.27	0.29	0.10	0.22	0.28	0.17	CL
	Total	1070							

NOTE: Alert status codes: CL = clear from alert; YE = yellow alert; AL = red alert; RA = remains in alert; WA = watch.

rates and appear to be heading for alert status (see Fig. 18-3). This is a great help in analysis. Some of the data collected may be compared on a monthly basis, by event, or by sampling.

Table 18-1 is a listing of pilot reports (PIREPS) or maintenance logbook entries recorded by a typical airline for 1 month of operation for a fleet of aircraft. The numbers are examples only and do not represent any particular operator, aircraft, or fleet size. For these data, a tally is kept by ATA Chapter, and event rates are calculated as PIREPS per 100 landings. The chart shows data for the current month (August '99) and the two previous months along with the

3-month rolling average. The alert level or UCL and the mean value of event rate, calculated as discussed in the text, are also included. Seven of these ATA Chapters have alert indications noted in the last column.

Chapter 21 has had an event rate above the UCL for 2 months running (July, August); therefore, this represents a yellow alert (YE). Depending on the severity of the problem, this may or may not require an immediate investigation. Chapter 24, however, is different. For July, the event rate was high, 1.15. If this were the first time for such a rate, it would have been listed in the report for that month as a watch (WA). The rate went down in July but has gone up again in August. In the current report, then, it is a full alert condition. It is not only above the alert level, it has been above 2 of the 3 months, and it appears somewhat erratic. It is left as an exercise for the student to analyze the other alert status items. What about ATA Chapter 38?

Data analysis

Whenever an item goes into alert status, the reliability department does a preliminary analysis to determine if the alert is valid. If it is valid, a notice of the on-alert condition is sent to engineering for a more detailed analysis. The engineering department is made up of experienced people who know maintenance and engineering. Their job relative to these alerts is to troubleshoot the problem, determine the required action that will correct the problem, and issue an engineering order (EO) or other official paperwork that will put this solution in place.

At first, this may seem like a job for maintenance. After all, troubleshooting and corrective action is their job. But we must stick with our basic philosophy from Chap.7 of separating the inspectors from the inspected. Engineering can provide an analysis of the problem that is free from any unit bias and be free to look at all possibilities. A unit looking into its own processes, procedures, and personnel may not be so objective. The engineering department should provide analysis and corrective action recommendations to the airline Maintenance Program Review Board (discussed later) for approval and initiation.

Note: Appendix C discusses the troubleshooting process that applies to engineers as well as mechanics; and Appendix D outlines additional procedures for reliability and engineering alert analysis efforts.

Corrective action

Corrective actions can vary from one-time efforts correcting a deficiency in a procedure to the retraining of mechanics to changes in the basic maintenance program. The investigation of these alert conditions commonly results in one or more of the following actions: (*a*) modifications of equipment; (*b*) change in or correction to line, hangar, or shop processes or practices; (*c*) disposal of defective parts (or their suppliers); (*d*) training of mechanics (refresher or upgrade); (*e*) addition of maintenance tasks to the program; or (*f*) decreases in maintenance

intervals for certain tasks. Engineering then produces an engineering order for implementation of whatever action is applicable. Engineering also tracks the progress of the order and offers assistance as needed. Completion of the corrective action is noted in the monthly reliability report (discussed later). Continual monitoring by reliability determines the effectiveness of the selected corrective action.

Corrective actions should be completed within 1 month of issuance of the EO. Completion may be deferred if circumstances warrant, but action should be completed as soon as possible to make the program effective. Normally, the Maintenance Program Review Board (MPRB) will require justification in writing for extensions of this period; the deferral, and the reason for deferral, will be noted in the monthly report.

Follow-up analysis

The reliability department should follow up on all actions taken relative to on-alert items to verify that the corrective action taken was indeed effective. This should be reflected in decreased event rates. If the event rate does not improve after action has been taken, the alert is reissued and the investigation and corrective action process is repeated, with engineering taking a different approach to the problem. If the corrective action involves lengthy modifications to numerous vehicles, the reduction in the event rate may not be noticeable for some time. In these cases, it is important to continue monitoring the progress of the corrective action in the monthly report along with the ongoing event rate until corrective action is completed on all vehicles. Then follow-up observation is employed to judge the effectiveness (wisdom) of the action. If no significant change is noted in the rates within a reasonable time after a portion of the fleet has been completed, the problem and the corrective action should be reanalyzed.

Data reporting

A reliability report is issued monthly. Some organizations issue quarterly and yearly reports in summary format. The most useful report, however, is the monthly. This report should not contain an excessive amount of data and graphs without a good explanation of what this information means to the airline and to the reader of the report. The report should concentrate on the items that have just gone on alert, those items under investigation, and those items that are in or have completed the corrective action process. The progress of any items that are still being analyzed or implemented will also be noted in the report, showing status of the action and percent of fleet completed if applicable. These items should remain in the monthly report until all action has been completed and the reliability data show positive results.

Other information, such as a list of alert levels (by ATA Chapter or by item) and general information on fleet reliability will also be included in the monthly report. Such items as dispatch rates, reasons for delays and/or cancellations,

flight hours and cycles flown and any significant changes in the operation that affect the maintenance activity would also be included. The report should be organized by fleet; i.e., each airplane model would be addressed in a separate section of the report.

The monthly reliability report is not just a collection of graphs, tables, and numbers designed to dazzle higher-level management. Nor is it a document left on the doorstep of others, such as QA or the FAA, to see if they can detect any problems you might have. This monthly report is a working tool for maintenance management. Besides providing operating statistics, such as the number of aircraft in operation, the number of hours flown, and so forth, it also provides management with a picture of what problems are encountered (if any) and what is being done about those problems. It also tracks the progress and effectiveness of the corrective action. The responsibility for writing the report rests with the reliability department, not engineering.

Other Functions of the Reliability Program

Investigation of the alert items by engineering often results in the need to change the maintenance program. This can mean (*a*) changes in specific tasks; (*b*) adjustments in the interval at which maintenance tasks are performed; or (*c*) changes in the maintenance processes (HT, OC, and CM) to which components are assigned. A change in the task may mean rewriting maintenance and/or test procedures or in implementing new, more effective procedures.

Adjustments in the maintenance interval may be a solution to a given problem. A maintenance action currently performed at, say a monthly interval, should, in fact, be done weekly or even daily to reduce the event rate. The reliability program should provide the rules and processes used to adjust these intervals. The MPRB must approve these changes and, in certain instances, the regulatory authority must also approve. Generally, though, the change to a greater frequency (shorter interval) is not difficult. One should keep in mind, however, that this means higher cost of maintenance due to the increase in maintenance activity. This cost must be offset by the reduction in the event rate that generated the change and a reduction in the maintenance requirements resulting from the change. The economics of this change is one of the concerns engineering must address during the investigation of the alert condition. The cost of the change may or may not be offset by the gain in reliability or performance (see objective 5 in Chap. 3).

Administration and Management of the Reliability Program

On the administration and management side, a reliability program will include written procedures for changing maintenance program tasks, as well as processes and procedures for changing maintenance intervals (increasing or decreasing them). Identification, calculation, establishment, and adjustment of alert levels

and the determination of what data to track are basic functions of the reliability section. Collecting data is the responsibility of various M&E organizations, such as line maintenance (flight hours and cycles, logbook reports, etc.); overhaul shops (component removals); hangar (check packages); and material (parts usage). Some airlines use a central data collection unit for this, located in M&E administration, or some other unit such as engineering or reliability. Other airlines have provisions for the source units to provide data to the reliability department on paper or through the airline computer system. In either case, reliability is responsible for collecting, collating, and displaying these data and performing the preliminary analysis to determine alert status.

The reliability department analyst in conjunction with MCC keeps a watchful eye on the aircraft fleet and its systems for any repeat maintenance discrepancies. The analyst reviews reliability reports and items on a daily basis, including aircraft daily maintenance, time-deferred maintenance items, MEL, and other out-of-service events with any type of repeat mechanical discrepancies.

The analyst plans a sequence of repair procedures if aircraft have repeated the maintenance discrepancy three times or more and have exhausted any type of fix to rid the aircraft of the maintenance discrepancy. The analyst is normally in contact with the MCC and local aircraft maintenance management to coordinate a plan of attack with the aircraft manufacturer's maintenance help desk to ensure proper tracking and documenting of the actual maintenance discrepancy and corrective action planned or maintenance performed. These types of communication are needed for an airlines to run a successful maintenance operation and to keep the aircraft maintenance downtime to a minimum. This normally occurs when a new type of aircraft is added to the airline's fleet. Sometimes maintenance needs help fixing a recurring problem.

Maintenance program review board

The solution of reliability problems is not the exclusive domain of the reliability section or the engineering section; it is a maintenance and engineering organization-wide function. This group approach ensures that all aspects of the problem have been addressed by those who are most familiar with the situation. Therefore, oversight of the program is assigned to a MPRB that is made up of key personnel in M&E. Based on the typical organization of Chap. 7, the MPRB would consist of the following personnel:

1. Director of MPE as chairman
2. Permanent members
   a. Director of technical services
   b. Director of airplane maintenance
   c. Director of overhaul shops
   d. Director of QA and QC
   e. Manager of QA and QC

f. Manager of engineering
g. Manager of reliability

3. Adjunct members are representatives of affected M&E departments
   a. Engineering supervisors (by ATA Chapter or specialty)
   b. Airplane maintenance (line, hangar)
   c. Overhaul shops (avionics, hydraulics, etc.)
   d. Production planning and control
   e. Material
   f. Training

The head of MPE is the one who deals directly with the regulatory authority, so as chairman of the MPRB, he or she would coordinate any recommended changes requiring regulatory approval.

The MPRB meets monthly to discuss the overall status of the maintenance reliability and to discuss all items that are on alert. The permanent members, or their designated assistants, attend every meeting; the advisory members attend those meetings where items that relate to their activities will be discussed. Items coming into alert status for the recent month are discussed first to determine if a detailed investigation by engineering is needed. Possible problems and solutions may be offered. If engineering is engaged in or has completed investigation of certain problems, these will be discussed with the MPRB members. Items that are currently in work are then discussed to track and analyze their status and to evaluate the effectiveness of the corrective action. If any ongoing corrective actions involve long-term implementation, such as modifications to the fleet that must be done at the "C" check interval, the progress and effectiveness of the corrective action should be studied to determine (if possible) whether or not the chosen action appears to be effective. If not, a new approach would be discussed and subsequently implemented by a revision to the original engineering order.

Other activities of the MPRB include the establishment of alert levels and the adjustment of these levels as necessary for effective management of problems. The rules governing the reliability program are developed with approval by the MPRB. Rules relating to the change of maintenance intervals, alert levels, and all other actions addressed by the program must be approved by the MPRB. The corrective actions and the subsequent EOs developed by the engineering department are also approved by the MPRB before they are issued.

Reliability program document

The Maintenance Review Board (MRB), derived from the FAA Advisory Circular AC 121-22B, provides guidelines for the aviation industry to use minimum scheduled interval/tasking requirements for derivative and/or newly type-certificated aircraft and their power plants for FAA approval. The AC 121-22B also refers to schedule interval requirements as the Maintenance Review Board Report (MRBR). After receiving approval from the FAA, an operator may generate or develop its own maintenance program for its particular type of fleet.

The air carrier may use this AC's provisions along with its own or other maintenance information to standardize, develop, implement, and update the FAA-approved minimum schedule of maintenance and/or inspection requirements for this program to become a final written report for each type of certificate holder.

The MRB revision issued by the manufacturer is sent to the fleet maintenance manager (FMM) or a maintenance person assigned by the air carrier. In some cases, this is the director of maintenance (DOM). The FMM/ DOM interfaces with the aircraft maintenance and production department to advise them about the MRB program updates and revisions. The air carrier normally tracks each revision by fleet type to ensure the corrective action plan has been recommended to bring the maintenance production department into compliance. The MRB runs concurrent with the continuous analysis and surveillance system (CASS) and the reliability-centered maintenance (RCM) and is applied using the maintenance steering group MSG-3 system. The MSG-3 origination is associated with the Air Transport Association of America (ATA). The ATA coding system (detailed in Chap. 5) divides aircraft into distinct ATA units, and every ATA unit is analyzed for regulatory purposes to understand the results retrieved from the system and then passed on to an aviation industry steering group/committee. After the data has been reviewed by the steering committee and approved by the regulatory board for the MRB, the results are published as part of the aircraft maintenance manual.

This document also includes detailed discussion of the data collection, problem investigation, corrective action implementation, and follow-up actions. It also includes an explanation of the methods used to determine alert levels; the rules relative to changing maintenance process (HT, OC, CM), or MPD task intervals; when to initiate an investigation; definitions of MPRB activities and responsibilities; and the monthly report format. The document also includes such administrative elements as responsibility for the document, revision status, a distribution list, and approval signatures.

The reliability program document is a control document and thus contains a revision status sheet and a list of effective pages, and it has limited distribution within the airline. It is usually a separate document but can be included as part of the TPPM.

FAA interaction

It is customary, in the United States, to invite the FAA to sit in on the MPRB meetings as a nonvoting member. (They have, in a sense, their own voting power.) Since each U.S. airline has a principal maintenance inspector (PMI) assigned and usually on site, it is convenient for the FAA to attend these meetings. Airlines outside the United States that do not have the on-site representative at each airline may not find it as easy to comply. But the invitation should be extended nevertheless. This lets the regulatory authority know that the airline is attending to its maintenance problems in an orderly and systematic manner and gives the regulatory people an opportunity to provide any assistance that may be required.

Chapter

19

Maintenance Safety

Industrial Safety

The Code of Federal Regulations, Title 29, Part 1910, deals with industrial safety (29 CFR 1910). Its title is "Occupational Safety and Health Standards" and is part of the U.S. Government regulations for the Department of Labor (DOL). The agency within DOL responsible for enforcing these regulations is the Occupational Safety and Health Administration (OSHA). Aviation is not addressed specifically in these OSHA regulations, but all aspects of the aviation maintenance activity (as well as flight operations, office, and terminal activities) are covered. Table 19-1 lists the subparts of Part 1910 as of January 2003. It is up to the aviation industry itself to ferret out those parts and subparts of 29 CFR 1910 that apply to aviation matters and materials and to tailor the requirements directly to those airline activities.

Safety Regulations

The federal hazard communications (FHC) standard, 29 CFR 1910.1200, requires that management provide information about chemical hazards in the work force to all employees. This becomes part of the airline's safety program through the distribution of material safety data sheets (MSDS). These data sheets are generated by the chemical manufacturer and identify the hazards, precautions, and first aid instructions relative to the chemical's use. The airline safety managers must make the appropriate MSDSs available to anyone who may use or come in contact with the chemical. The airline may add any additional information to the MSDS as necessary to clarify the use of the chemical, as well as provide information on reporting incidents and hazards. The manufacturer's MSDS is general and deals with the chemical; the airline additions to the MSDS address specific airline concerns and procedures.

TABLE 19-1 Occupational Safety and Health Standards

Subpart	Title
A	General
B	Adoption and extension of established federal standards
D	Walking–working surfaces
E	Means of egress
F	Powered platforms, man-lifts, and vehicle-mounted work platforms
G	Occupational health and environmental control (ventilation, noise, nonionizing radiation)
H	Hazardous materials
I	Personal protective equipment
J	General environmental controls (sanitation, lockout/tagout, marking of hazards)
K	Medical and first aid
L	Fire protection
M	Compressed gas and compressed air equipment
N	Materials handling and storage
O	Machinery and machine guarding
P	Hand and portable power tools and other hand-held equipment
Q	Welding, cutting, and brazing
R	Special industries (pulp, paper, textiles, etc.)
S	Electrical
T	Commercial diving operations

Physical hazards, such as noise, ionizing radiation, nonionizing radiation, and temperature extremes, for example, are governed by other parts of 29 CFR 1910 and should also be addressed in the airline's safety program. This program would provide for the availability, training, and use of protective equipment, safety measures, and safety processes.

Posture, force, vibration, and mechanical stress are common hazards workers are subject to in all work areas. The amount and type of exposure, of course, varies with the work being done. The airline safety program should address each work center's specific needs.

Viruses, bacteria, fungi, and other substances that can cause disease are included in the regulations. These biological hazards come under the health classification and also vary depending upon the kind of work being done and other work environment conditions.

Many of these safety and health requirements are already addressed in aviation industry documents and regulations. Airframe manufacturer's maintenance manuals, for example, usually cover safety features related to the performance of maintenance, such as the use of safety harnesses, use of protective clothing and equipment, the proper handling of hazardous materials, and the lockout and tagging of certain electrical and mechanical equipment to avoid inadvertent operation or subsequent accidents while people are working on or near such systems. The airline's operations specifications may identify other safety requirements. The TPPM, of course, should contain a summary of the entire maintenance safety program, and the safety manager should monitor all aspects of the program

to ensure compliance with the OSHA requirements. This compliance, of course, is part of the QA audit responsibilities, but due to the special nature, safety is established as a separate function to monitor these activities.

Maintenance Safety Program

FAR 119.65 identifies, but does not define, the basic positions required to operate an airline. Although certain positions are deemed necessary, the certificate holder will determine actual titles as well as the level of the office within the structure. Paragraph (d) of 119.65 says that the certificate holder will define the "duties, responsibilities, and authority"[1] for all positions in the organization. The person in charge of safety is responsible for the overall safety program at the airline. There may be separate safety program managers for flight operations, maintenance, and the other administrative and managerial functions of the airline. One may be coordinator of the others, but the individuals will have responsibilities in their own work areas. In our typical, midsized airline (see Fig. 7-1) we have identified the maintenance safety program within the MPE directorate with the other maintenance oversight functions.

The maintenance safety program manager has the following primary responsibilities:

1. Identify and assess all health and safety hazards within the various M&E work areas
2. Determine protective measures needed for hazardous conditions and ensure that protective clothing and equipment are available to the workers as necessary
3. Make information available to workers handling hazardous chemicals, on the hazards and handling procedures involved with those chemicals, including any data supplied by the manufacturer, and any additional information deemed necessary for the airline activities
4. Provide training on the identification of hazards, on the location and use of safety equipment, and on first aid and reporting procedures involved
5. Establish and document the safety program in the technical policies and procedures manual (TPPM).

General Responsibilities for Safety

Safety, as has been said by so many others, is everyone's job. Certain responsibilities for safety, however, are assigned to the company itself; other responsibilities are assigned to the safety manager (coordinator, director, or whatever his or her title), to the individual supervisors, and to the employees. Each of these is discussed in turn.

[1]Federal Aviation Regulation 119.65.

Airline safety management

As for any airline, safety is the number one priority. Every airline strives to be the leader in aviation safety by promoting safety to its employees from top management to mechanics and other personnel. An airline's commitment to safety, security, and quality is demonstrated by their enthusiasm in developing, implementing, maintaining, and continually improving their safety culture via safety management systems in order to achieve the desired results. Since there are many other departments besides aircraft maintenance, each department is responsible for training employees about accident prevention, on-the-job injuries, and environmental issues.

Airlines normally create policy manuals that help them evaluate, change, edit, modify, or delete policies and procedures as they see fit. The airline's safety program helps them conduct their operation in the safest way possible. Safety programs cover all property and equipment belonging to the company. The safety program's purpose is not to replace any other program or any other manuals, but to coexist with and effectively maximize all safety initiatives. The program serves as an early warning system for risk management. The airline's safety department must be up to date with developments in aviation. The airline's safety manual reflects its policies, procedures, and how it does business. It also shows that their commitment must extend to all employees, customers, and vendors to adhere to a maximum level of safety, and it encourages open communication, concern for safety, identification of hazards, and taking appropriate action to correct dangerous or potentially dangerous situations.

The airline is required to provide safe and sanitary working conditions in all its facilities. This will include adequately stocked and updated first aid kits in all hangars and work centers; eye wash and shower facilities in areas where acids and other caustic materials or irritants are used; and fire extinguishers, both chemical and CO_2 types as applicable, in easily accessible locations throughout the M&E work areas. Fire extinguishers should be checked regularly to ensure viability and tagged to indicate the date of inspection. Appropriate protective clothing should be available to employees who are required to work with acids and corrosive materials. Safety glasses or goggles, earplugs, and protective shields should also be available and accessible. The company is also responsible for providing the necessary training in the use and location of these safety items; and the establishment, in the technical policies and procedures manual, of requirements for the use of safety equipment, and the applicable procedures for such use. To protect equipment and personnel, the airline must also provide for adequate grounding of aircraft and adequate fire extinguishing capabilities on the flight line and in the hangar, including automatic deluge systems for the hangar. Procedures for moving people and aircraft out of burning hangars and buildings are also required.

Safety manager responsibilities

The safety coordinator is manager and administrator of the safety program. He or she is responsible for establishing the safety rules and procedures; for auditing

the M&E facilities, along with QA, for adherence to safety policy; for developing improvements in the safety program; and for maintaining records and filing claims relative to accidents and incidents involving M&E personnel and equipment. The filing of accident and incident claims may be an airline administrative function (personnel, legal, etc.), but the M&E safety coordinator will be directly involved with claims from the M&E areas.

Supervisor responsibilities

Each work center supervisor is responsible for the safety of his or her facilities and personnel, beginning with clean, well-kept offices, shops, and other work areas. The supervisor must enforce all safety rules and provide instructions and interpretations of rules, regulations, and methods for preventing accidents or incidents within his or her work area.

Employee responsibilities

Each employee of an airline, whether licensed mechanic, unlicensed helper, worker, supervisor, or manager, is responsible for compliance with all airline safety rules and practices. They are all responsible for reporting to their immediate supervisor or manager deficiencies such as abnormalities, unsafe practices, and unsafe equipment. Employees are also responsible for the proper use of tools and equipment and the proper operation of machinery. They are also expected to apply safety rules that they have learned from safety classes and training.

General Safety Rules

There are several special areas of concern for any airline maintenance safety program that require further discussion. These are smoking regulations, fire prevention, fire protection, storage and handling of hazardous materials, fall safety and protection, and hangar deluge systems.

Smoking regulations

The term *smoking materials* refers to cigars, cigarettes, pipes, and other flammable materials such as matches and lighters. The safety coordinator should designate "No Smoking" areas, and the regulations must be enforced. Typical no smoking areas include the following: (*a*) inside aircraft at any time; (*b*) within 50 feet of an aircraft parked on the ramp; (*c*) within 50 feet of any refueling activity or refueling equipment; (*d*) within 50 feet of oil, solvent, or paint storage areas; (*e*) inside hangars, except in offices, washrooms, and other areas designated for smoking; and (*f*) any location of the airport designated as no smoking by the airport authority.

Other requirements for fire safety relative to smoking materials also apply. Personnel should refrain from smoking after being subjected to fuel spills or other flammable materials or vapors. This applies to other personnel who may

encounter those involved in such spills. The restriction applies until the spilled material has been cleaned up and the vapors eliminated.

Lighted smoking materials should not be carried from one designated smoking area to another through nonsmoking areas. Smoking materials should be extinguished only in suitable ashtrays or other fireproof containers and not on floors, in trashcans, or in other unsuitable receptacles.

Fire prevention

Smoking materials are not the only sources of ignition for fires. Electrostatic discharge can also provide the spark needed for ignition of flammable vapors and other substances. For that reason, all aircraft should be properly grounded while they are in the hangar or on the ramp, especially during refueling and defueling operations. Other materials susceptible to combustion include rags and paper. Combustible rags must be stored in National Fire Protection Association (NFPA)-approved, closed containers, and paper and other combustible trash must be stored in suitable trash cans. Other items, such as volatile cleaning fluids with a low flash point, oils, and paints, must also be properly stored and handled. When these items are present, the no smoking rules will apply and adequate ventilation will be required.

The supervisor of any work center where these volatile materials are used must ensure that the products are stored properly and in quantities commensurate with reasonable needs. Use of these and other volatile materials will not be carried out in any room where there are open flames, operating electrical equipment, welding operations (arc or acetylene), or grinding activities.

Flammable materials, such as paints, dopes, and varnishes, must be kept in NFPA-approved, closed containers away from excessive heat or other sources of ignition. Bulk supplies of these must be stored in a separate building at a location remote from the maintenance activity. If it becomes necessary to perform welding activities on aircraft, the management must determine proper procedures and arrange for standby fire fighters and equipment during the exercise.

Hangar deluge systems

Airplane hangars are complex and expensive structures, and they often contain one or more aircraft, which are considerably more expensive than the building itself. The multitude of other equipment in the hangar, and the fact that aircraft may be jacked up, surrounded by scaffolding and maintenance stands, or in some other condition detrimental to moving them readily, make it imperative that these hangars be equipped with sufficient fire suppression equipment to protect the airline's investment.

There will be fire extinguishers positioned around the aircraft and hangar work areas (both CO_2 and foam as required) and all fire and safety regulations will be enforced. But there is one more very important system required to protect the 50-to 150-million dollar aircraft. This equipment, installed in numerous hangars around the world, is known as the *hangar deluge system*. These are

elaborate systems with tanks of fire retardant chemicals buried in the ground or beneath the hangar floor, connected with a plumbing system that essentially mixes the retardant with water to create the foam and dispenses it throughout the hangar. The system usually has a control room in, or adjacent to, the hangar where operators can operate the system and direct the firefighting equipment (movable, adjustable nozzles) to specific areas; or the system can be automatic, covering the entire hangar.

The order of activity is to evacuate personnel from the hangar and release the fire suppressant. The time it would take to move an aircraft out, if it were in a condition to allow such movement, would very often be more than one would have.

Fall prevention and protection

The OSHA regulations concerning fall protection and prevention refer to work surfaces, scaffolding, and other high and precarious places, such as building construction sites, but not specifically the wings and fuselages of airplanes where maintenance people have to go occasionally. However, the same philosophy exists. Dangerous areas must be identified and should have specific equipment and procedures in place to protect anyone involved in working these areas.

Aircraft do not have nice, flat surfaces as afforded by buildings and scaffolding. Although OSHA rules for such structures (rails, safety belts, and harnesses) do apply, the rounded surfaces of aircraft present additional problems. For one thing, aircraft surfaces are not always safe to walk on at all and are so noted with large, black letters: “NO STEP.” The curved surfaces, and the fact that there is usually no structure to grab hold of to retard your fall, makes aircraft walking even more dangerous than other high places. The OSHA rules specify that a worker should not have a distance greater than 4 feet in which to fall. Anything greater requires safety gear in the form of rails, belts, or harnesses or some combination of these. The top of a 747 fuselage is 32 feet 2 inches from the tarmac—approximately three stories high.

Accident and Injury Reporting

Each incident involving airline personnel that results in damage to facilities and/or equipment or in injury to personnel must be reported to the safety manager, regardless of whether the personnel, equipment, or facilities is owned by the airline or some other unit. An initial report will be made immediately after the accident or incident occurs using telephone, telex, fax, radio, or any other means of communication available. This report should be made directly to the safety office if the event occurred on the home base or through the MCC if it occurred at an outstation. Within 24 hours of the event, the work center supervisor where the accident or incident occurred will send a completed accident report or personnel injury report, as applicable, to the safety office. Forms for such reports should be developed by the safety office and made available to all airline work centers. Samples of these forms and the instructions for proper

completion and submission of the forms should be included in the safety program section of the technical policies and procedures manual.

The safety office will create a log of all accident and incident activities involving airline personnel whether at the home station, at outstations, or at contractor facilities. The PP&C organization will issue a work order number for the tracking of each accident or incident through the process of investigation, repair, insurance claims, or any other process required. The work order will also serve to collect time and cost data relative to the accident or incident.

Part

V

Appendixes

The material in the following appendixes is provided to enhance the other chapters in the book. Systems Engineering, Appendix A, normally a design engineering activity, is extended here to include the entire life span of the equipment. Understanding systems is important to understanding aircraft and maintenance problems. Both engineers and maintenance personnel can benefit from this approach.

Human factors in maintenance has received a lot of emphasis in recent years. Appendix B of this book provides a brief history of the field and an overview of human factors activities in aviation maintenance. It also discusses the need to include human factors in the systems engineering concept.

Troubleshooting is often poorly taught in tech schools and sometimes it is omitted all together. Appendix C, "The Art and Science of Troubleshooting," is provided here as a guideline to assist M&E in developing better techniques for solving problems in line, hangar, and shop maintenance as well as in engineering.

Appendix D, "Investigation of Reliability Alerts," is about the process of analyzing reliability alert conditions and resolving maintenance problems. It is primarily for use by reliability and by engineering. This process is both an application of and extension of the troubleshooting process discussed in Appendix C.

Appendix E is a brief discussion of the extended range operations with two-engine aircraft (ETOPS).

Appendix F is a glossary of commonly used terms.

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Appendix A

Systems Engineering

Introduction

Ordinarily, when we speak of systems or systems engineering, we think of electrical, mechanical, or hydraulic systems or systems which combine some or all of these disciplines. We usually think of weapons systems, communications systems, and other collections of many parts, components, and disciplines. But there are other types of systems: governmental systems (democracy, oligarchy, dictatorship, etc.), operational systems (checklists, procedures, etc.), and maintenance systems (groups of scheduled tasks, procedures for unscheduled maintenance, etc.). Even paperwork can be considered a system; for example, a series of forms one fills out for a job or for a government or commercial contract. A system, then, can be more than mechanical or electrical parts. A system is a set of elements of one sort or another that, together, perform some function or allow some desired result. Any organized set of components, procedures, or actions—mechanical, electrical, mental, physical, procedural, conceptual—that are organized to produce some intended result can be classified as a system. A system is an instrument of accomplishment.

This system concept can be applied before, during, or after the fact. By that we mean system concepts can be applied prior to the creation of some entity (design work); during the process of design and development (step-by-step procedures through a process); or after the fact (analysis of results, maintenance, or operation of the system).

Systematic versus Systems Approach

There are two terms that are used, often interchangeably, which are not quite the same. Those terms are the *systematic approach* and the *systems approach*. The term *systematic approach* usually refers to a step-by-step process, an essentially linear process or procedure where one accomplishes some goal by performing one

step at a time, in sequence, until the desired result or goal is achieved. An example would be a flight crew's checklist or a maintenance procedure for testing a unit or for removing and replacing a component. The systematic approach is a deliberate step-by-step process performed the same way every time. It is methodical; it is systematic.

The *systems approach*, as used in this book, is somewhat different. A system can be simple in construction and involve a series of steps or processes performed one at a time or in a continuous flow. But most systems are a bit more complex. Perhaps there are numerous elements performing simultaneously, in consonance with or, in some instances, in opposition to one another, such as feedback loops (electrical) or dampers (mechanical). There can be various inputs and outputs exchanged by various elements of the system all controlled by numerous internal and external events. This is truly a multidimensional process—quite different from a simple, linear one.

The systems approach to any problem or system involves the ability to see all of these interacting elements in relation to one another and to understand the overall outcome of their activity. The systems approach is the process of looking at, understanding, and reacting to all aspects of the complex system individually and collectively. While all the parts must function as intended by the designers, the conglomerate of all these interacting parts must also function together as the system was intended. The systems approach, then, is the process of seeing and understanding all aspects of the system at once and how they interact to achieve the desired goal. And this is true whether you are designing a system, using a system, maintaining a system, or teaching the system's attributes to someone else. You may use the systematic approach at certain times during the process, but the systems approach requires simultaneous knowledge and understanding of all processes and elements within the system. In Appendix C, we illustrate how one sometimes needs to use a systematic approach on one section, function, or aspect of a system while trying to pinpoint a problem, but the overall process of fault location must also consider the system and its function as a whole. Thus, although the systems and the systematic approaches are significantly different, they are not necessarily mutually exclusive.

Systems Engineering

Systems engineering is a term used to describe the work of engineers and designers who address the "total systems aspect" at the design level of systems. The systems engineer is concerned with the system as a whole. He or she is tasked with ensuring that all interrelated components of a system interface properly and that all elements within the system ultimately function to provide the overall intent of the original system concept. The systems engineer is responsible for the "big picture" design aspects, for compatibility of interconnecting components (interface control), and for the overall system performance.

Definitions

To understand systems more thoroughly, we must first define a few terms: system, system boundaries, system elements (internal and external), and system interfaces. These are addressed below in turn.

System

Each engineering discipline has its own definition of a system. The *Systems Engineering Handbook*, by Robert E. Machol[1] lists six definitions of a system from various sources. Some of them are fairly concise; some are quite wordy. One of the definitions given involves mathematical equations. Other sources list additional, but similar, definitions.[2,3,4] When scrutinized, however, all of these definitions are essentially identical. We can generalize them by stating, "A system is a collection of components working together to perform a certain function."

This, however, is not an adequate definition. In Fig. A-1,[5] Rube Goldberg's "system" satisfies the definition but it is hardly an efficient method of performing the intended function. It isn't repeatable; it may not even work at all. In other words, it is a bad design. Some additional engineering must be done to Mr. Goldberg's system to solve the problem more efficiently. Two important concepts, design and efficiency, are missing from the basic definition stated above. We need to add these words to the definition so we can avoid imperfect systems.

> A *system* is a collection of components designed to work together to efficiently perform a certain function.

These two added words are the most important parts of the definition. No system is a good system unless it does its designed function efficiently. And no system can do that if it is composed of a collection of parts that were selected without regard to the interaction of those parts with one another. We will see later that the successful interface between individual components of a system is a very important part of systems engineering.

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[1]Machol, Robert E. (ed.): *System Engineering Handbook*, McGraw-Hill, New York, NY, 1965.

[2]Skolnik, Merril I.: *Introduction to Radar Systems*, Chap. 13, Systems Engineering and Design, McGraw-Hill, New York, NY, 1965.

[3]Meredith, Dale D., et al: *Design and Planning of Engineering Systems*, Prentice-Hall, Englewood Cliffs, NJ, 1973, p. 6.

[4]Fink, Donald G., editor-in-chief: *Electronics Engineers' Handbook*, Section 5, Systems Engineering, McGraw-Hill, New York, NY, 1975, p. 5-2.

[5]Wolfe, Maynard Frank: *Rube Goldberg Inventions*, Simon & Schuster, New York, 2000, p. 122. Reprinted with permission.

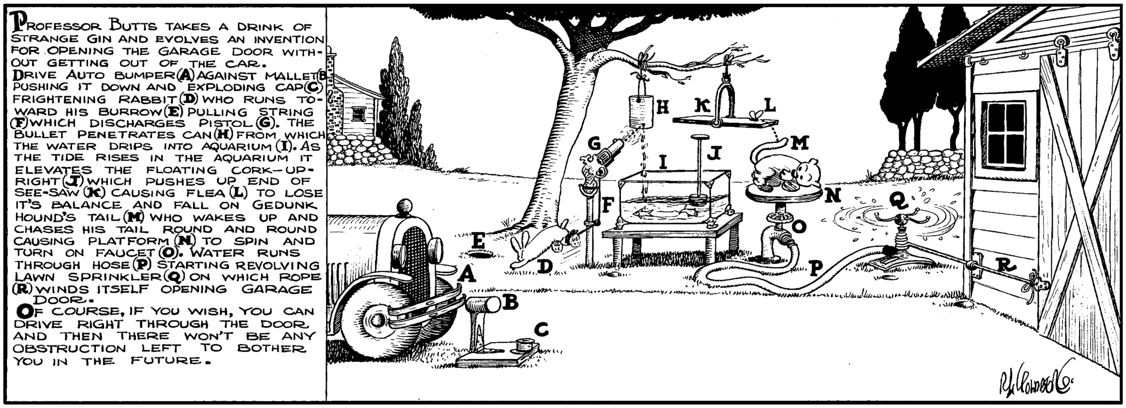

Figure A-1 A Rube Goldberg system. (*Source: Rube Goldberg is the ® and © of Rube Goldberg, Inc.*)

System levels

Any system can have associated parts, which can be called subsystems. These subsystems are systems in their own right and these systems, too, can have subsystems. Everything from the atom to the universe (not inclusive) is a subsystem of some other system and every thing from the atom to the universe (inclusive) is made up of subsystems. This "onion structure" defines the complexity of the world of systems engineering. To simplify matters, we need to define the limits of what we wish to study or build. This is done by identifying system boundaries.

System boundaries

The limits of consideration for a study, analysis, observation, or usage of a collection of components will identify the system boundaries. These boundaries vary with the extent of the study or with the degree or scope of consideration. For example, to an avionics engineer, a system may consist of the components that make up the spoiler control system on an airplane. A circuit designer might consider a single printed circuit board (PCB) in the spoiler control module as his or her system. To an aeronautical engineer, however, this spoiler control system would be just one component of the airplane flight controls system.

System element

Any component that can be assigned a function or an attribute within the context of the defined system is referred to as an element of the system. System elements can be internal or external depending on how the system boundaries are defined. We also use the terms *component* and *subsystem* interchangeably with the term *element*.

Internal elements

Internal elements are those elements that are within the defined boundaries of the system. They are the components or parts with which the system designer, user, operator, or maintainer is most concerned. These elements are what make the "black box" or system work, provided the inputs are available and correct.

External elements

Elements outside the defined boundaries of the system that have a direct or indirect relationship with system operation are called external elements. These elements may or may not be controllable. External elements consist, mainly, of system inputs and outputs. This would include operator or user inputs or signals, voltages, etc. from other interfacing systems. Electromagnetic interference (EMI) and weather might also be external elements of some systems.

System interface

An interface exists whenever two systems or two elements of a system connect or interact. This interaction can be direct or indirect; it can be electrical or mechanical; it can be through sensory devices or transmission devices. One interface we will consider in Appendix B is the interface between the human being and the defined system.

System Interface Control

One of the primary functions of the systems engineer at the design level is to ensure that, wherever two systems or system elements interact, this interface is designed for optimum performance. This is called interface control. With very complex systems, and in systems where various elements and subsystems are designed and built by different organizations, these interfaces must be precisely defined with specifications and tolerances, in a systems interface specification. This will ensure that all designers concerned will be working to the same set of specifications and that the system which results when these elements are connected together will "efficiently perform" the intended function.

Interface control, then, is the process of ensuring that all elements of the system efficiently and effectively interact with all other related elements. Mechanical or physical parts that have to engage; electrical or digital signals that are exchanged; data transmission modes and media required for communication; and many other elements, all have to be "designed" to interface properly.

Here is one fairly obvious example: One element of a system requires 28 volts direct current (dc) power input. Another element in the same system requires 115 volts alternating current (ac) at 400 Hertz. A computer chip, used in one of the unit's circuit boards, requires a regulated ±5 volts dc. The power supply designer, who may work for a different department or even a different company, must provide a power supply unit (i.e., a subsystem) that will deliver all these

voltages to the main system. Other specifications, such as voltage regulation and current limiting parameters, may also be specified by the system designer. Cables and connectors from the power supply must be compatible with all the interfacing units and care must be taken so that the cables supplying power to these units cannot inadvertently be crossed, delivering the wrong power to the unit. Possible signal loss or deterioration due to cable length must also be considered.

System Optimization

System optimization is another important concept in systems engineering. Optimizing one element or interface of a system will not necessarily optimize the entire system. When all elements of a system are optimized according to their respective designs and the corresponding state of the art in that discipline, they may no longer be compatible with regard to interface control. Here are some examples. One sophisticated electronic element may be too sensitive to variations in the inputs from some interfacing elements (signals or power inputs). A mechanical element (e.g., a metal clamp) may be made of a highly durable material to withstand extreme heat and vibration in the area where it will be used (on a jet engine, for example). But this clamp may be too hard for the delicate insulation of the fire sensing wire it is required to hold in place. As a result, the insulation could wear away, under the extreme vibration it endures, and eventually cause a short circuit and a false fire warning indication.[6]

There are a number of examples like the one concerning the clamps that are discovered during the operation of a system. While not all possible malfunctions or system imperfections can be predicted prior to or during the design phase of the system, the next similar system developed can have the benefit of these "lessons learned."

System optimization is the process of ensuring that all elements and all interfaces work together in such a way as to provide the best overall performance of the total system. System optimization includes not only operational performance but also system reliability, maintainability, and economic factors related to operation and maintenance.

An Example of a System—The "Onion Layered" Structure

Let us talk about the component at the center of our interest in this book, the commercial aircraft. These systems (airplanes) are a part of the commercial aviation system that is, in turn, part of the air transportation system. Air transportation is a part of the total national transportation system, which consists of air, land, sea, pipeline, and rail systems.

If we consider the airplane our system of interest, we can consider any of its hundreds of subsystems—flight controls, for example. Flight controls can be

[6]This situation actually occurred on a modern jet airliner engine.

divided into two broad categories: primary flight controls (ailerons, elevators, rudders) and secondary flight controls (flaps, slats, spoilers, trim tabs). Any one of these systems or subsystems can be further divided into components categorized as electrical, mechanical, or hydraulic, and each of these could be designated a subsystem or even a sub-subsystem of the chosen system.

An electronics control unit for a flight control system may include one or more black boxes (and they aren't always black); each box will contain subsystems and components such as transformers, terminal strips, printed circuit boards and so forth. The PCBs will consist of circuits (hard wired or integrated) that consist of other components, such as resistors, capacitors, and the like. We can take this "onion-layer structure," as it is sometimes called, all the way down to the level of the atom if we wish. Those responsible for the development of integrated circuits (ICs) and other solid-state devices might be very much interested in that "system."

As you can see from this discussion and from Table A-1, the use of the system/subsystem terminology could get quite unwieldy after three or four layers. So, to avoid confusion, we will address any level in this hierarchy as a "system" and its components or constituent parts as "subsystems." The standard terminology, then, will be this: a system is the set of components we are concerned with and this system is identified by the boundaries we set. Then we can speak of any additional components or elements as being "internal" or "external" to our specified system.

But a system is not just components. A system will include people (users, operators, maintainers), as well as processes and/or procedures for the system's use, operation, or maintenance. A system may require inputs from electrical, mechanical, and/or hydraulic systems or components, as well as inputs from a user, an operator, or a maintenance technician. A system will undoubtedly provide outputs in various forms (electrical signals and waveforms, mechanical motion, instrument displays, computer data) to be used by humans, by other systems, or by both.

How deep one goes into this layered world is dependent on one's interest in the system. Let us take a printed circuit board, for example, whose purpose is

TABLE A-1 Systems and Subsystems

Transportation system
Air transportation
Commercial aviation
Airplane
Flight controls
Primary and secondary flight controls
Electrical, mechanical, hydraulic components
Black box units, mechanical units
PC boards, transformers, etc.
Circuits
Components
Molecular structure

to provide an analog voltage to a flight deck display showing the angle of flap extension on the airplane wing. For the line mechanic who is addressing a flap system write-up, the area of interest would be the black box containing the errant PC board. This "black box" is a unit that can easily be removed and replaced so as to return the airplane to service. The technician in the avionics shop, however, would have a keen interest in the PC board and its effect on the operation of the system; i.e., the flap angle indicator. Those mechanics and engineers interested in any higher-level system in the chain would not be as interested in the PC board details. Likewise, only those building the PC board or its integrated circuits would have any interest in the physical and atomic properties of the components on the IC.

Summary

It is conventional, in design engineering, to apply the systems engineering concepts at the outset of new system development. This effort ensures that each component or subsystem is designed for compatibility with the rest of the system to guarantee that system goals and objectives will be met regardless of who builds the component or subsystem. Although the users of these systems will not (usually) be involved with the design or redesign of the systems, the knowledge of systems concepts and systems engineering techniques are important in understanding the system and its operation. Knowledge of systems is also useful in the maintenance and troubleshooting of these systems. This should be kept in mind as you read and study the main chapters in this book.

Appendix

B

Human Factors in Maintenance

Background

In the early 1980s, the aviation industry implemented crew resource management (CRM) in an effort to detect and correct human errors made by flight crews. The action was successful and is continuing. In the 1990s, it was determined that the same approach should be used to identify and correct errors in maintenance activities that contributed to aircraft accidents and incidents. This activity—human factors in maintenance (HFM)—has developed into the maintenance resource management (MRM) program. The FAA addresses this activity in Advisory Circular AC 120-72.[1]

While many people assume that human factors in maintenance refers to the actions of mechanics, the MRM program admits to several major areas where maintenance errors can occur. These areas are (*a*) equipment design and manufacture; (*b*) manufacturers' documentation and procedure writing; (*c*) airline procedures and work areas; and (*d*) mechanic training and performance.

The airframe and equipment manufacturers have implemented HF programs to improve design so maintenance can be performed more easily and to reduce the number of possible errors that can be made. Improvements in maintenance manuals and other documents are also under manufacturer's scrutiny and certain academics are looking into the problem of human error. But the airlines also have a responsibility to monitor the processes and procedures they employ and to modify those with respect to human error reduction. The training organization should modify courses to accommodate any changes necessary to meet the HF aspect and is also required to develop and implement an HFM course. The AC mentioned above provides guidelines on establishing such a course.

[1]Federal Aviation Administration: AC 120-72, Maintenance Resource Management Training, September 28, 2000.

In this appendix, we will first discuss human factors as a part of systems engineering (see Appendix A); then we will address some of the other activities in HFM.

Basic Definitions

The term human factors is defined in the *Handbook of Aeronautical and Astronautical Engineering* as follows:

> Ergonomics [*Human factors*] is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theory principles, data and methods to design in order to optimize human well-being and overall system performance. ...[2]

Another popular definition is rather brief but captures the essence of *human factors*.

> In capsule form, the nub of human factors can be considered as the process of designing for human use.[3]

In the past, human factors has usually referred to physical characteristics of people, such as size, strength, physical dexterity, and visual acuity. But there are other human attributes that affect a system's performance and the human's ability to use or maintain the system. Such human characteristics as a lack of knowledge or understanding of how the system works can lead to improper use or to inadequate troubleshooting or improper maintenance. Human forgetfulness or even a person's attitude can affect how well the system works, or how that person interfaces with the system. The human attributes of those people who interface with systems in any way can have an effect on how well the system performs through their ability or lack of ability. Design people may not understand the needs of maintenance, trainers may not be able to communicate the correct information to others, and operators may use the system improperly.

Human Factors and Systems Engineering

In Appendix A, we discussed systems engineering. We discussed systems boundaries, system elements, and the interfaces relative to the interaction of these systems, subsystems, and components. Here, we take up the notion that the human being—the user, operator, or mechanic, as well as all others (writers, designers, teachers, etc.) who interface with the system—must be considered as elements of the system. Likewise, these elements and interfaces must be addressed during the design stage of the system.

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[2]Kesterson, Bryan P., William L. Rankin, Steven L. Sogg: Maintenance Human Factors, Section 18, Part 8, *The Handbook of Aeronautical and Astronautical Engineers*, McGraw-Hill, New York, NY, 2001.

[3]McCormick, Ernest J.: *Human Factors in Engineering and Design*, 4th ed., McGraw-Hill, New York, NY, 1976, p. 4.

The human interaction with systems makes it imperative that the users, operators, and maintenance people be considered during the design, development, and operational phases of the system's life. During design and development, the human requirements and interactions must be known or anticipated at all levels of the system. This includes not just the equipment but also the manuals and the training program for that equipment. During the operational phase, feedback from the field will dictate changes necessary for system improvement relative to the operator, user, or mechanic in terms of local procedures, as well as the manufacturer's procedures, training, and design efforts. Lessons learned during this operational period relative to human interaction with the system can be used to advantage by the manufacturers in the development of new systems or modification of existing ones.

Traditionally, the systems engineer needs to be familiar with a variety of engineering disciplines to perform his or her job successfully. Adding human factors to the toolbox means adding one more discipline: human factors engineering. This involves not just the understanding of human characteristics but also how these characteristics relate to the overall operation of the system. It requires the systems engineer to understand the effects these humans can have on the system operation whether the necessary interaction exists or not, whether the response is correct or incorrect, and even if the response or interaction is absent when it is required. It is necessary for the systems engineer to address these effects as part of the basic system design. The effects of human presence are as real as the presence of voltages and mechanical linkages. The human being is an element of the system. When all the elements are working properly, the system will work properly.

Goals of the System versus Goals of the User

Elwyn Edwards[4] states that the effectiveness of a system is measured by the extent to which the system goals are achieved. McCormick[5] also mentions the functional effectiveness of the system as one of the goals of design. In this appendix, we integrate the philosophy of systems engineering, discussed in Appendix A, with the philosophy of human factors. In doing that, we consider the significant goals to be not the goals of the system but rather the goals that the user of the system expects to achieve by employing the system.

We can no longer design for the sake of the system or for the sake of technology. This new philosophy requires that we now design for the system application. A system, whether a simple tape player or an exotic mode of transportation, is just a tool. It is a tool used by people to accomplish some personal or work-related goal. To make that tool,"user friendly," we must design it to be usable by

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[4]Wiener, Earl L., David C. Nagel (eds.): *Human Factors in Aviation*, Academic Press, Harcourt Brace Jovanovich, no date. From the introduction by Elwyn Edwards.

[5]McCormick, *Human Factors in Engineering and Design.*

human beings. That means that the system not only has to perform some function efficiently, but it has to perform that function in the manner that the system user wants it performed.

A system that achieves the design goals of a collection of mechanical and electrical parts may represent engineering perfection, but if the device cannot be used by people for some human purpose, it is just a collection of mechanical and electrical parts; just another "contraption."

Designing for the Human Interface

Whether we are talking about electrical or mechanical systems, about processes or procedures to be carried out, or about forms we need to complete during maintenance, the interface between these systems and the human users must be addressed as any other system interface; and the system optimization efforts we spoke of in Appendix A must be applied to make the total system—including the user—work efficiently. The main difference, however, is that these humans, unlike the other system elements, cannot be redesigned during the optimization process for the improvement of the total system operation. Therefore, the designers of these systems must adhere to several basic rules. The first of these is to design the system to be compatible with human abilities, capabilities, needs, and strengths. The second is to design these systems around human failings and deficiencies so as to avoid possible human error.

The third rule is especially important in developing good, usable systems. For any problem or condition that cannot be accommodated by the first two rules above or one that is limited due to various constraints, such as design limits, trade-offs, or budget requirements as discussed in Chap. 1 of this book, the designers must provide the users, operators, and mechanics—as well as other human elements involved—with sufficient education and training on the system to resolve any human factors–related problems that could arise from improper understanding of the design. These basic design rules for human interface with systems are summarized in Table B-1.

Human Factors in Maintenance

In Appendix A, we extended the definition of systems to include more than just the electromechanical components we normally consider. A system can also be a checklist, a procedure, or a form to be filled out. Maintenance, of course, deals

TABLE B-1 Human Factors Design Guidelines

1. Design the system to be compatible with human abilities, capabilities, needs, and strengths.
2. Design the system to compensate for human failings and deficiencies to avoid human errors.
3. Provide the human elements of the system with sufficient education and training to resolve any human factors–related problems that could not be alleviated by application of the first two rules above.

with all of these kinds of systems, and the human element is just as important in each of these. How maintenance people perform is only part of the problem; the facilities in which they work, the equipment they encounter, and the forms, processes and procedures they use are all subject to human actions and, therefore, to human error. And the errors are not always due to the mechanic. There are several areas in maintenance that contribute to the errors made by the users, operators, or mechanics.

Human Factors Responsibilities

Human factors efforts are usually divided into three basic categories of activity: (*a*) aircraft and component design, (*b*) maintenance product design, and (*c*) maintenance program applications.[6] Each of these is discussed below.

Aircraft and component design

The responsibility for this category rests with the manufacturers of airframes, engines, and installed equipment. It deals with the task of designing for maintainability. This concerns the design of equipment that can be worked on for service, inspection, adjustment, and removal/installation (R/I) efforts. These design efforts must ensure that there is sufficient workspace to do the work required and that there is also enough space to use the tools and test equipment that may be needed. The manufacturer's responsibility also includes consideration of the weight and handling characteristics of the unit undergoing maintenance. Equipment parameters must be within the physical limits of the workers required for the particular task. If this cannot be accommodated, special handling equipment must be developed to permit proper handling and to protect both the equipment and the workers from harm. Design effort should also take into account the number and skills of the workers required for a given task to be completed with reasonable staffing requirements.

Whenever computer diagnosis is utilized, using built-in test equipment (BITE) or other external systems, the equipment, processes, menus, and other task or information selection methods must be designed for the mechanic's ease of use and understanding; that is, it should be user friendly. Results from such activities must be understandable and usable by the mechanic.

Maintenance product design

Maintenance personnel require auxiliary equipment and written material to perform the required maintenance on aircraft systems. Ground support equipment (GSE), special tools and test equipment, and various forms of documentation must be designed with the mechanics' capabilities and limitations in mind, and these products must be made available to the mechanics. Mechanics must be able to use

[6]Kesterson, Rankin, and Sogg: *Maintenance Human Factors*.

the GSE and tools effectively, so the design requirements discussed above for airframes, engines, and installed equipment must apply to these elements also.

Documentation, whether written by the manufacturer, the regulators, or the airline, must be clear, understandable, and accurate (i.e., technically correct) for the mechanic to effectively utilize the information. This written information must also be accessible to the mechanics on the line, in the hangar, and in the shops, as necessary. It must also be available to the training organization. The user-friendly approach is also required for all these maintenance products.

Maintenance program applications

The basic maintenance program developed by the MSG process is based on the needs of the equipment (i.e., design goals, safety, and reliability) and on the regulatory requirements (safety, airworthiness, etc.). When the airline receives the aircraft and its initial maintenance program, that program is usually tailored to the specific airline operation. This adjustment of tasks and task intervals must also include human factors considerations. That is, the adjustment of the program must be in line with the human capabilities and requirements concerning work schedules, endurance, and skill makeup of the work crew to avoid over work, fatigue, etc. The appropriate GSE, tools, and test equipment must be provided to do the work, and the work force must be properly trained on all aspects of the job: the actual maintenance work to be performed; the use of GSE, tools, and test equipment; the use of built-in or external computer diagnostic equipment; and the basic human factors aspects of the job. These actions are the responsibility of the airline itself.

Safety

Chapter 20 of this book discusses the safety and health issues related to maintenance. It does not take much deep thought to realize that safety is also a human factors issue. Although the two fields relate to different aspects of the maintenance activity, they are not mutually exclusive.

Summary

The manufacturers of airframes, engines, and installed equipment are doing their part to reduce the chances of human error in maintenance, but they require inputs from airline operators and third-party maintenance organizations. Research from the academic community (behavior scientists, etc.) is also necessary to advance the state of the art. Meanwhile, the airline operators and other maintenance facilities are responsible for the actions of their mechanics and the materials with which they work. In human factors, as well as in safety, the work force at all levels must be constantly aware of problems and be ready to effect solutions. Human factors is a way of life.

Appendix

C

The Art and Science of Troubleshooting

Introduction

One of the most common misconceptions about troubleshooting is that it is basically a series of wild-assed guesses (WAGs) or, at best, a series of scientific WAGs (SWAGs). This is not the case if you know what you are doing; it is of little help if you do not. And then there are those who claim that you cannot "teach" troubleshooting. This author disagrees with that notion. It is possible that some people cannot teach the subject due to a lack of knowledge or skill, and it may also be possible that some people cannot learn the technique for some reason or another. But experience has shown that the art and the science—and it is a combination of the two—can be taught. That is, it can be taught up to a point. Since there is some skill involved in troubleshooting (i.e., the art), what one learns about it must come from within. However, there are some basic concepts to be applied in troubleshooting (i.e., the science) that can be taught.

This appendix will attempt to show you the systematic approach to troubleshooting, the aspects that can be taught. It will address both the art and the science of troubleshooting.

As electronic and mechanical equipment gets more and more complex, the job of the technician or mechanic gets more and more frustrating. Today's new generation jet airplanes constitute the most intricate and complex systems ever engineered by human effort. In the past, each piece of equipment or each system required its own specialist to maintain and repair it to optimum condition. Troubleshooting consisted of checking out the system to determine if it was at fault and querying the user to determine if it was properly operated.

Today, with electronic control of mechanical systems, redundant systems, computer fault recording, and cross-feeding of data between and among systems for logical decision making, the technician or mechanic requires not only a broader knowledge of his or her own equipment but also knowledge of those

systems with which that equipment interfaces. Inputs from air/ground relays, gear-down sensors, air data computers, and from numerous other systems and sensors, blur or even erase the dividing lines between individual systems and components. Now, the repairman needs to know the entire airplane to effectively isolate the problems indicated by crew write-ups, fault balls, computer fault messages, flight deck lights, and other "things that go bump in the flight."[1] The mechanic needs to understand the systems approach.

While airplane manufacturers provide fault isolation manuals to the mechanic that include systematic fault trees for the isolation of problems, this effort is neither complete nor entirely satisfactory. These fault location procedures were usually written to find specific faults; they do not necessarily allow you to find all the faults that might occur within the system addressed by that fault tree. It is up to the mechanic or technician to provide the additional procedures or make modifications to existing procedures to find these other problems. These procedures constitute part of the science of troubleshooting, and it is an incomplete science at that.

The art of troubleshooting, which is just as important as the science, can only be learned by continued effort in studying and repairing the equipment. This art involves the ability to think a problem through and to apply all you know about the problem, the equipment, and the nature of failure so that you can fathom the most difficult and perplexing of problems. This appendix will, first, identify the basic steps in the troubleshooting process and will, then, discuss the process by which one learns the art of troubleshooting.

Three Levels of Troubleshooting

You can divide maintenance problems into three general categories: (*a*) problems with components or systems (i.e., self-contained); (*b*) problems relating to systems and their environments; and (*c*) problems related to the interaction of two or more systems. Each of these categories or levels requires a different approach and each will be discussed in turn below.

Level 1: the component or system

This type of problem exists within the component's or the system's own world. It is a simple, standard fault with a simple, standard solution. This is the normal, day-to-day activity for the problem solver. The troubleshooting charts or common sense is usually enough to resolve these problems.

This system or component is malfunctioning or has failed completely. Check inputs, outputs, etc. Troubleshoot within the unit/system. Know how the system works and follow normal troubleshooting practices.

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[1]Book jacket comment by Library Journal concerning the book *This Is Your Captain Speaking* by Captain Thomas M. Ashwood, National Chairman Flight Security, Airline Pilots Association, Published by Stein and Day, Briarcliff Manor, New York, 1975.

Level 2: the system and its environment

A system fails or "acts up" during some portion of its operation. It may recover and exhibit no more symptoms or may falter intermittently. It may work fine on the ground or in the shop when tested, but the malfunction still reoccurs in the air during normal flight operation.

Troubleshooting these problems requires knowledge of and investigation of the primary system or component, as well as its inputs and outputs, but the external environment and its effect on the system must also be considered. This includes investigation of how the system or equipment was operated (correctly or not?) and what else was happening during the time of the malfunction (extraneous inputs).

Level 3: the interaction of systems

Something happens in one system when another system is exercised. The two systems may or may not be interrelated or interconnected. Here, assuming that other standards of troubleshooting have failed, you look for some mechanical interference, such as rubbing of parts or electromagnetic interference coming from a nearby unit, electrical cable, or other system. As a last resort, you look for interference from radiated fields (high or low intensity, any frequency). These are emanations from on-board or off-board systems that interfere with the problem system. This is occurring more and more with the composite (nonmetallic) materials used in airplanes. The composite materials used in modern aircraft do not provide the electromagnetic shielding that the old, metal frames and fuselages used to provide.

Again, the span of knowledge needed to pinpoint these problems is broader than the simple component or system failure discussed above. Knowledge of this type of interaction between (and among) systems may only come with time and experience, but it is necessary to gain that insight as you progress through the ranks from maintenance helper to master mechanic and troubleshooter. Once you have achieved this, you are an artist.

Knowledge of Malfunctions

There are a few general concepts of problem solving and troubleshooting that one must understand before we get into the process itself. These are discussed briefly below.

What kinds of things can go wrong?

Most systems will have a set of known things that can and will go wrong with them. The same failures will come up over and over again. Experience with these component or system characteristics will aid the troubleshooter more and more as his or her knowledge base is developed. Armed with this knowledge, the mechanic can sometimes skip certain steps and checks in a troubleshooting

chart or procedure and go straight to those steps that are directly related to the problem at hand. Without this prior knowledge of failures, however, a good troubleshooter can still zero in on problem areas by knowing what kinds of things might go wrong with the system. Discussion with others who have worked the same system, and possibly had similar problems, is most useful.

Experience is the best teacher

The expression “experience is the best teacher” is so common that it is almost a cliché and is often treated as just that. However, it is not an untruth. Until you get too old to remember things, remembering, in the maintenance field, can be one of your greatest and most useful assets. The same problems keep coming back. If the problem is the same then the solution is the same. Troubleshooting gets easier as you go. But there is always that stubborn problem that stymies even the best troubleshooter, and that is where all that experience, understanding, and luck have to be called upon. Without any of these, you’re out of it.

No fault found

No discussion about troubleshooting will be complete without mention of the concept of *no fault found* (NFF). It is a common action in maintenance to sign off a problem in the airplane logbook with the comment “No fault found” after ground checks have failed to reveal any problem. The NFF conclusion may also be used after an unsuccessful troubleshooting session. This NFF entry seems to be a catchall for ineffective or poor troubleshooting. If the flight crew wrote up an item in the logbook, then there must be some sort of problem. The fact that the mechanics cannot find the source of the problem does not mean that the write-up is in error. If you cannot find the problem through conventional processes, it will be necessary to use a different approach. The NFF result is not the end of troubleshooting; NFF is a signal to regroup, to start a different tack in the troubleshooting process. It may mean moving into a level 2 or level 3 approach.

Rogue units

There is a special category of high–failure rate items generally referred to as *rogue units*. These are not unit types (i.e., black boxes, component parts, etc.) that have high failure rates but rather individual units of a type (serial numbered or not) which seem to fail regularly. As an example, suppose you have 25 black boxes (radios, for example) and you have failures in 10 of these boxes over a month. Each time the failure occurs it is a different box or a different aircraft. This may be considered a high failure rate for the system or unit, but it is not referred to as a rogue unit. On the other hand, if most or all of the failures involve a single unit (serial numbered or not), then that specific unit might be considered a rogue.

In Chap. 1, we talked about tolerances and their effect on reliability. There is another consideration concerning tolerances we must address. Even though

components are built to within design specifications, there can be some differences in how the overall unit performs. Pistons and piston bores in an automobile engine block are built to specification, which define an ideal diameter with a specified tolerance that allows these parts to fit together and work together.

If the piston is at one end of this tolerance band and the bore is at the other end, the actual fit may be tight or loose depending on the individual case. Although these parts are within tolerance in both cases, their performance may differ because, in one case, the parts are tight, resulting in more friction and thus more heat generation and wear out; while, in the other case, the fit is loose, causing some energy loss due to undesirable side motion (slop). Thus, although the parts are built to within the allowable tolerance, there may be some detriment to efficient operation in extreme cases. When there are several of these "detrimental tolerance conditions" in a given system, or interacting parts of connected systems, they can be additive; the system can perform poorly; and the system can break down more frequently than another unit built to the same specifications with less extreme variation in tolerances. We generally call this unit a lemon or a rogue.

A rogue unit can sometimes be fixed if you know what components are causing the problem and these components can be exchanged or reworked. This task is usually left to the manufacturer, but it is often too expensive or even impossible to do. In most cases of rogue units, it is more sensible to remove the errant unit from the supply system. Although this may be difficult to do with units as expensive as those used on modern aircraft, that cost must be compared with the cost of continual maintenance, as well as with the cost of rebuilding the unit.

Bogus parts

Rogue units should not be confused with bogus parts. Bogus parts are those parts built by vendors or contractors that are not up to the original manufacturer's specifications, and very often, those parts that are built without authorization by the original manufacturer or the regulatory authority. These parts are usually cheaper, which is the primary attraction, but they are also inferior. Generally, they have high failure rates, poor wear-out properties, or other detrimental performance characteristics. Although there is a considerable difference between rogue units and the bogus units, the airline's reliability program should be able to find and eliminate both types.

Other significant differences

Experience has shown that maintenance people address problems differently based on their training and experience. Mechanics tend to look for previous write-ups or they observe the equipment in operation prior to using any troubleshooting charts or procedures. Avionics technicians, on the other hand, tend to go straight to the charts or procedures. The primary difference here is in the nature of the malfunctions. Avionics equipment (electrical and electronic) looks essentially the same whether it is working properly or not. But many mechanical faults can

be seen or felt by simple operation or they can be gleaned from the crew's description of what happened. Not all mechanics or avionics technicians work the same and not all problems warrant the same approach, but it is possible that many problems can be addressed by using the senses; others must go straight to the theory. This, of course, differs from problem to problem and from person to person.

Knowledge Is Power

The most important tool you can have to assist you in troubleshooting is a solid understanding of how the equipment works and how it is supposed to be used by the operator or user. Improper operation can occur in one of two different ways, and this needs to be distinguished during the troubleshooting process.

If an operator does not get the desired results from the system, he or she usually writes a discrepancy. The operator may not be aware of the fact that the system was operated incorrectly or that some switch was in the wrong position. It is for him or her a valid write-up.

Certain misuses of the equipment could cause erroneous results and, at times, could actually damage the equipment. Although, in the latter case, the equipment must be repaired or replaced, the solution to the problem (misuse) must also be addressed. The error and its effect on the equipment can also be logged away in the knowledge bank for reference in future troubleshooting.

Know the system

Troubleshooting is essentially a thinking process. It starts with a thorough understanding of how the system works. Know the theory of operation of the equipment or system. Know all the functions and modes of operation, if there is more than one. Understand what components or circuits are common to various operational modes and what ones are specific to each mode. Understand what other systems have to be operating for your system to get all its required inputs.

Know the fault indicators

Know what fault balls, fault messages, flight deck effects, etc. relate to the system, and understand which indications can and cannot appear in each operational mode. Know how to address specific problems without starting at the beginning of a fault tree and performing a series of unnecessary or unrelated steps. Understand what circuit breakers, fuses, and auxiliary systems (hydraulic, pneumatic, electrical, etc.) are required for operation of your system.

Know what kinds of things can go wrong with your system

This, of course, would vary with each system. Use your past experiences; use the experiences of others; use any applicable data available from condition monitoring programs or reliability programs; use information from service tips, service letters, and service bulletins; talk to mechanics, technicians, or engineers

from other companies using the same equipment. In other words, know your equipment intimately.

Know the interfacing systems

In addition to knowing what systems must be operating to allow yours to work properly, you must also understand how these other systems or equipment interface with yours. Understand what circuit breakers, fuses, and auxiliary systems (hydraulic, pneumatic, electrical, etc.) are required for operation of these interfacing systems. Know and understand the effect each of these systems has on your system. Know what the consequences are if the inputs from these interfacing systems (logical, electrical, mechanical, pneumatic, or electromagnetic) are not present or are present but not correct.

Know what fault indications would exist for these systems, and determine if any of them were malfunctioning. Know what this malfunction does to your system. Know if fixing the interfacing system problem will likely reduce or eliminate your problem.

Know how the system is used

Know how the operator uses the system and what he or she expects of the system during that operation. Their usage, right or wrong, may affect the system's operation as well as your troubleshooting efforts. Common errors of operators or users are (*a*) failure to turn equipment on; (*b*) failure to select correct mode; (*c*) failure to check for correct settings; (*d*) failure to check CBs or fuses. (*Note*: Some of these are not requirements of the user but some are. It depends on the equipment and the operation.)

There are three types of people that interface with equipment and systems—users, operators, and maintainers (see Table C-1). They each have a different

TABLE C-1 Definitions

User: One who benefits from the equipment or system: a passenger in a vehicle, a viewer of television, a listener of radio or recorded music, a home or apartment dweller enjoying the benefits of any number of modern conveniences. They don't have to know how the devices work, they just need to know how to use them for their own advantage, and how to recognize when they are not working properly.

Operator: One who operates or drives the equipment: a pilot of an airplane; the driver of a truck, bus, or automobile; a diesel generator engineer who provides electrical power to a facility. These people may have varying degrees of knowledge of how the system works, or how it is supposed to work, but the details are not important. When an operator uses a piece of equipment, he or she expects certain responses, certain indications, and certain results. If they don't get that feedback, they consider the unit to be malfunctioning. They don't have the time or, in some cases, the knowledge to figure out what's wrong. That is the job of maintenance.

Maintainer: One who is responsible for the maintenance and repair of the system: his or her relationship to the equipment is quite different from the operator or user. The maintainer not only covers the detailed theory of operation of the system and its many components and subsystems; he or she must know about and understand failure, failure modes, and other equipment anomalies. The maintainer also has to understand how to troubleshoot the system, how to test it, how the test equipment works, and on and on. Added to this, to be able to carry out the test and validation process after repair has been made, he or she must also know how to operate and use the system.

view of the equipment or system and a different relationship with it. Therefore, what they know about it and what they need to know about it varies widely.

Don't let the theory get in your way

Too much theory can be a detriment to the troubleshooting effort. Look for the simplest, most obvious problems first: equipment not turned on, proper mode not selected, blown fuses or tripped circuit breakers, improper operation, unit not plugged in. Perform tests and measurements on those problems that are not so obvious. Are inputs and outputs correct? Are proper signals being received from other units? Sometimes it is easy to get bogged down in schematics, wiring diagrams, and maintenance manuals when you've overlooked some simple thing.

Building Your Own Knowledge Base

Many of the modern aircraft maintenance organizations have extensive computer systems that are used for the logging of maintenance data, such as pilot write-ups, reliability program data, and problems found during routine maintenance. The records show the discrepancy, corrective action taken, parts replaced, tests performed, and even the flight, cabin, and maintenance crews involved. Other data tallied include flight information (aircraft type, origin/destination, flight phase where discrepancy occurred). This database can be accessed whenever a problem occurs in order for the mechanic or technician to determine if the same or a similar problem has occurred previously. Corrective actions taken on these previous faults may be used in the solution of the current write-up.

A good mechanic or technician, however, often remembers his or her own experiences with past problems and the solutions they ultimately employed. In most airline operations, however, mechanics go from one airplane to another, one type to another, in the course of a day's (or night's) work. Keeping track of each airplane and each failure is difficult if not impossible. However, shift supervisors, maintenance control center personnel, as well as maintenance and reliability engineers should be able to amass a certain amount of this knowledge based on their positions and experience—with considerable help from the computer. There are few problems that should be a complete mystery to everyone in the organization.

Experience

Part of the education of maintenance people is the formal training received in various technical and vocational schools. Part of it is semiformal; that is, special training established within the work unit and training classes conducted by manufacturers or other airlines. The final aspect of training for maintenance personnel is personal. The mechanic's personal efforts throughout his or her career will consist of ongoing education—formal as well as informal study—interaction with other maintenance people, and the competitive effort to get ahead of coworkers.

Much of this education will come from experience. Working on the same equipment day after day lets you learn the easy way, by sheer repetition.

Keep track of the faults that occur on your system, equipment, or vehicle. In spite of the complexity of some modern systems, the same faults often keep coming back. What went wrong the first time was fixed the first time, so if the problem recurs, the same solution should fix it. However, if the fault was not adequately addressed or if it recurs often and at short intervals, perhaps the repair action taken was insufficient. It is necessary in those cases to retroubleshoot the problem. Come up with a better fix—even if you have to call in management or engineering—and then remember the new fix.

Continuing education

The continuing education of a mechanic or technician takes place in several venues: at work, at home, on the job, and in the classroom. At work, you have the day's work and the interaction with others working on the same or similar problems. You always have copies of the maintenance manuals close by. One of the "arts" used in troubleshooting is brainstorming. Just talk about the problem with other people. Hypothesize about the problem. Suggest some possible solution and discuss why that could be the answer or why it cannot be the answer. You can get as far-fetched as you want (if time permits), because this gets the mind working and helps create new ideas. Soon the right answers start poking through the fog.

At home, you have time to relax and let your mind deal with other things. That would be your conscious mind, of course. Fortunately (or not), your subconscious mind continues to work on any problems you have posed to it. With a well-organized storehouse of knowledge and information, your subconscious mind can develop solutions for you while you are at play. Be careful, though: they may pop out at inconvenient and embarrassing times. Nevertheless, a well-organized mind is one of your best tools for troubleshooting.

In class, whether it is a formal course, a company training class, or on-the-job training; whether it is new material or refresher training; you have the chance to learn, relearn, and fill in the gaps in your knowledge from previous studies. You can always learn more even if all you are doing is repeating what you already know or you are explaining something to a coworker. What you know is one thing; putting that into words for others to hear or read is another. An electrical engineering professor this author had in college told the class, "If you want to know how much you really understand about this stuff, try to explain it to someone who does not have any technical background at all. If you can do that successfully, then you know your subject."

Understanding the Sequence of Events

There are several sequences of events associated with nearly every system you will encounter in your maintenance and troubleshooting activities and you need to understand them all. The first is the sequence of turning on and setting up

a system for use. The second is the operational sequence of a properly operating system while in use and while being switched between operational modes. The third and final sequence to understand is the sequence of events leading up to the current failure. A more specific explanation follows.

Sequence of events to engage the working system

Know how the system is turned on, powered up, tuned in, adjusted, positioned, etc. by the operator or user at the start of operations, as well as during normal, ongoing operations. This includes switches and CBs being in the correct positions, as well as other equipment being turned on or off. It is important to know this sequence and to compare it with that actually used by the operator. As we said before, incorrect procedure may be the operator's problem, and training the operator or user may be the solution to the problem. On the other hand, improper use of the system may cause the equipment or system to be damaged or impaired. The troubleshooter must know this and know how to determine if this is the case for the particular system he or she is working on.

Sequence of events within the operating system

Know how the system operates internally; that is, know the normal sequence of events occurring during normal operation or use of the system. Know what it does while in operation, when it does it (e.g., in flight, on ground, in conjunction with certain other actions performed, or with other equipment in use), and know in what portion of the sequence certain actions, responses, and fault indications can and cannot occur. Know the sequence of events in each mode and the sequences involved in transition from one mode to another. This can be useful in following up on the user's explanation of how the system performed just prior to the malfunction (see next section).

Sequence of events leading up to the malfunction

Know the sequence of events leading up to the degraded performance, failure, or malfunction. This must be obtained from the user or operator who was "at the controls" of the system when the dysfunction occurred. It is very important to know this sequence in many troubleshooting efforts, because this sequence of events may reveal a developing pattern or an indication, not only of the fault, but also the possible location of the fault.

Eight Basic Concepts of Troubleshooting

Part of the troubleshooting process is knowledge and experience; the rest is a combination of logical procedure, innovation, and sometimes, luck. The simplicity of certain equipment or systems may permit the omission of some of the following steps while the complexity of others may require a more detailed procedure.

The following eight concepts should cover the bulk of your troubleshooting efforts.

1. *Know your equipment*. When it comes to troubleshooting any system—no matter how simple or complex—nothing will serve you better than a good understanding of how the system works. Know all its functions, its operational modes, and the failure modes and their effects in each mode and function.
2. *Know how the controls and displays work*. The troubleshooting process often requires you to operate and adjust the various controls and switches on your equipment, to turn it on, run it through various tests, and check out its overall operation. Know how the operator uses the equipment and what modes or configurations he or she uses. This will help you understand what they tell you in the malfunction reports which are given to you.
3. *Know how other equipment interfaces with your own*. Know what ancillary equipment is connected to the system or equipment you are working on (including BITE). Many of today's avionics systems rely on inputs from other systems. Sometimes electrical, electronic, and/or mechanical inputs from ancillary equipment affect the operation and function of your own system. These interactions must be known and their effects must be known, both the effect on your system when the interfacing equipment is working properly and when is not. The effect on your system when the input signal is not there or is incorrect must also be known.

   Know the outputs from your system and where they go. Understand how other equipment receiving your outputs can effect your own equipment. Bad or missing inputs from your system can affect return data; shorting out or blocking of inputs from your system by the ancillary equipment could also affect your system. These differ from system to system.
4. *Know and understand the maintenance documents*. The maintenance, schematic, and wiring diagram manuals provided with the equipment are your best source of information about how your equipment or system works. They also provide data on equipment that interface with yours and how these work. The documents will tell you how to turn on and operate the equipment (yours and theirs) and what prerequisites and precautions are necessary for safe operation; that is, electrical, hydraulic, or pneumatic systems that need to be on or off, what circuit breakers need to be in or out, and similar setup requirements during testing and troubleshooting.
5. *Approach the problem in a systematic and logical manner*. Once the necessary preparation has been taken to accommodate the above steps, the actual troubleshooting can begin. You must proceed systematically and logically from the known symptoms to the cause. This is easier said than done, of course. The first approach would be to follow the obvious track, then the not so obvious, and finally, if those approaches do not work, start addressing the improbable or the seemingly impossible.

6. *Analyze the information available in light of equipment operation*. Some basic determinations should be made at the outset of troubleshooting in order to establish the plan of attack. The following five steps are guidelines:
   (*a*) Determine what is and is not working properly. If two or more modes or functions are faulty, determine if there are any commonalities between (or among) these and look for a common cause.
   (*b*) Determine whether or not the equipment is operating correctly but inaccurately, or determine if it is operating incorrectly or not at all.
   (*c*) Determine if one, several, or all modes of operation are affected. Based on those symptoms, zero in on the appropriate problem area by determining what area(s) the problem could (or must) be in.
   (*d*) Identify what other systems interface with yours and determine their effects (if any) on the problem at hand.
   (*e*) Analyze how the equipment is used or operated.

Table C-2 lists a number of specific questions that should be asked and answered in the effort to pinpoint a problem, but not all questions would be required in every case. Determining which ones to ask and to answer, of course, is part of the "art" of troubleshooting.

7. *Be able to perform complete checkout procedures on the equipment and understand the results*. There are usually established procedures for checking out a system: (*a*) ground checks on the aircraft (operational checks, functional tests); (*b*) bench checks in the shop; (*c*) built-in test equipment (BITE) in the unit itself. The BITE system may have an internal fault that results in an

TABLE C-2 Questions to Ask in Troubleshooting

Problem history: Are there any records—on paper, in the computer, or in human memory—of any previous failures or malfunctions that are the same or similar to the one you are investigating? If so, what were the similarities? Did the corrective action taken correct the problem? If not, why not? If this was the correct fix for the previous problem, would it apply to the current problem?
Operation: Was the faulty equipment turned on? Were all the necessary circuit breakers closed and/or fuses installed and serviceable? Was the system being operated correctly when the problem occurred?
Power/signal cables: For electronics equipment, was the black box properly seated in its rack (racks incorporating connectors)? Were all connectors properly attached and secure? Are there any blown fuses or tripped circuit breakers in the faulty equipment? If these are replaced or reset, does the problem go away? (Original failure could be due to a power surge and not a malfunction. That is what fuses and CBs are for.)
Multiple systems: If the system or equipment you are investigating has input from and/or outputs to other equipment or systems, were these equipment or systems operating correctly? Were they properly engaged? Check fault balls, fault messages, write-ups, etc. related to these other systems.
Interfacing systems: Were all electrical, hydraulic, and/or pneumatic systems required for operation of your system properly engaged and functioning?
Environment: For systems that rely on information from a ground station, was the ground station up and running properly? Was the aircraft within range of the ground station? Was there any interference (i.e., high- or low–intensity radiated fields) in the vicinity that could cause the problem with your equipment?

erroneous indication. In all cases, you must understand what these procedures will and will not tell you.

8. *Be able to use the proper tools and test equipment needed for the job*. Many troubleshooting activities are assisted and enhanced by the use of common or specialized tools and/or test equipment. Knowledge and understanding of how these tools should be used and how this equipment works is essential to effective application of them to problem solving. Know the capabilities and limitations of these tools and this equipment as well as that of the system you are troubleshooting. It is equally important that you are able to determine whether or not the tools and test equipment are working correctly.

Summary

Troubleshooting is not guesswork, it is not a haphazard approach to problem solving, and it is not a shotgun or a shot-in-the-dark technique. If you don't understand this, you've missed the point of this appendix. If you don't know this, you will have difficulty in troubleshooting and fixing complex systems.

We define a troubleshooter as one who pinpoints and resolves problems. Troubleshooting, then, is the art and science of pinpointing problems. The key word in both of these statements is *pinpoint*. One has to search, to zero in on the problem using systematic and focused techniques. Of course, once you've found the problems you are able to correct them.

The term "shotgun troubleshooting" is a four-letter word. I know, it's two words and it's 22 letters; but, still, it is a dirty, obscene, and unacceptable term. The shotgun approach implies blasting away with a wide pattern of shot and hoping to hit something. It is a sign of a poor troubleshooter, a sign of someone who has given up and is groping around in the dark for an answer.

From this point on, you must consider troubleshooting as a systematic approach to finding problems (troubles). You will know your equipment, you will know your profession (that of a troubleshooter), and you will get better and better at both the art and the science as you pursue your career.

Good luck and may all your troubles be pinpointed.

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Appendix

D

Investigation of Reliability Alerts

Introduction

During a visit to a small but prominent international airline to help with their reliability program, the author was asked by the head of the engineering department—who was new on the job and not too many years out of college—"Just how do I go about investigating these reliability alerts?" It was not a question to be answered quickly or briefly. The assumption that engineers would know what to do is not always a valid one because finding a problem is difficult enough, and knowing where to start and how to proceed to solve it is often no easier. The answer given was general but acceptable. Later, when writing this book, the author expanded the explanation to the material in this appendix. The process that resulted will not find all the answers, and it will not provide you with cut and dried procedures, but it should help you in zeroing in on the unique problems you will be required to solve in these reliability investigations. We will begin with a review of reliability and a quick discussion of the cross-functional process of reliability investigations shown in Fig. D-1. That discussion will be followed with the processes of preliminary and detailed investigations in Figs. D-2 through D-5.

A Review of Reliability

A reliability program is a set of rules and practices for managing maintenance and controlling the maintenance program. Reliability programs provide continuous audits of maintenance activities and establish standards for determining intervals between overhauls, inspections, and checks of airframes, engines, and appliances. The reliability program measures equipment performance against established standards to identify problem areas and initiate corrective actions.

For midsized to large airlines (10 airplanes or more), a reliability program based on statistical analysis is usually employed. In this statistically oriented program, the utilization of alert levels and trend lines aids the operator in limiting the

number of items to be investigated. For airlines with a small number of airplanes, a statistically oriented reliability program is not really feasible because of the small amount of data available. For these smaller airlines, one approach is to review and investigate all malfunctions and removals. This is called an event-oriented reliability program; that is, every event is investigated. Another option is to use historical data; that is, data from previous years (or months) to judge the current performance. In either case, a systematic approach to the problem is required.

All alerts generated by the statistically based reliability program must be investigated and acted upon as appropriate. This function is usually provided by engineering. Engineers responsible for each area—components, airframe, systems, and power plant—should provide analysis and corrective action recommendations to the maintenance program review board (see Chap. 18 for makeup of the MPRB). These corrective actions can vary from one-time actions to fleet-wide improvements to changes in the maintenance program. Alerts commonly result in modifications of equipment; correction of shop, line, or hangar processes; disposal of defective piece parts; additional mechanic training; or changes in maintenance intervals. Since each problem is unique, each solution is also unique.

Alert Investigation—A Cross-Functional Activity

Figure D-1 is a cross-functional chart depicting the identification and processing of a reliability alert. This is not something done exclusively by the reliability department or by the engineering department. It involves various units within the maintenance and engineering organization working together to assess the problem and develop a satisfactory solution. This is just one example of the need for cross-functional cooperation in daily activities we discussed in Chap. 7. A brief explanation of the process is given below. Numbers in parentheses refer to the block numbers in Fig. D-1.

The reliability (1) section collects and tabulates data submitted by the various M&E work centers (9) on a continuing basis. Monthly, these data are charted and analyzed (2) to determine possible problems in the maintenance activity. Such problems are submitted to engineering (3) whose responsibility it is to analyze the problem in detail (5), using additional inputs as necessary from various M&E work centers (10), and develop a corrective action plan (6) to resolve the problem. This plan is reviewed by the maintenance program review board (14) that includes people from the affected work centers (11). If necessary, the MPRB will contact the regulatory authority (15) for approval (16). Once approved by the MPRB, the corrective action plan is returned to engineering, and the plan is issued in the form of an engineering order (EO) (7) to all applicable work centers. Each work center performs its portion of the corrective action plan (12), coordinating as required with other work centers, and notifies engineering (13) when this has been completed. When all work centers have reported completion of their portion of the work, engineering closes out the EO (8) and notifies reliability of such action. Reliability then continues to monitor the parameter to determine the effectiveness of the corrective action (4).

Each problem, of course, is unique, and the work centers involved in developing and/or implementing the solution will vary, but the process is essentially the same. The bulk of responsibility lies with engineering since they are the technical experts of M&E and also the developers of the maintenance program. The following sections discuss reliability's preliminary and engineering's detailed investigative processes in detail.

Zeroing in on the Problem

Not all problems will require the same course of action. Very often, the nature of the problem or the location of occurrence of the problem will determine the course of action. For example, say an alert exists in ATA Chapter 33, Lights. The first step in the investigation would be to review the reliability data generating this alert and determine if the excessive rate is related to a specific lighting system (panel, strobe, landing, etc.) or is distributed throughout the chapter (i.e., all lights, all subchapters). Some ATA Chapters, such as 33 or 25, contain many types of systems while others, say Chapter 29 or 32, are more limited. In any case, the investigation could proceed in various ways based on distribution of malfunctions in any given chapter.

In the case of the problem being concentrated in one area (one or two sections of the ATA Chapter), the problem investigation should proceed to the equipment type involved. Check the maintenance history of the item to see what has occurred in the past in terms of failures and repair actions. Check the adequacy of these actions. Check the current paperwork to see if the maintenance and inspections (if required) were done correctly. If maintenance procedures appear to be inadequate or appear to have been performed incorrectly, evaluate the procedures to determine if there is a discrepancy in the procedure or query the mechanics to determine if there is a misunderstanding on their part as to how the procedure should be performed. The corrective action required may be in the form of rewriting and improving procedures or providing the mechanics with additional or remedial training on the equipment and/or procedures.

In the case where the failures (removals, etc.) are distributed throughout the subchapters of the ATA Chapter, the implication is that there is a common problem through all the chapter's activities. This could mean that there is something wrong with shop, line, or hangar procedures or with the mechanics or specialists who work on this equipment. There could also be a parts problem from some common source (manufacturer, vendor, supplier, or repair facility).

Another area in which to focus the initial investigation is to determine whether or not the problem is related to a specific airplane (i.e., aircraft tail number), a specific airplane model, a specific engine type, a specific station (line or home), or even a specific shift, crew, or mechanic. Again, the course of action would be dictated by these conditions.

One final note: The approach to analysis differs for systems, components, and events. Some guidelines of these various approaches are given in the following discussion.

About the Alert Analysis Flow Charts

The process of investigation has been broken down and displayed on four, interconnected flow charts (Figs. D-2 through D-5). The first, Fig. D-2, is the overall chart. It refers to each of the others for details of specific parts of the process. We will discuss the process, step by step, moving from one flow chart to another as necessary. This will give you a feel for the total flow process. Each possible alert will result in a different track through the charts and may involve more or less action at the various steps. For reference, blocks in the flowcharts are numbered. These numbers are shown in parentheses in the text; e.g., block (7).

Figure D-2, block (1): Reliability has identified a possible problem area based on the alert level established for the parameter and on the event rates for the current and the previous month. Figure D-2, block (2): The first step is for reliability to perform a preliminary investigation.

This takes us to Fig. D-3, block (1). The preliminary investigation will involve several actions, depending on the conditions, to determine if this is a valid alert. Consider the current event rate and the overall pattern of the event rates: wide swings of the event rate above and below the UCL and behavior of the monthly and 3-month rates. Determine if this is normal activity (no alert), a condition that needs to be watched (watch for trends), or something that may require further action (possible need for investigation). If the answer to the question in block (3) is "no," the next question, block (2), asks if this is a "watch." If the answer is "yes," reliability identifies it as such on data sheets and in the monthly reliability report (4). For that particular item, then, we return to Fig. D-2, block (3). If it is not a watch, i.e., if the answer to block (2) Fig. D-3 is "no," then go to block (7) directly. This sends you back to Fig. D-2, block (3) with a "no" answer to its question. However, what if the answer to block (3) in Fig. D-3 is "yes" and we do have a valid alert? Proceed to the next question in Fig. D-3, block (5).

Determine if the alert also involves a repeat item. Repeat items are usually defined in the reliability program document or in the Ops Specs as events that occur three times within 5 days (or four times in 7 days). They are to be investigated by the MCC on the spot. If a reliability alert item is also a repeat item, the two may or may not be related. This fact must be noted and engineering must do an investigation. It is possible that the MCC procedures for repeat items are ineffective or not properly employed. It is also possible that there is no connection at all between the two conditions. Engineering will determine this later in their detailed investigation.

Whether or not the alert item is a repeat item, reliability continues to analyze the data in block (8) to determine if this alert condition is shown to be in some specific area such as those indicated in the side table "Specific Areas." The manner in which the data are collected can assist in this analysis. For example, data could be tallied by two-, four- or six-digit ATA numbers, by station, crew, etc. If the answer to the question in block (9) is "yes," this information is noted for use

in the alert notice sent to engineering (10) to aid in their investigation. For either answer (yes or no) we go to block (11) and return to Fig. D-2, block (3).

Figure D-2, block (3) asks if a detailed investigation is needed. After the preliminary investigation, we have determined "yes" so reliability issues an alert notice to engineering (5) specifying the condition and requesting an investigation. If, in Fig. D-3, we identified a possible relationship to a repeat item or identified any specific area of interest, these would also be noted on the alert notice. Block (6) of Fig. D-2 sends us to Fig. D-4, block (1): detailed investigation.

Engineering begins the analysis using conventional troubleshooting techniques, realizing that different problems, due to their nature, will require different approaches. The first step, however, is to identify the problem correctly. It has been said that proper identification of the problem is 90 percent of the solution. If the problem is poorly or incorrectly identified, the subsequent solution will be ineffective.

We concluded earlier that all problems would fall into one of six basic categories: people, procedures, parts, maintenance program, interference, or equipment design (see Chap. 18). For the sake of analysis, we will further break these into two larger categories. The most likely causes are shown in Fig. D-4 as blocks (3) through (6) and those causes that are a little more rare are shown in blocks (9) through (12). Each will be addressed in detail.

People (3): Mechanics may not be performing the tasks properly. This may refer to scheduled, as well as unscheduled, maintenance tasks. Inadequate troubleshooting skills of the mechanic may also be a problem. If this is determined to be the cause of the high event rate (i.e., the alert), then the solution will most likely be training of the mechanics. This could be anything from a reminder to adhere to proper procedures to full classroom training on some area of maintenance. The exact nature, of course, should be determined through the detailed investigation performed by engineering.

Procedures (4): A second source of trouble may be the maintenance, troubleshooting, or other procedures used to conduct required maintenance and servicing activities. The procedures in the AMM, the MRB report, or the airline's Ops Specs might be wrong or inadequate. This may require consultation with the manufacturer. Procedures used could have been modified or created by the airline, and these may be ineffective or incorrect. Also, the procedure could be misunderstood by the mechanic because of the way it is written. These causes would require either rewriting of the procedure, retraining of the mechanic, or both.

Parts (5): Parts can be a source of problems and in several different ways. Improper parts might be used because the procedures for drawing parts from stores allowed the wrong parts to be issued or the part number used was incorrect. This may be a people problem or a material problem (or both). Another possibility of a parts-caused problem could rest with the parts suppliers. They could be providing you with parts that do not meet the required specifications (inferior or bogus parts). If the parts are repairable, the repair facility responsible (yours or third party) may not be performing up to par. It is the responsibility of

QA to audit M&E units, as well as outside suppliers, and repeating that effort may be part of the solution to the alert condition under investigation. Parts could also be damaged during installation or during shipment. Handling procedures by mechanics, material personnel, and shippers may be at fault here. In some cases with time-limited parts, the part may have expired without notice by the material section or by the installer.

These parts problems could be addressed at several levels: mechanics training on drawing and handling of parts; material processing, handling, and storage of parts; parts suppliers and contractors (third-party maintenance) procedures. In every case, it is the responsibility of engineering to determine the cause and determine a suitable solution.

Maintenance program (6): Engineering decided at the outset what maintenance tasks would be used, what the task intervals would be (if different), and how tasks and check packages would be scheduled. As might be expected, this original plan may prove to be less than perfect for the actual operational conditions. As stated in Chap. 2, these tasks and intervals, and their combinations and phasing, may need to be changed relative to experience as shown by reliability data. Therefore, engineering's investigation of alert conditions may indicate a need to change this ideal maintenance program. Tasks may be added or removed; intervals may be shortened; new tasks might even be developed. It could also be necessary to incorporate modifications (SBs, SLs, or even ADs) that were previously rejected to resolve the problem that generated the current alert condition.

These areas represent most of the common problems encountered. Block (7) of Fig. D-4 asks if the problem is in one (or more) of these areas. If "yes" you are directed to block (13) and back to Fig. D-2, block (7). If the answer is "no" to this question—which means you have not pinpointed the cause of the alert condition—then proceed to block (8) of Fig. D-4 to identify other possible areas. These are areas that, although rare, are still distinct possibilities. These are addressed in blocks (9) through (12) of Fig. D-4.

Environmental conditions (9): When an aircraft is sitting on the tarmac, there are many flight conditions that no longer exist and cannot be duplicated. These are extremes of temperature (high and low), vibration, and the prolonged subjection of installed equipment to these conditions. In normal conditions on the ground and in the "pristine" environment of a shop or a laboratory, the equipment may work perfectly; the result of ground test is "no fault found," NFF (see Appendix C for a discussion of NFF). However, to isolate any problem, one must consider and, if possible, duplicate the exact conditions under which the original fault was encountered. This may require a mechanic, technician, or engineer to fly with the aircraft in order to observe and then resolve the problem. In some (rare) cases a special nonrevenue flight may be necessary to accomplish this.

Other environmental sources of equipment problems could be weather, corrosion, sand, or dust. This may vary from airline to airline depending on where they are based and where they fly. Nevertheless, these are possible causes that must be addressed.

Electrical and mechanical interference (10): Electromagnetic interference (EMI) can come from various sources and can affect various electronics components in a variety of ways. The impact of EMI can be continuous, intermittent, or fleeting, and the isolation and resolution of the problem can be quite elusive. Interference can come from the ground (transmitters of various kinds); from other aircraft nearby; or from electronic or computer equipment within the aircraft. In the case of an in-aircraft source, it can be equipment installed in the aircraft that has a shielding or ground loop problem, for example, or the interference could be coming from passenger-carried equipment.

Interference of another type could also occur in certain types of equipment. This could be termed *mechanical interference*. Cables, pulleys, and other moving, mechanical parts could be interfering with other equipment on board and causing problems in either system or both. Unlike electromagnetic interference, mechanical interference can usually be seen and sometimes felt. Such observations could help determine the solution.

A third possibility for interference problems may be the sharing of inputs, outputs, power supplies, or power busses by two or more systems. These common connections could cause a malfunction or error in one system to affect performance of another system. Again, this may be rare but it is a possibility. It needs to be considered.

Flight and cabin crew procedures (11): Aviation maintenance people are conscientious. Whenever there is a discrepancy or a write-up related to aircraft systems and equipment, it is assumed to be a maintenance problem first. (Thus, the consideration of the previous blocks.) Occasionally, however, a discrepancy or write-up is the result of flight crews or cabin crews who do not use the equipment in the way it was intended to be used. These problems may be due to the crew's lack of understanding about what the equipment can and cannot do. Sometimes it is improper procedures in operation (knobs/switches in the wrong position; use of wrong mode, etc.) or, in other cases, equipment that is not turned on, not switched to "transmit" or has circuit breakers pulled or not engaged (for various reasons). The flight crews use equipment to provide them with certain information or control. If they do not get that information or do not believe the results they do get, or if they do not get adequate control as they expect, they will, most likely, write it up as a malfunction. The same can be said of equipment operated by the cabin crew. As one pilot told the author, "We don't have time to troubleshoot the system; if we don't get what we are supposed to get, we write it up and proceed to employ some alternate measure."

When maintenance checks out this equipment and finds it working properly, the operational procedures could be suspect. The solution, of course, is to provide the appropriate flight crew or cabin crew members with adequate training or to clarify the procedures.

The need for redesign of equipment (12): In blocks (3) through (6) of Fig. D-4, we have looked at normal, possible problem areas related to the maintenance of these aircraft systems. In blocks (9) through (11) of Fig. D-4, we have looked at other possible areas that relate to the equipment but are not necessarily

directly related to maintenance. If the engineering investigation has not shown the problem to be in any of these areas, then one must turn to the final possible source—equipment design. If the reliability standards cannot be met and it has been determined that (*a*) maintenance and operational procedures have been implemented correctly and (*b*) no other outside sources are to blame; then the only alternative is to contact the equipment or airframe manufacturer for a possible fix or redesign.

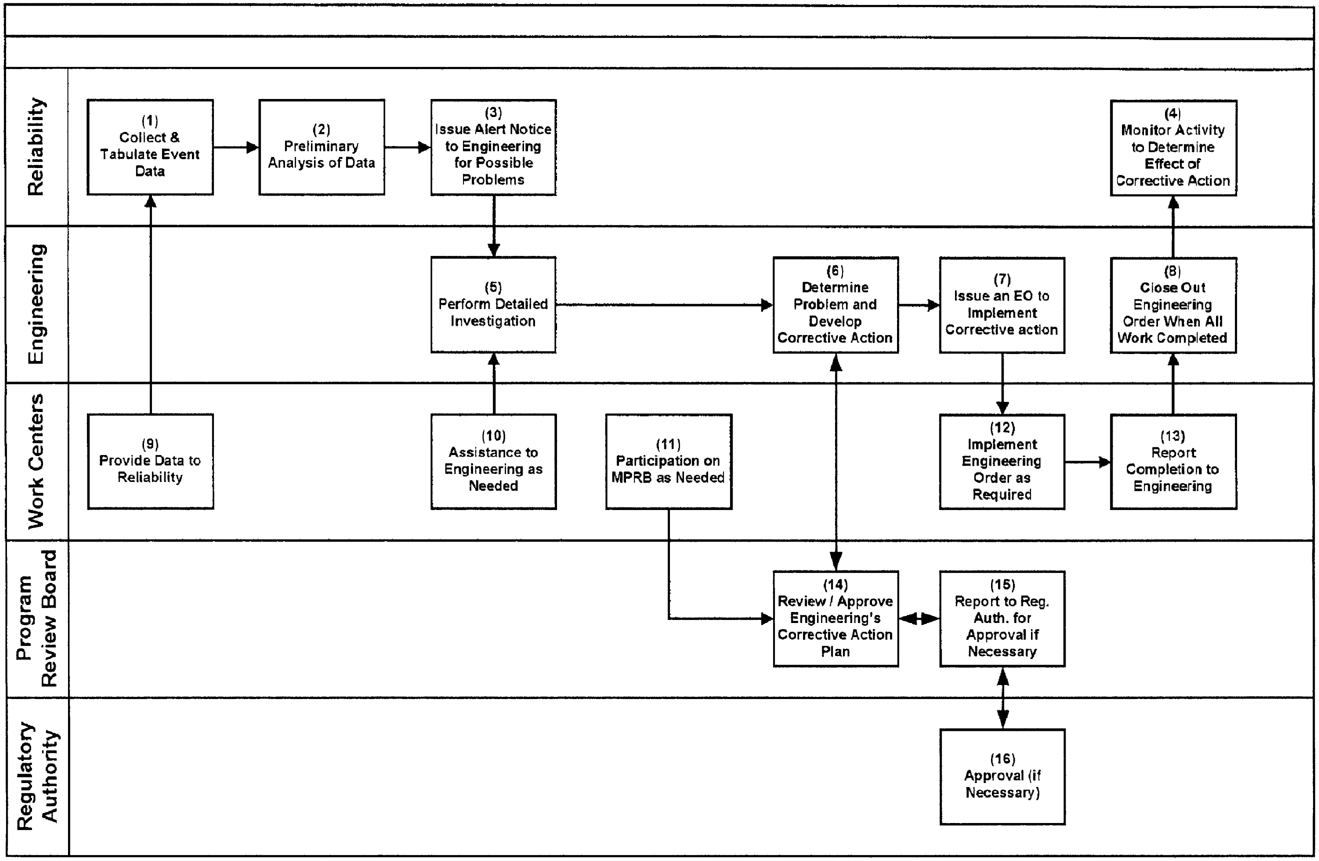
The first step would be to determine if the manufacturer is aware of the problem, and find out if other airlines have had similar experiences. The manufacturer may already have (or be working on) a fix. This may be in the form of an SB, SL, or an AD, or some redesign effort may be under way. If not, the problem may be determined to be unique to the airline and its operational conditions (environment). In this case, the airline and the manufacturer should work together to obtain a solution. In any case, the airline may need to provide the manufacturer with data on event rates and other aspects of the problem to assist in the solution of the problem.

Figure D-4, block (13): Regardless of where the problem lies—blocks (3) to (6) or blocks (9) to (12)—return to Fig. D-2, block (7) to determine the corrective action required. This will direct you to Fig. D-5, block (1).

Figure D-5, block (1): After determining the problem, the corrective action should be defined. What should be done and who should do it (1) will be outlined in detail on a draft engineering order. The corrective action plan will also include parts, manpower, etc., required to accomplish this (2). The corrective action plan will then be discussed in the monthly (or a special) meeting of the MPRB (3). Attending this meeting will be the permanent members of the MPRB and any others involved with the particular problem (see Chap. 18). This committee will review the order for accuracy and feasibility. Once the MPRB agrees on the corrective action plan and the implementation schedule, block (4), returns you to Fig. D-2, block (8).

Figure D-2, block (8): The EO is finalized and issued by engineering to all affected organizations. Each organization notifies engineering of completion (9). When all action has been completed (10), engineering closes the EO and reports completion to reliability, the MPRB, and the regulatory authority as necessary (11). Reliability then continues to monitor parameters as usual to determine the effectiveness of the corrective action (12).

Thus, the loop is closed and all (hopefully) is well. If reliability determines through subsequent data collection that the corrective action has not been effective in reducing the event rate, the process will be repeated.



Work Centers means any and all work centers involved with a given problem, including the airline and outside contractors.

Figure D-1 Reliability alerts—a cross-functional process.

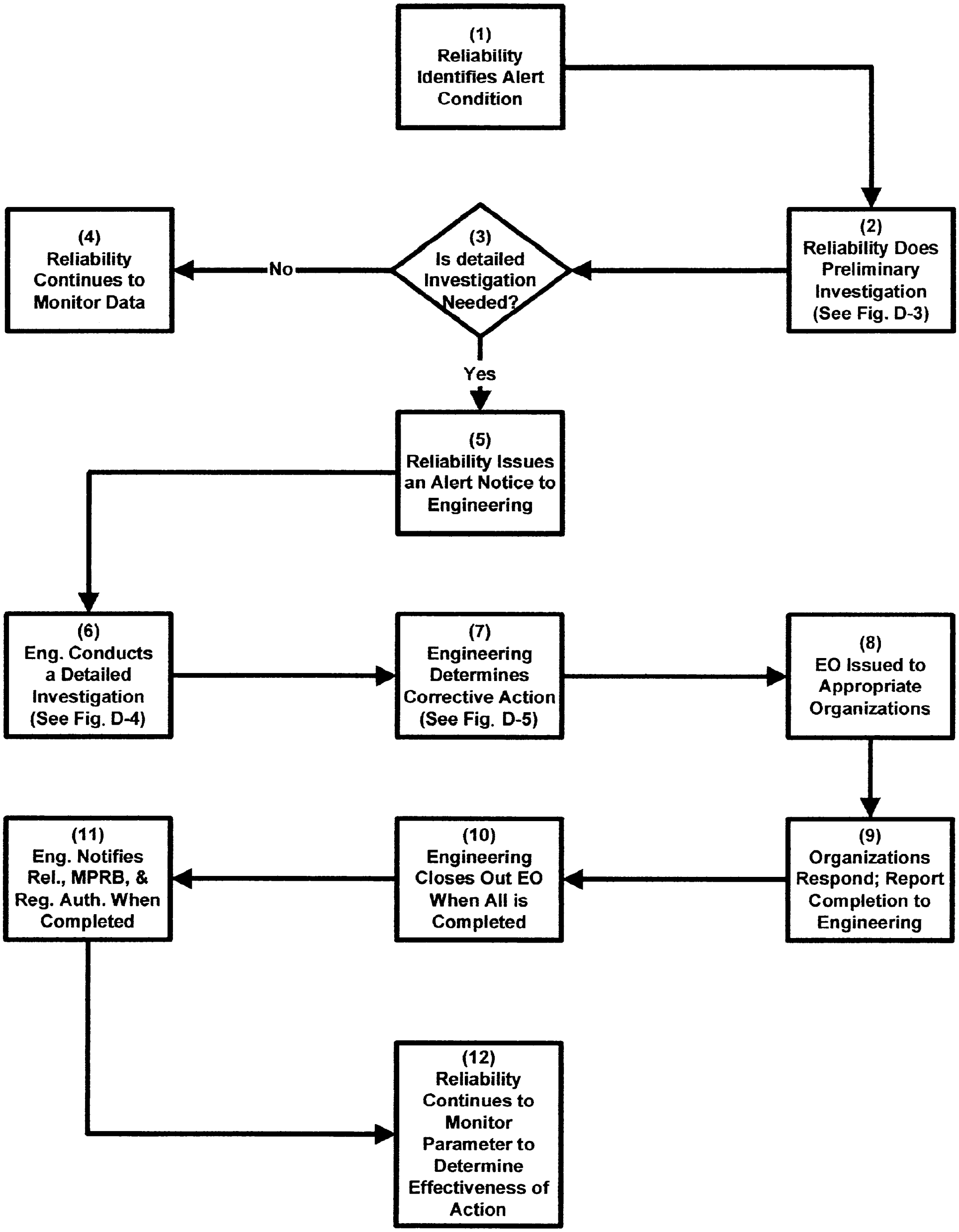


Figure D-2 Analysis of reliability alerts.

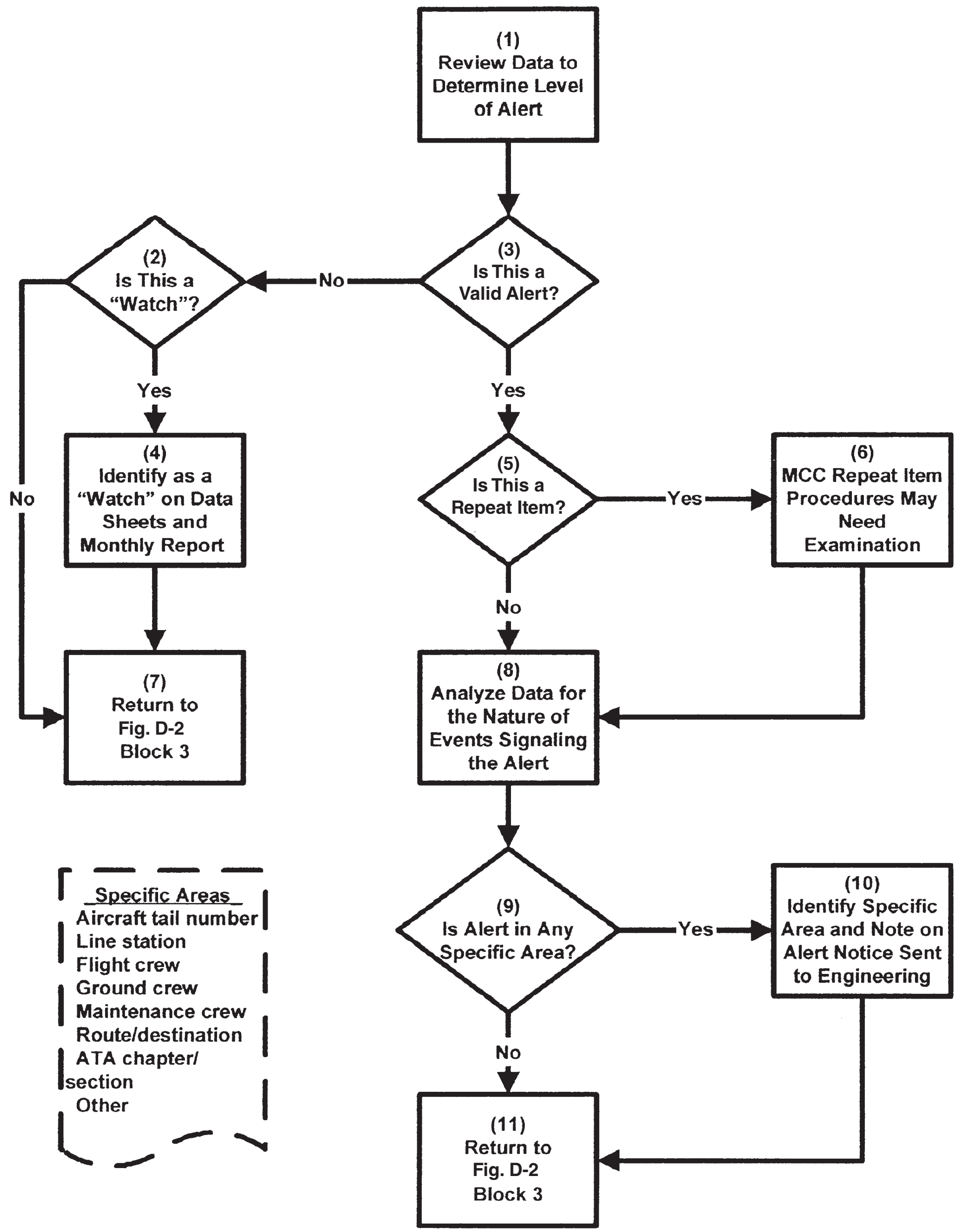


Figure D-3 Preliminary investigation of alert conditions.

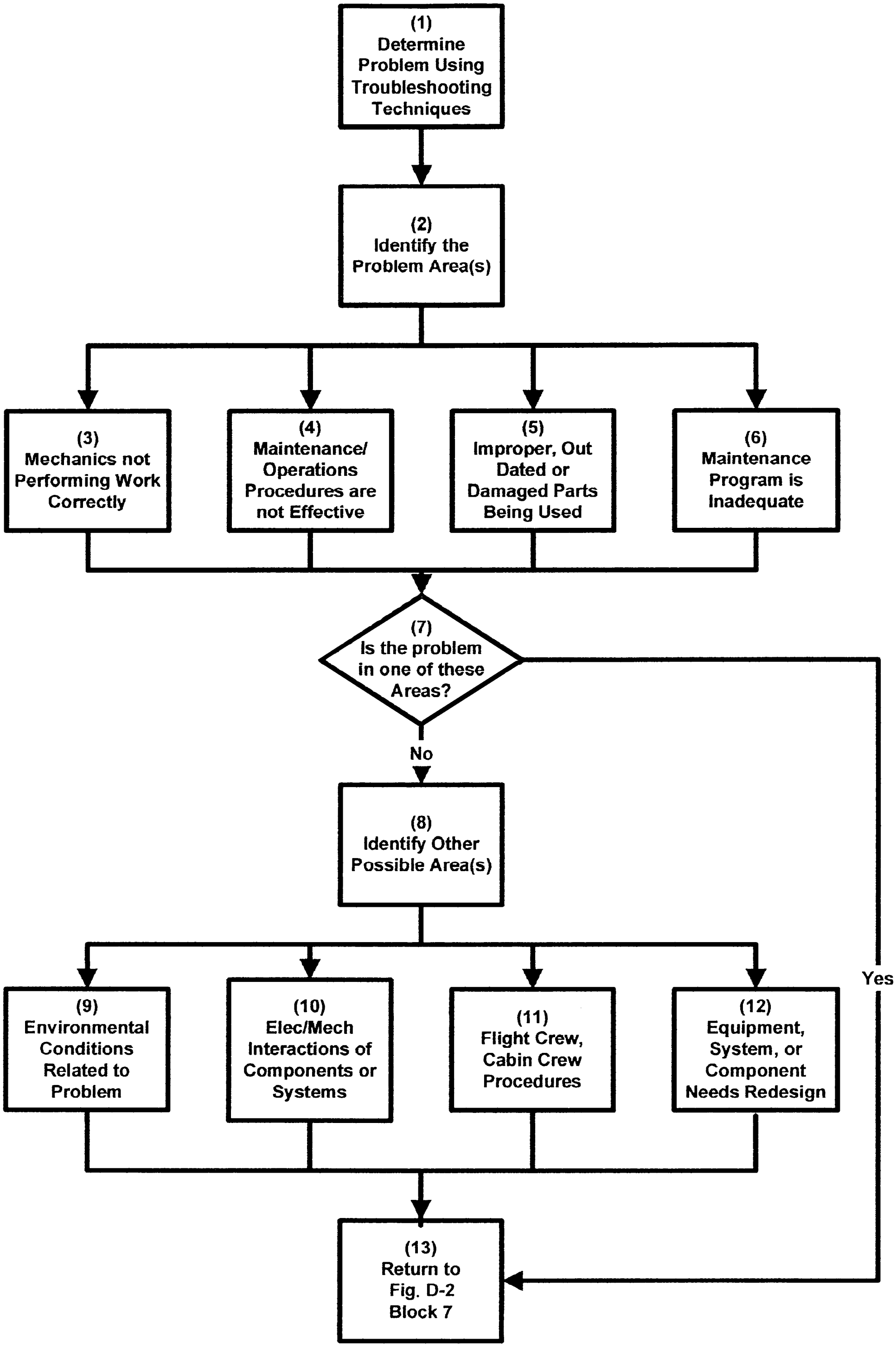


Figure D-4 Detailed investigation of alert conditions.

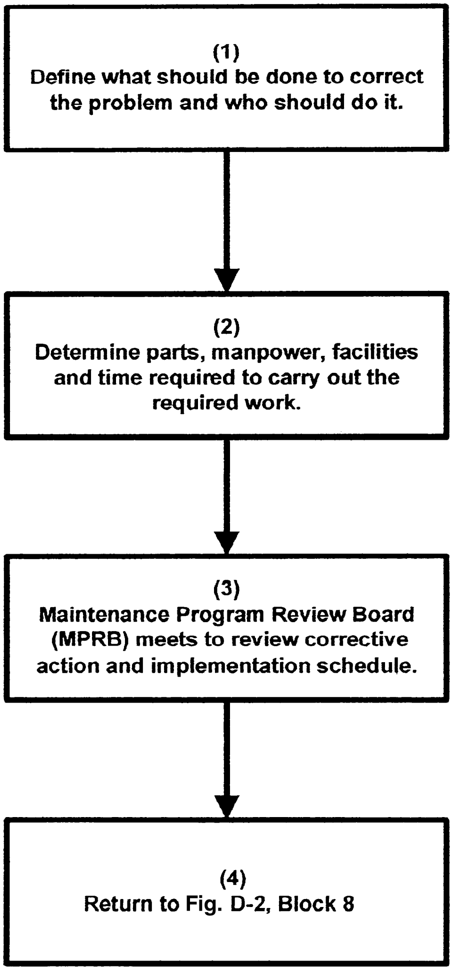


Figure D-5 Determination of corrective action.

Appendix

E

Extended Range Operations (ETOPS)

Introduction

The commercial aviation industry has been flying extended range operations (ETOPS) for more than 15 years, but there is still some confusion about what ETOPS is all about and what is required of the airline operator to fly ETOPS. This appendix will provide some history of the development of ETOPS and identify just what is required to accomplish this new approach to aircraft operations and maintenance.

Background

In the mid-1950s, the FAA established a basic rule for two- and three-engine airplanes (except three-engine turboprops), which still exists today. That rule is FAR 121.161 and states, in part, the following:

> Unless otherwise authorized by the Administrator, based on the character of the terrain, the kind of operation, or the performance of the airplane to be used, no certificate holder may operate two-engine or three-engine airplanes (except a three-engine turbine powered airplane) over a route that contains a point farther than 1-hour flying time (in still air at normal cruising speed with one-engine inoperative) from an adequate airport.[1]

The FAA further states in an Advisory Circular on ETOPS, "It is significant to note that this rule is applicable to reciprocating, turbopropeller, turbojet, and turbofan airplanes transiting oceanic areas or routes entirely over land."[2]

At the time the rule was written, essentially all two-engine airplanes were powered by reciprocating (piston) engines with propellers. These internal combustion

[1]Federal Aviation Regulation 121.161.

[2]FAA Advisory Circular AC 120-42A, Extended Range Operations with Two-engine Airplanes (ETOPS), December 1988 and AC 120-42B (ETOPS and Polar Operations) June 2008.

engines were subject to in-flight failures and shutdown; and adding more engines to the aircraft did not appreciably improve the situation. However, the three- and four-engine airplanes usually had enough power to sustain safe flight with one engine out. Thus, the three- and four-engine airplanes could fly farther away from the alternate airport with safety. The two-engine airplanes were required by FAR 121.161 to remain within 60 minutes of the alternate airport in case one engine would have to be shut down.

When the jet engines were introduced, they were tremendous improvements over the reciprocating engines, and they had much better safety and performance records. Over the years since the jet engine was first employed, these engines got better and better.[3] When the modern "glass cockpit" airplanes (B757, B767, A300) were introduced in the early 1980s, operators wanted to use these airplanes on their North Atlantic routes from the United States to Europe. The problem, however, was that the two-engine rule required them to remain within 60 minutes of a suitable, alternate airport throughout the entire flight. This meant flying over Greenland from New York to London and other European destinations while the three- and four-engine airplanes could fly the North Atlantic tracks, which allowed them to fly a shorter route over the southern tip of Greenland.

To alleviate this discrepancy, the industry asked the FAA to change the 60-minute rule, citing significant improvements in engine technology and performance along with better navigation systems of the day. The FAA, instead of eliminating or changing the 60-minute rule, produced an advisory circular in 1985 that provided guidelines allowing an operator to obtain approval from the FAA to "deviate from the rule." This gave an operator, after meeting certain requirements (to be explained later), permission to fly up to 120 minutes from a suitable, alternate airport. This allowed ETOPS-approved operators of twins to use the North Atlantic tracks—a shorter, more competitive route.

Later (1988), when operators sought other world routes for the twins, the AC was revised (AC 120-42A) and allowed operators who complied with some additional requirements the privilege of flying up to 180 minutes from a suitable, alternate airport. This revision to the AC made it possible to fly two-engine airplanes almost anywhere in the world.[4] Operators in the North Pacific region, however, were limited by the availability of suitable alternate airports. In recent years, FAA permission to fly more than 180 minutes from a suitable alternate airport was extended to 207 minutes (a 15 percent extension over 180) for these operators. This not only closed up the holes (except Antarctica), it allowed twins operating in the North Pacific a better choice of alternates.

[3]One engine on the B777 twin-jet delivers more thrust than all four engines of the original B707, i.e., 80,000 to 90,000 pounds thrust on each engine for the B777 versus 18,500 pounds of thrust for the original B707 (74,000 pounds total).

[4]At 120 minutes diversion time, twins could not fly over Antarctica, a large area of the Pacific Ocean, and a number of other isolated areas throughout the world. These areas were closed up, for the most part, by the 180-minute approval. A section of the Pacific Ocean and Antarctica were still unavailable to twins.

The airplane, in order to qualify for 207-minute ETOPS, had to be originally designed for ETOPS and the approval would be given on a case-by-case basis. As of the date of writing this text the AC has not been changed to address this 207-minute operation. There are also, at this time, discussions to extend ETOPS diversion time to 240 minutes (i.e., 4 hours). This extension would not open up any significant airspace for twins, but it would allow all operators with such approval a better selection of alternate airports. This would allow carriers to provide improved passenger comforts in the event of a diversion.[5]

Deviation from the 60-Minute Rule

Although the basic rule, FAR 121.161, has never been changed, the FAA has established requirements for approval to deviate from the rule. These include specific changes to the equipment and to the airlines' maintenance and flight operations programs.

Equipment modification

The primary requirement for ETOPS was to change the airplane engines to meet a higher standard of reliability, which resulted in a number of engine modifications. Other modifications were incorporated in on-board equipment. The auxiliary power unit (APU), originally designed to operate on the ground to provide AC power when the engines were not running, was modified for ETOPS to serve as a backup power source in the event one engine had to be shut down in flight. This modification assured the APU would start and run at altitudes up to 41,000 feet. In addition, a hydraulic motor generator (HMG) was installed on some models to provide an additional source of AC power in case the APU was inoperative.

All of these modifications were identified by service bulletin (SB) and compiled in an FAA-approved document called the configuration maintenance and procedures (CMP) standard. This document also included any maintenance or operations procedures that may have been needed. These SBs, although optional to non-ETOPS operators, became mandatory for ETOPS through the FAA-approved CMP. Thus, for ETOPS operators, these SBs had the status of airworthiness directives (ADs). Generally, these modifications would differ from one engine type to another and by airframe. Thus, a CMP was created for each model and included information for all engine and APU units available for that airframe. These modifications, in the beginning, would take up to a year to incorporate in the operator's fleet. This period gave the operator time to get acquainted with the airplane and develop the ETOPS program. In later years, an operator could buy or lease the airplane in ETOPS configuration.

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[5]The "suitable, alternate airport" designation refers to the suitability for aircraft landing and taking off. Some of these airports, however, may not have adequate passenger amenities.

Flight operations requirements

The ETOPS Advisory Circular states that the workload for the flight crew should not increase due to ETOPS. That is, flying further than 60 minutes from a suitable alternate airport or flying to an alternate airport on one engine should not require any additional crew duties over those of a conventional flight. There are, however, additional requirements for the airline in preparation for ETOPS flights.

Once the origin and destination of the ETOPS flight are determined, alternate airports must be identified and the route plotted. The distance from each alternate is determined based on the airframe/engine combination and the area where the flight will take place. The altitude to be flown with one engine out is determined by the actual terrain over which the flight will be flown and the altitude necessary for optimum fuel burn. The flight speed is determined for these conditions, and the time to the alternate is calculated and translated into distance. This is the distance from the alternate that can be flown per FAA approval.[6] This route and corresponding flight path and altitude will remain the same throughout the operation. However, for each flight, dispatchers at the airline must determine winds and weather on the route (standard procedure) as well as conditions at the chosen alternate(s). The fuel reserves needed to accomplish the diversion to an alternate are then calculated and added to basic fuel requirements.

Maintenance program changes

Maintenance experts agree that the FAA requirements for an ETOPS supplementary maintenance program are, essentially, what any good maintenance program should be. The AC states that if the airline's current, FAA-approved maintenance program does not include the processes and actions stated in the AC, then the program should be upgraded to include them, or other processes and actions that will achieve the same goals must be employed.

The supplemental maintenance program outlined in the AC identifies a number of actions. There are six items which directly affect the day-to-day maintenance activities on the flight line: items 1 to 6 in the list that follows. There are four other requirements, items 7 through 10, which should be included in the maintenance management activities to aid in the implementation of the ETOPS program. The following items constitute the ETOPS supplemental maintenance program:

1. *Predeparture service check*. An ETOPS service check to be performed prior to each ETOPS departure. Consists of normal transit check, oil consumption monitoring tasks, and any additional checks deemed necessary for ETOPS.

[6]This distance is determined assuming still air. During an actual flight, prevailing winds may alter flying time but does not alter the approval to fly the area.

2. *Oil consumption monitoring program*. A monitoring program to identify engine and APU oil consumption rate for each flight leg for an ETOPS airplane, whether an ETOPS flight or not.
3. *Engine condition monitoring program (ECM)*. A program to (*a*) ensure that engine parameters are not exceeded and (*b*) to address problems before they cause degradation or shutdown. Use this in conjunction with the oil consumption monitoring to monitor overall engine health.
4. *Propulsion system monitoring program*. A program to monitor in-flight shutdown rates for the ETOPS airplanes and to ensure that action is taken to restore the engine and also to determine if the recurrence of the problem can be avoided or reduced in the future.
5. *Resolution of discrepancies program*. A program to ensure that proper and expedient corrective action is taken following an engine in-flight shutdown, an ETOPS significant system failure, and any adverse trends indicated by the oil consumption and/or engine condition monitoring programs. Check out the repaired system after maintenance to ensure the effectiveness of the corrective action before releasing the airplane for flight.
6. *Maintenance of multiple, similar systems*. A program to avoid doing maintenance on both units of a dual system, such as engines, fuel lines, etc., at the same maintenance visit. Different crews can be used on the separate systems if the work must be performed at one visit.
7. *ETOPS parts control program*. A program to ensure that only ETOPS-authorized parts (as identified in the CMP or other SBs or ADs) are used on an ETOPS airplane.
8. *APU high altitude start program*. A program to ensure adequate high altitude start capability for the auxiliary power unit. Usually done during the first 2 months of operation. The operator should establish a 95 percent or higher start rate during this period. This will ensure that the modifications and maintenance actions are adequate.
9. *ETOPS training*. All personnel involved with the ETOPS maintenance program must receive training on the philosophy of ETOPS and on the specific requirements, with emphasis on the differences from the normal operation.
10. *Identify ETOPS significant systems*. This is a list of systems, created by the operator for his specific operation, which identifies those systems that are directly related to ETOPS operation. These are the systems of concern in the other supplemental activities.

ETOPS Maintenance versus Conventional Maintenance

As stated earlier, these AC requirements for ETOPS maintenance do not constitute a substantial change in the conduct of maintenance. The proposed program is no more than a different approach to maintenance—what might be called the “real-time” maintenance approach.

Conventional maintenance activity is primarily reactive and predictive. The reactive approach involves addressing malfunctions when they occur or, in some cases, deferring maintenance to another, more convenient time or passing the problem on to the crew at the next station. The predictive approach involves data collection and analysis of the discrepancy, after the fact, with an effort to predict when or how often such problems will likely occur so as to create certain maintenance actions to address these problems on a scheduled basis. Of course, experience has shown that different items require different approaches and most maintenance programs include both reactive and predictive maintenance.

The real-time approach to maintenance is more proactive. The main feature of real-time maintenance is to react promptly and effectively to malfunctions and to monitor certain functions to identify any trends that show an impending problem. Thus, action can be taken before the condition escalates into a more serious problem. As an example, the oil consumption and engine condition monitoring requirements of ETOPS will show engine problems as they develop. Maintenance action can be taken to correct the deficiency before a failure or engine shutdown occurs. The resolution of discrepancies concept of ETOPS is an effort to react promptly to problems and to ensure that the action taken has been effective.

The proactive approach is not necessary for everything on the airplane, nor are the reactive and predictive approaches needed universally. The three approaches should be used selectively for any good maintenance program. This is not a drastic change in maintenance philosophy; it is just a more conscientious approach to maintenance.

ETOPS for Non-ETOPS Airplanes

Two-engine airplanes not used for ETOPS, and three- and four-engine airplanes, can benefit from this real-time approach to maintenance as much as ETOPS-configured airplanes. Although the modifications for ETOPS may or may not be included in a particular airplane (or even available for some models), the maintenance efforts listed above can be applied to all aircraft. The oil consumption monitoring and the engine condition monitoring programs will provide an ongoing view of engine health for all engines on all aircraft. The quick resolution of discrepancies and immediate validation of the corrective action taken can also have benefits to all aircraft whether ETOPS or not. The ETOPS efforts for monitoring all important systems to track and respond to trends are appropriate and effective for all aircraft types. The attitude of being on top of the status of equipment and reacting quickly and responsibly to problems can benefit any maintenance activity (even your car and other ground equipment). In the long run, it can save money in preventing or reducing the number of major problems.

Some airlines configure all airplanes of a given type for ETOPS so that equipment can be swapped between ETOPS and non-ETOPS service quickly to the benefit of scheduling and on-time performance. Other airlines flying both kinds of flights will configure all the engines for a given type airplane for ETOPS so that

the engine buildup process can be simplified. This also requires fewer spare engines; i.e., there is no need to have a spare engine for each configuration.

Airplane manufacturers can provide airplanes in either ETOPS or non-ETOPS configuration as the operator desires, but the trend is to build all airplanes as ETOPS ready. This could be the final step in ETOPS evolution: the elimination of the differences in ETOPS and non-ETOPS operations.

Polar Operations (AC 120-42B)

Introduction

AC 120-42B refers to ETOPS and polar operations. In February 2001, the Aviation Rulemaking Advisory Committee (ARAC) recommended that the guidelines in the Polar Policy letter be incorporated in the ETOPS regulations in response to U.S. carrier plans to conduct north polar operations. The intention of the Polar Policy letter was to require airlines to develop necessary plans, equipment, and configurations for all airplanes, regardless of number of engines.

Polar Areas

- North Polar area: The entire area north of 78° North latitude
- South Polar area: The entire area south of 60° South latitude

In polar areas, AC 120-42B, sections 1 and 2, require that the operations specifications of the certificate holder must contain the following:

1. The designation of alternate airports that may be used for enroute diversions and the requirements the airports must meet at the time of diversion
2. Except for supplemental, all-cargo operations must have a recovery plan for passengers at diversions alternates
3. An aircraft fuel freeze strategy and procedures for monitoring fuel freezing
4. A plan to ensure communication capability for polar operations
5. A MEL for polar operations
6. A training plan for operations in polar areas
7. A plan for mitigating crew exposure to radiation during a solar flare
8. A plan for providing two cold weather antiexposure suits in the aircraft to protect crewmembers during outside activity at a diversion airport with extreme climatic conditions

Maintenance program—polar operations

The certificate holder must comply with all part 121 flight operations and maintenance requirements pertaining to ETOPS and polar operations as discussed in AC 120-42B. This includes the MMEL provision for 120 minutes of provisions,

and the certificate holder must operate in accordance with the ETOPS-polar authority as contained in the air carriers Ops Spec. The AC's Chapter 3 refers to dual maintenance-type programs for ETOPS and polar operations.

ETOPS maintenance is discussed earlier in this appendix, but there are a few things that will be discussed to better understand the AC maintenance program.

1. *Configuration, maintenance, and procedures (CMP) document*. A document approved by the FAA that contains minimum configuration, operating and maintenance requirements, hardware life-limits, and master minimum equipment list (MMEL) constraints necessary for airplane-engine combinations to meet ETOPS-type design approval requirements.
2. *Dual maintenance*. Dual maintenance means maintenance on the "same" ETOPS-significant system. Dual maintenance is a maintenance action performed on the same element of identical, but separate ETOPS-significant systems during a scheduled or unscheduled maintenance visit. Dual maintenance on "substantially similar" ETOPS-significant systems means maintenance actions performed on engine-driven components on both engines during the same maintenance visit.
3. *MEL considerations*. The certificate holder must amend its MEL to reflect the items that must be operational for these types of operations. An MEL review is required for consideration of the dispatch availability of the following system or equipment:
   a. Fuel quantity indication system
   b. APU system
   c. Auto-throttle system
   d. Communication system
   e. External defibrillator (except for cargo ops)

Summary

The ETOPS and polar operations supplemental program is a real-time approach to aircraft maintenance that allows the operator to be current on all equipment condition, support of ETOPS and polar operations for monitoring any adverse trends, and responding promptly and efficiently to maintenance problems. By performing validation checks on the maintenance action, the program ensures that adequate solutions to problems have been implemented, so the airline can ensure a better flight time to maintenance downtime ratio. This can be seen as a cost-saving measure for maintenance in the long run by avoiding major problems and minimizing aircraft downtime.

Appendix

F

Glossary

"A" Check A maintenance check performed approximately every month (every 300 flight hours, for example).

A&P Airframe and power plant

AC Advisory circular—Information issued by the FAA to identify ways in which an operator can meet the requirements of certain aviation regulations.

AC Airworthiness certificate—A certificate issued by the FAA to each aircraft built to assure that it has been built to type certificate (TC) standards and delivered to the customer in an airworthy condition.

Accidental Damage The physical deterioration of an item caused by contact or impact with an object or influence that is not a part of the airplane; damage as a result of human error that occurred during manufacture, operation of the vehicle, or performance of maintenance.

AD Airworthiness directive—A document issued by the FAA whenever an unsafe condition exists in an aviation product. ADs may prescribe inspections, modifications, conditions, or limitations under which the product may continue in operation. Incorporation of an AD is mandatory.

Airworthiness Meeting the FAA established standards for safe flight; equipped and maintained in a condition to fly.

Alert An arbitrary level of failure (or removal, etc.) rate set by reliability to call attention to a possible problem area. Must be established by the analyst to provide useful guidelines.

AMM Airplane maintenance manual—Manual produced by the airframe manufacturer containing pertinent information about the aircraft and its installed equipment.

AMT Aviation maintenance technician—Latest terminology for aircraft mechanic; includes those trained and qualified in airframe, power plant, avionics, etc.

AOG Aircraft on ground—An aircraft that is out of service (i.e., grounded) waiting for a part or parts before it can be returned to service.

APU Auxiliary power unit—A turbine engine used to generate electrical power on the ground when aircraft engines are not operating. Sometimes used in flight when one engine is out (ETOPS) to replace the inactive engine-driven generator.

ATA Air Transport Association of America—A U.S. trade organization for commercial aviation operators.

ATC Air traffic control—An FAA service to promote the safe, orderly, and expeditious flow of air traffic.

Backshops Another name for overhaul shops for maintenance and repair of off-aircraft equipment.

BITE Built-in test equipment—Special equipment associated with certain systems to monitor health and operation of those systems and to aid in fault location efforts.

Block Hours Hours measured from the time aircraft leaves the gate (wheel chocks removed) to the time aircraft stops at the destination gate (wheel chocks in place) (see also Flight Hours).

"C" Check A maintenance check performed approximately every 12 to 18 months (every 4000 flight hours, for example).

CAMP Continuous airworthiness maintenance program—The FAA-approved maintenance program for a commercial aircraft operator.

CASS Continuing analysis and surveillance system—A program (or programs) established by the operator to ensure that the maintenance and inspection programs of the carrier's Ops Specs are effective.

CDL Configuration deviation list—An amendment to the TC that identifies airframe and engine parts that can be missing at dispatch provided that they are not safety related and the aircraft is dispatched with limitations as identified in the CDL for that deviation.

CFR Code of Federal Regulations—A codification of general and permanent rules published by executive departments and agencies of the U.S. government.

CM Condition monitoring—A primary maintenance process for items that do not have characteristics that would allow the establishment of HT or OC intervals to determine serviceability. CM items are operated to failure.

Critical Failure Failures involving a loss of function or secondary damage that could have an adverse effect on operating safety.

CRT Cathode ray tube—A type of electronic display device using a vacuum tube similar to a conventional TV screen.

CSDD *Common Source Data Dictionary*—Document issued by ATA containing standard aviation definitions.

Daily Check A maintenance check performed every day or any time the aircraft has sat on the ground for more than 4 hours. For recent aircraft models, this has been changed to a 48-hour interval.

D&O Description and operation—Part of the AMM that describes how the aircraft's various systems work.

DDG Dispatch deviation guide—Maintenance guidelines necessary to properly configure for safe flight those items that have had maintenance deferred by MEL action.

Dedicated Inspector Person assigned as a QC inspector full time. May be in QA, QC, or work center.

Delegated Inspector Person assigned as a QC inspector for specific inspections or a specific work center only; a part-time QC inspector.

Designated Inspector Same as a delegated inspector.

Detailed Inspection An intensive visual inspection of a specified detail, assembly or installation using adequate lighting and, where necessary, inspection aids such as mirrors, hand lenses, etc.

Discard The act of removing a component from service permanently after a specified lifetime.

DMI Deferred maintenance item—A maintenance item deferred by MEL or CDL rules to be accomplished at a later time.

DOC U.S. Department of Commerce—Sets standards for air commerce.

DOL U.S. Department of Labor—Parent organization for the Occupational Safety and Health Administration (OSHA).

DOT U.S. Department of Transportation—Sets standards for U.S. transportation systems. Parent organization of FAA.

EBU Engine Build-Up—The process of adding components to a basic engine to configure it for installation on a specific aircraft and position. Allows for quicker engine changes (see also QEC).

Engine Cycle Operation of the aircraft engine from start-up to shutdown.

Engineer A problem solver; a technical expert in the M&E organization.

Entropy Unavailable energy; the difference between the theoretical system and the practical one.

Environmental Deterioration The physical deterioration of an item's strength or resistance to failure as a result of chemical interaction with its climate or environment. May be time dependent.

ETOPS Extended range operations with two-engine aircraft—Allows two-engine aircraft operator to fly up to 180 minutes (or more) from a suitable, alternate airport.

Evident Failure A failure of an aircraft system or component that is noticeable to the flight crew.

FAA U.S. Federal Aviation Administration—Component of the U.S. DOT responsible for aviation and air transportation.

Failure Effect The effect that a specific failure has on the operation of a system.

Failure Mode The manner in which a system or component can fail.

FAK Fly-away kit—A collection of parts/supplies carried on board the aircraft to facilitate maintenance at outstations where such parts/supplies are not available.

FAR Federal Aviation Regulation—Term used to identify U.S. Code of Federal Regulations (CFR) relating to aviation.

Fatigue Damage The initiation of a crack or cracks due to cyclic loading and subsequent propagation of such cracks.

FH Flight hours

Flight Hours Actual flight time measured from takeoff (wheels up) to landing (touchdown) (see also Block Hours).

FSDO Flight Standards District Office of the FAA.

Functional Check A quantitative check to determine if each function of an item performs within specified limits. This check may require use of auxiliary equipment.

General Visual Inspection A visual examination that will detect obvious, unsatisfactory conditions or discrepancies.

GMM General maintenance manual—Another name for the airline's technical policies and procedures manual.

Goal A goal is a point in time or space where you want to be; a level of accomplishment you want to achieve.

GSE Ground support equipment—Equipment used in the maintenance and servicing of the aircraft and its equipment.

HF Human factors

HFM Human factors in maintenance

Hidden Failure A failure of an aircraft system or component that is not evident to the flight crew.

HMG Hydraulic motor generator—An AC generator, powered by the hydraulic system, to provide an additional source of power for ETOPS operation.

HMV Heavy maintenance visit—A maintenance check that involves structural inspections, major modifications, and other major repairs. Usually extensive downtime.

HT Hard time—A primary maintenance process that requires replacement of a component at specific intervals (lifetime).

IATA International Air Transport Association—An international Aviation Trade Organization.

IDG Integrated drive generator—An aircraft engine–driven electrical generator.

IFSD In-flight shutdown (of an aircraft engine).

Inherent Reliability The "designed-in" reliability of a component or system. This reliability is a combination of design and preventive maintenance efforts.

Inspection An examination of an item and comparison against a specific standard.

ISC Industry Steering Committee—Experienced representatives of manufacturers and operators who oversee the activities of the maintenance steering group (MSG) in generating an aircraft maintenance program.

ISO International standards organization—An international organization responsible for establishing standards throughout the world.

IWG Industry working group—A group of aviation industry experts developing the maintenance program for a new or derivative aircraft.

JAA Joint Aviation Authorities—An association of European Aviation Authorities working to standardize regulations throughout Europe. Not a regulatory authority.

LCD Liquid crystal display—Type of instrument display device.

LEP List of effective pages—Identifies pages in a document that comprise the latest revision (helps to identify missing or added pages).

Letter Check Standard check cycles for certain maintenance efforts. May be called A, B, C, etc. Airlines may use other names. Frequency varies from aircraft to aircraft and from operator to operator. Can be measured in flight hours, flight cycles, or calendar time.

LRU Line replaceable unit—An aircraft component designed for quick removal and installation to reduce maintenance downtime and minimize flight interruption.

Lubrication An act of replenishing oil, grease, or other substances used for the purpose of maintaining the inherent design capabilities of a unit or system by reducing friction and/or conducting away heat.

M&E Maintenance and engineering—The airline organization responsible for all maintenance and servicing of aircraft and any engineering activities related to that maintenance.

Maintenance The process of ensuring that a system continually performs its intended function at its designed-in level of reliability and safety.

Maintenance Zone Identified area on an aircraft where visual inspections are performed on all elements within the zone.

MCC Maintenance control center—The hub of maintenance activities on the flight line for in-service aircraft.

Mechanic An FAA certified technician or mechanic

MEL Minimum equipment list—A list of equipment that flight crews agree to accept as inoperative for short periods. Time intervals set by the FAA and airframe manufacturer in the MMEL. Operator creates an MEL unique to his or her own configuration.

MIDO Manufacturing Inspection District Office—FAA organization that is responsible for inspecting airframe, engine, and appliance manufacturers for capabilities and for issuing the production certificate.

MMEL Master minimum equipment list—Master list of MEL items. Includes all related items available for the aircraft type whether installed on operator's vehicle or not. Developed by airframe manufacturer and FAA approved.

MOE Maintenance organization exposition—Another name for the airline technical policies and procedures manual.

MPD Maintenance planning data document (Boeing and Airbus) that identifies MRB and other recommended maintenance tasks for a given model aircraft (see also OAMP).

MPRB Maintenance Program Review Board—The governing body of the airline's CASS Program; made up of directorate and work center managers.

MRB Maintenance Review Board—The FAA organization that oversees the development of aircraft maintenance programs created by the MSG process.

MRBR MRB report—FAA-approved maintenance program, developed by the industry through the MSG process, that identifies maintenance requirements for a given aircraft.

MSDS Material safety data sheet—An information sheet for chemical substances that provides data on the potential hazards of the product, the required safety standards to be used, and any emergency actions necessary for handling the product.

MSG Maintenance steering group—Oversight group, consisting of manufacturer, operator, and regulatory personnel, responsible for creating the maintenance program for new and derivative aircraft.

MSI Maintenance significant item—An item, determined by the manufacturer, whose failure would either affect safety, would be hidden from the flight crew, or would have an operational or economic impact.

MTBUR Mean time between unscheduled removals (repairable equipment)

MTTF Mean time to failure (nonrepairable equipment)

MTTR Mean time to repair (time in shop for maintenance)

NDI Nondestructive inspection—Inspection technique that does not alter the unit being inspected.

NDT Nondestructive testing—Testing technique that does not alter the unit under test.

NDT/NDI or NDT/I Nondestructive test and inspection

NFF No fault found—Negative result of a troubleshooting action. Not necessarily the end of the investigation.

NFPA National Fire Protection Association—An organization to reduce the burden of fire and other hazards; provides scientifically based codes and standards, research, and education in fire safety.

NIST National Institute of Standards and Technologies—Establishes various standards of measurement including those used to calibrate tools and test equipment.

OAMP On-airplane maintenance program (McDonnell-Douglas) that identifies MRB and other recommended maintenance tasks for a given model aircraft (see also MPD).

Objective An objective is the action or activity you employ in order to help you achieve a goal.

OC On condition—Primary maintenance process that schedules periodic inspections or tests to determine remaining serviceability of a component or system.

OC Operating certificate—Certificate issued by the FAA allowing the holder to engage in air operations.

OJT On-the-job training—Training given while working at the normal job as opposed to classroom training.

OSHA Occupational Safety and Health Administration—U.S. Department of Labor organization responsible for establishing the health and safety regulations for business and industry.

Operating Cycle Take-off, flight, and landing of an aircraft.

Operational Check A task to determine if an item is fulfilling its intended purpose. This is a failure-finding task and does not require quantitative tolerances or any equipment other than the item itself.

Ops Specs Operations specifications—An airline, model-specific document that identifies the operations and maintenance programs of the airline in detail. Must be approved by the FAA.

Oversight Functions Those elements of the M&E organization that monitor the performance of the other M&E activities.

PAI Principle avionics inspector—An FAA representative assigned to an airline for liaison and assistance in matters related to avionics systems.

PC Production certificate—A certificate issued by the FAA to the manufacturer of an approved aircraft model.

PERT Program evaluation and review technique—A graphical planning and scheduling technique for complex projects. Identifies each item to be accomplished, the sequence in which items should be performed, and any conflicts which may arise.

PIC Pilot in command—Senior officer of an aircraft flight crew.

PIREP Pilot report—A logbook entry or other report (verbal or electronic) by a flight crew member concerning an aircraft discrepancy or malfunction.

PMI Principle maintenance inspector—An FAA representative assigned to an airline for liaison and assistance on maintenance matters.

POI Principal operations inspector—An FAA representative assigned to an airline for liaison and assistance in matters related to flight operations.

PP&C Production planning and control—The M&E organization responsible for planning and scheduling all maintenance activity at the airline.

Program Module Part of a computer program designed to provide specific operations/manipulations of stored or input data.

QA Quality assurance—The M&E organization responsible for setting standards of operation and for monitoring the operator units to ensure that such standards are met.

QC Quality control—The M&E organization responsible for conducting inspection of maintenance work (when required) and for calibration of tools and test equipment. QC inspectors can be dedicated (full time) or delegated (part time).

QEC Quick engine change—The process of removing and replacing an aircraft engine with a minimum of downtime. All engine build-up (EBU) activities have been done prior to the QEC to facilitate quick removal and installation.

RCB Reliability control board—The governing body of the airline's reliability program; made up of all affected work center managers.

R&I Removal and installation—Procedure for removal and installation of aircraft parts or systems designated as LRUs.

Redundancy The use of two or more items in parallel or in a primary/secondary arrangement to ensure full support in case one unit fails.

Reliability The probability that an item will perform a required function, under specified conditions without failure, for a specified amount of time.

Reliability Program A set of rules and practices for managing maintenance and controlling the maintenance program.

Residual Failure A failure mode that remains if a proposed modification of the unit or proposed change of maintenance program were rejected. Cost of these failures must be considered in the decision to incorporate or not to incorporate the modification.

Restoration That work necessary to return an item to a specific standard. Restoration may vary from cleaning the unit or replacing a single part up to and including a complete overhaul.

RII Required inspection item—Those items that could result in unsafe operation of the aircraft if maintenance is not performed correctly or if improper parts are used.

SB Service bulletin—Document issued by the manufacturer to modify or improve operation of an aircraft component or system. Could include substitution of parts; special inspections or checks; or a change in life limits. Incorporation by airline is optional.

Scheduled Maintenance Simple maintenance and/or servicing activities designed to maintain the inherent level of safety and reliability of a system; done at specified intervals.

SD Standard deviation—A statistical parameter identifying the relative dispersal of data points about a mean value.

Servicing An act of attending to basic needs of components and/or systems for the purpose of maintaining the inherent design capabilities.

SL Service letter—Document issued by the manufacturer to identify a maintenance tip or new procedure. Incorporation is optional.

Special Detailed Inspection An intensive examination of a specific location; similar to the detailed inspection but with the addition of special techniques.

SSI Structurally significant item—Any detail, element, or assembly which contributes significantly to aircraft loading and whose failure could affect the structural integrity necessary for safety of the aircraft.

System A collection of components designed to work together to efficiently perform a certain function.

System Boundaries The limits of consideration for a study, analysis, observation, or usage of a collection of components.

System Element Any component that can be assigned a function or an attribute within the context of the defined system

System Interface A point where two systems or two elements or subsystems connect or interact. This interaction can be direct or indirect; it can be electrical or mechanical; it can be through hard wire, sensory, or transmission devices.

Systematic Approach A step-by-step process; an essentially linear process or procedure where one accomplishes some goal by performing one step at a time, in sequence, until the desired result or goal is achieved.

Systems Approach An approach to the study of a complex system considering all parallel and interacting aspects at once as opposed to the systematic approach, which is a linear process.

Systems Engineering The application of engineering principles to the study and development of a system.

TC Type certificate—A certificate issued by the FAA that identifies a specific, approved aircraft design.

Third Party Any person or organization outside the airline performing service or maintenance activities for the airline.

Transit Check A maintenance check performed prior to each flight (i.e., at aircraft turnaround).

Troubleshooting The process of studying and analyzing a problem in order to pinpoint the cause and resolve the trouble.

TN Tail number—Aircraft identification number, usually painted on the tail.

UCL Upper control limit—A statistical parameter used in establishing a reliability alert level (a mean value plus some multiple of the SD).

Unscheduled Maintenance Maintenance performed to restore an item that has failed or deteriorated beyond usable levels to its inherent (designed-in) level of reliability and safety.

Validation Accepting a test procedure after actually performing it successfully.

Verification Accepting a test procedure based on knowledge of the unit under test and understanding of the procedure. (Procedure is not actually performed.)

Visual Check An observation to determine if an item is fulfilling its intended purpose. This is a failure-finding task and does not require quantitative tolerances.

Zonal Inspection Several visual inspection tasks performed in a specific area (zone) of the aircraft.

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