Commercial Airplane Certification Process Study

An Evaluation of Selected Aircraft Certification, Operations, and Maintenance Processes

March 2002

The Report of the FAA Associate Administrator for Regulation and Certification's Study on the Commercial Airplane Certification Process

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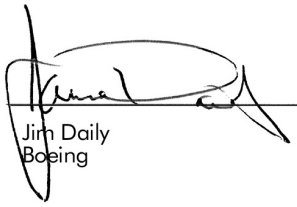

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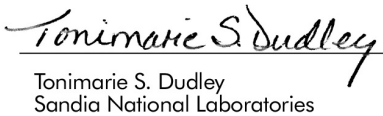

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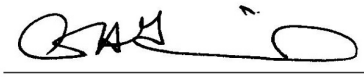

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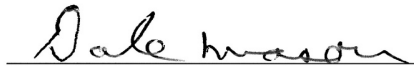

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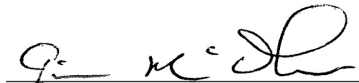

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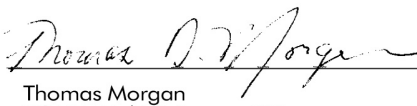

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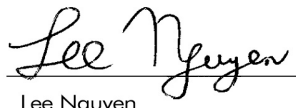

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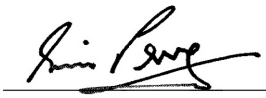

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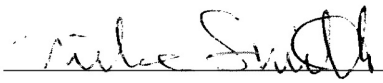

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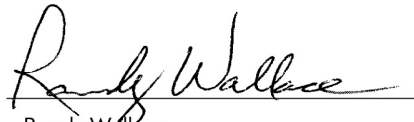

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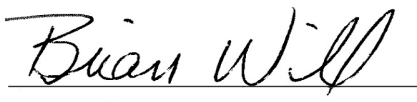

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March 14, 2002

Federal Aviation Administration
Associate Administrator for
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800 Independence Avenue, S.W.
Washington, DC 20591

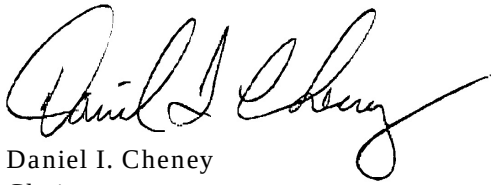
Dear Mr. Sabatini,

It is a pleasure to forward the team's report, Commercial Airplane Certification Process Study – An Evaluation of Selected Aircraft Certification, Operations, and Maintenance Processes. The main objective of this evaluation was to identify opportunities for process improvements, and I am confident that this study has met that goal. The findings and observations contained in this document should form the basis for additional efforts, enabling a remarkable safety system to become even better.

In the course of this year's work, the team and I have frequently remarked on how successful the vast majority of today's processes and procedures are in accomplishing their safety objectives. This does not imply that there are not areas that could be improved upon, and this study identifies some of them. However, I suggest that as we move forward with the identification and implementation of improvements, due consideration be given to the complex interrelationship among these many successful processes that already exist.

Thank you for the opportunity to chair and lead this team. It was a pleasure to work with such talented and professional individuals, both from government and private sectors. I look forward to continuing to support this effort.

Respectfully,



Daniel I. Cheney
Chairman

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Acknowledgements

Many people played a role in this study to make it a success. There is not space to name and thank them all, but I would like to recognize a few in particular. Foremost, I would like to acknowledge the invaluable insight and guidance provided by Tom McSweeny and Elizabeth Erickson during the initial stages of this effort. Without their vision and support, this study most likely would not have been undertaken. I would also like to express my appreciation to all the Oversight Board members, including the support provided by acting members Ron Hinderberger, John Hickey, and Tom Edwards, for their continuous guidance to the CPS team throughout the study. Additionally, I wish to acknowledge the expert support and tireless patience provided by the representatives from Sandia National Laboratories.

I would like to thank all of the organizations, both government and industry, that contributed human and financial resources in order to make this study a success and most of all, the CPS team members themselves. The tremendous dedication and talent they put forth for more than a year will enable a remarkable aviation safety system to become even better. Especially vital during the later stages of the study were the contributions made by the Editorial Committee members in finalizing the document. I am particularly grateful for the long hours spent by them in coordinating and integrating revisions.

And finally, I would like to join the rest of the CPS team and Oversight Board in expressing our heartfelt thanks to Julie Zachary of the Seattle Aircraft Certification Office for her outstanding support through all phases of the study including research, planning, scheduling, and document construction.

Daniel I. Cheney
Chairman, Commercial Airplane Certification Process Study

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Executive Summary

Introduction

The safety of large transport airplanes operating in commercial service throughout the world has improved over the last several decades. Recently, this rate of improvement has slowed, as many of the major, high-impact safety improvements have been developed and implemented by the industry. However, several recent accidents have highlighted the complex nature of accident prevention and the importance of understanding and improving the processes associated with the certification, operations, and maintenance of airplanes.

In 1998, the Federal Aviation Administration (FAA) implemented the Safer Skies initiative, the goal of which was to reduce the US commercial fatal accident rate by 80 percent by 2007. This initiative has focused on using data to understand the root causes of aviation accidents and incidents in order to identify and apply intervention strategies.

As a complement to the Safer Skies initiative and to address the role that processes play in accident prevention, the FAA Associate Administrator for Regulation and Certification chartered the Commercial Airplane Certification Process Study (CPS) in January 2001. The team was led by the FAA, co-chaired by industry, and comprised of technical experts from the FAA, the US aviation industry, National Aeronautics and Space Administration (NASA), the Department of Defense (DoD), and Sandia National Laboratories, as well as representatives from a major non-US manufacturer and a non-US independent airworthiness consultant. The team was chartered to conduct a comprehensive review of the processes and procedures associated

with aircraft certification, operations, and maintenance, starting with the original type certification activities and extending through the continued operational safety and airworthiness processes intended to maintain the safety of the US commercial airplane fleet in service.

The CPS team accomplished a detailed analysis of the various processes, relationships, and life-cycle considerations. The CPS team identified five primary focus areas under which to group their findings and observations.

- Airplane Safety Assurance Processes
- Aviation Safety Data Management
- Maintenance, Operations, and Certification Interfaces
- Major Repair and Modification
- Safety Oversight Processes

Figure 1. *CPS high-Level processes.*

The CPS effort focused on certification, operations, and maintenance processes, and the information paths between them, as depicted in Figure 1. Of special interest were the content and effectiveness of the information paths between certification and operations and maintenance activities (the arrows). Findings and observations were continuously reviewed against this diagram to ensure they were applicable to the CPS charter.

Following analysis and investigation, the team developed and documented fifteen findings and two observations.

Summary of the Findings and Observations

Airplane Safety Assurance Processes

There are many elements to safety assurance of commercial airplanes. These include the safety assessments performed to support type certification and the continuing adherence to essential operations and maintenance procedures for the life of the airplane. The design team of a new airplane must ensure that all the safety and performance requirements are met. This requires a development assurance process to track the design as it evolves. The airplane safety assessment process can be thought of as a part of this *design and development assurance* process. As with all design assurance processes, for the safety assessment process to be effective, it must trace through the entire life cycle of the product.

Finding 1

Human performance is still the dominant factor in accidents:

- *The processes used to determine and validate human responses to failure and methods to include human responses in safety assessments need to be improved.*
- *Design techniques, safety assessments, and regulations do not adequately address the subject of human error in design or in operations and maintenance.*

If significant strides are to be made in lowering the accident rates, a much better understanding of the issues affecting human performance is required. Airplane designers will be challenged to develop systems that are less error-prone. Procedures will also have to be more explicit and more robust with respect to the range of skills and techniques of operations and maintenance personnel. This area would benefit from a better understanding of lessons learned and a sharing of human engineering best practices throughout the industry.

Finding 2

There is no reliable process to ensure that assumptions made in the safety assessments are valid with respect to operations and maintenance activities, and that operators are aware of these assumptions when developing their operations and maintenance procedures. In addition, certification standards may not reflect the actual operating environment.

It will always be necessary to make assumptions in safety analyses; however, where possible, those assumptions may need to be validated by actual experience. There is currently no organized program to periodically revisit design safety assumptions to ensure that they reflect the full range of environments and operations as the fleet ages.

Finding 3

A more robust approach to design and a process that challenges the assumptions made in the safety analysis of flight critical functions is necessary in situations where a few failures (2 or 3) could result in a catastrophic event.

This finding highlights the need to examine every safety analysis assumption for its impact on the overall safety of the airplane. Where any assumption has a major effect on the outcome, the analysis and design should address the potential for the assumption being too optimistic. Risk can often be reduced by selection of a relatively conservative design approach with respect to systems with potentially catastrophic failure consequences.

Finding 4

Processes for identification of safety critical features of the airplane do not ensure that future alterations, maintenance, repairs, or changes to operational procedures can be made with cognizance of those safety features.

Changes developed without Original Equipment Manufacturer (OEM) involvement or without understanding of the original

certification assumptions add risk because the modifier, maintainer, or operator may not be aware of the criticality of the original type design feature being modified. It is difficult for operators to develop such procedures in accordance with those design constraints because only the OEM may have the detailed understanding and documentation of the underlying safety issues.

Aviation Safety Data Management

The effective management of data is crucial if the FAA and industry are to fully understand the nature of the safety challenges facing them. Data systems and sources within the FAA and industry were reviewed and analyzed. How these systems are managed and their success at meeting the needs of their customers are important indicators of their effectiveness. Finally, the data systems must provide the user with the necessary information if they are to be effective at identifying safety issues and accident precursors.

Finding 5

Multiple FAA-sponsored data collection and analysis programs exist without adequate inter-departmental coordination or executive oversight.

Overlapping objectives, activities, and limited resources indicate FAA data programs are not adequately coordinated. There is minimal intra-FAA data management program coordination and no clearly defined office responsible for coordinating these activities. Significant effort is underway to improve the quality of aviation safety data identification and collection. Implementing an oversight function in accordance with FAA Order 1375.1C, *Data Management* (June 20, 2001) would permit the FAA to streamline resources and programs and expand program capabilities.

Finding 6

Basic data definition and reporting requirements are poorly defined relative to the needs of analysts and other users.

Data are being collected in non-standardized formats and stored in multiple, often incomplete, databases. Analysis tools are usually incompatible and narrowly focused on a specific objective or product. As a result, resources are expended on multiple projects and produce separate, yet essentially equivalent products. As a result of multiple dissimilar data collection programs, associated products may not serve the aviation safety needs of government and industry.

Finding 7

There is no widely accepted process for analyzing service data or events to identify potential accident precursors.

Data management programs must create products and services that effectively identify accident precursors. Data collection, data mining, and analysis with automated tools to alleviate resource constraints and human error must be developed and used.

Maintenance, Operations, and Certification Interfaces

The sharing of information between manufacturers, airlines, and regulatory agencies is an essential element in the certification process and in maintaining the airworthiness of in-service airplanes. Accident and incident investigations continually focus on the breakdown in the communication paths between the members of the aviation industry as being causal or contributory to those events. These breakdowns occur as a result of either inadequate processes or the inherent constraints on communication present in the industry. Additionally, lack of formal communication processes between certain FAA organizations exist.

Finding 8

Adequate processes do not exist within the FAA or in most segments of the commercial aviation industry to ensure that the lessons learned from specific experience in airplane design, manufacturing, maintenance, and flight operations are captured permanently and made readily available to the aviation industry. The failure to capture and disseminate lessons learned has allowed airplane accidents to occur for causes similar to those of past accidents.

The knowledge of experienced individuals must be passed on in one form or another. This transfer of knowledge can be accomplished either formally, in documentation required by policy, or informally. However, no requirement currently exists in the FAA or in industry to ensure that the important lessons of the past are documented and used when future systems or programs are revised or developed. Without such a process, industry's memory fades and critical lessons may be painfully relearned.

Finding 9

There are constraints present in the aviation industry that have an inhibiting effect on the complete sharing of safety information.

The FAA has made considerable progress in reducing the constraints of legal liability, enforcement action, and public disclosure of safety information. However, the operator or manufacturer may be reluctant to fully disclose all safety information in a timely manner until complete confidentiality is guaranteed. Until this is achieved, the operator or manufacturer may elect not to contribute data out of concern for potential consequences.

Finding 10

There are currently no industry processes or guidance materials available which ensure that

- *Safety related maintenance or operational recommendations developed by the OEM are evaluated by the operator for incorporation into their maintenance or operational programs.*
- *Safety related maintenance or operational procedures developed or modified by the operator are coordinated with the OEM to ensure that they do not compromise the type design safety standard of the airplane and its systems.*

OEM operational or maintenance recommendations are not always fully considered by operators. Some cases have been identified where this has contributed to accidents or incidents. There have also been cases where operators, without consulting with the OEM, have modified operations or maintenance

procedures and practices that have, or potentially could have, impacted the safety of the type design. The challenge will be to identify the additional communication and reviews required to achieve a real safety benefit versus a non-productive communication requirement.

Finding 11

The absence of adequate formal business processes between FAA Aircraft Certification Service and Flight Standards Service limits effective communication and coordination between the two that often results in inadequate communications with the commercial aviation industry.

There are informal processes that have evolved between Flight Standards and Aircraft Certification, but they are neither consistent nor complete. The lack of documented formal business processes between these offices compromises timely communication and coordination that subsequently affects the FAA's ability to address industry safety issues effectively and industry's ability to comply fully.

Major Repairs and Modifications

Once the manufacturer releases an aircraft to an operator, the operator is responsible for maintaining its continued airworthiness. Maintaining continued airworthiness involves routine maintenance, as well as repairs and alterations to the aircraft. For all of these activities, an approved configuration must be maintained. Maintenance, repair, and alteration work is accomplished using either FAA approved or accepted data, including operator and manufacturer documents.

Finding 12

The airline industry and aircraft repair organizations do not have a standardized process for classifying repairs or alterations to commercial aircraft as "Major" as prescribed by applicable Federal Aviation Regulations (FARs).

There is no standard process used across the commercial aviation industry or regulatory authority to determine and classify

repairs or alterations to commercial aircraft as "Major" as defined by applicable FARs. The result of misclassifying a repair or alteration is the lack of adequate review, validation, and reporting of the sufficiency of repairs or alterations developed.

Finding 13

Inconsistencies exist between the safety assessments conducted for the initial Type Certificate (TC) of an airplane and some of those conducted for subsequent alterations to the airplane or systems. Improved FAA and industry oversight of repair and alteration activity is needed to ensure that safety has not been compromised by subsequent repairs and alterations.

Processes for the design and accomplishment of repairs and alterations, including oversight, have not always ensured the continued airworthiness of the airplane. Safety assessments prepared for certification of alterations to the airplane or systems may not meet the same standards as those for the original type certificate, although the FARs require they do so. There have been cases where the modification station or company did not have the appropriate expertise or access to original certification data to conduct adequate safety analyses.

Observation 1

OEM and operator's maintenance manuals, illustrated parts catalogs (IPC), wiring diagrams needed to maintain aircraft in an airworthy configuration after incorporation of service bulletins (SB) and airworthiness directives (AD), are not always revised to reflect each aircraft's approved configuration at the time the modifications are implemented.

Maintenance manuals, IPCs, wiring diagrams, and other FAA accepted or approved manuals are required for continued airworthiness. Incorrect data as a result of delayed revisions to user manuals can result in the release of an aircraft into service in a non-airworthy configuration. A process is needed to adequately assure that proper repairs and modifications are implemented and mandated configurations are not altered. All manuals and documents that are needed to support the correct implementation of ADs, Alternative Methods of Compliance (AMOCs), Supplemental Type Certificates (STCs) or other authorized documents should be revised to reflect the mandated

aircraft design configuration in order to assure continued airworthiness.

Safety Oversight Processes

FAA and industry oversight of the design, manufacture, and operation of commercial aircraft involves a large number of tasks. These oversight tasks are often the basis for the discovery of information used to establish safe practices and processes. Oversight also serves as a means to assess the adequacy of existing standards and requirements. Strong and effective industry and FAA oversight processes can be used to identify potential safety problems and accident precursors. Making improvements in this area can further enhance the present exceptional commercial aviation safety record.

Finding 14

Consultant DERs have approved designs that were deficient or non-compliant with FAA regulations.

The DER system is generally working well, but still needs emphasis. This system has been enhanced by the addition of new processes for selection and annual review of DERs. However, some consultant DER project approvals, which do not require FAA review, have resulted in designs that were deficient or non-compliant with FAA regulations because of a lack of DER and FAA technical expertise in certain specialized fields.

Finding 15

Processes to detect and correct errors made by individuals in the design, certification, installation, repair, alteration, and operation of transport airplanes are inconsistent, allowing unacceptable errors in critical airworthiness areas.

For some certification activities there are well-ordered and effective processes; for others, no formal process exists, or existing processes may be ineffective. When there has been a lack of an effective process, individuals working independently have made errors in critical airworthiness areas; some of these errors have resulted in accidents.

Observation 2

Some air carriers do more extensive oversight than others of their in-house and outsourced flight operations and maintenance activities, with major safety and economic benefits.

Briefings provided by large Part 121 certificated air carrier personnel indicated that when voluntary internal quality assurance and technical analysis processes are used, significant safety and economic benefits could be realized. The effectiveness of these processes was substantiated in interviews with FAA principal inspectors with maintenance and operations oversight responsibilities. The FAA should encourage all segments of the air carrier industry to enhance their existing processes. It has been suggested that FAA incentives could be considered to influence others in the aviation community to enhance internal and external quality assurance and technical analysis activities.

Conclusions

Several key conclusions were drawn from the study. First, the findings and observations in this study were found to be interrelated. For example, the team identified four areas of commonality:

- Information Flow
- Human Factors
- Lessons Learned
- Accident Precursors

Although other common elements could be identified and documented, the key conclusion is that the findings and observations in this study are clearly interrelated and should not be addressed in isolation. Doing so will most likely lead to less than optimal solutions.

Second, many of the accidents reviewed during this study followed one or more previous incidents that were not acted

upon because those involved in industry and government were unaware of the significance of what they had observed. Often the reason for this lack of awareness was failure to view the significance of the event at the *airplane level*, rather than at the system or subsystem level. Safety awareness at the airplane level is needed for all key safety specialists, regardless of their organization, and is achieved by both proper training and adequate experience. Safety initiatives could be better coordinated and more effective if the operator, manufacturer, and FAA could achieve and maintain this level of safety awareness.

Finally, traditional relationships among the regulators and industry have inherent constraints that have limited the ability to effectively identify accident precursors. Further safety improvements will require significant intra- and inter-organizational cultural changes to facilitate a more open exchange of information. Process improvements alone will not improve safety unless the leaders of government and industry and their respective organizations are committed to working together to achieve this goal of cultural change.

Introduction

The remarkable safety of commercial aviation is an outcome of numerous complex, interrelated processes involving government and industry organizations working together toward the common goal of aviation safety. To maintain this high level of safety, continuous effort is required among many organizations and individuals. Even with this high level of safety, accidents still occur. When accidents do occur, it is important to understand their causes and to take steps to minimize or eliminate the risk of accident recurrence. Accident prevention also requires a periodic evaluation of existing processes to identify areas for improvement.

Recent accidents, such as the Alaska Airlines MD-83 in January 2000, or the Trans World Airlines Boeing 747 in July 1996, raise questions about the adequacy of airplane certification processes and the consistency by which these processes relate to the operation and maintenance of the airplane.

To address these concerns, the FAA initiated the Commercial Airplane Certification Process Study (CPS) in early 2001 to review the certification processes being applied in the United States. The CPS was a separate but complementary effort to the FAA's Safer Skies initiative. Safer Skies identified accident intervention strategies (a problem focused activity), while CPS has identified process improvement opportunities (a process focused activity).

These processes include:

- Understanding and communicating airplane failure modes and design or certification assumptions
- Ensuring airplane operations are consistent with the design or certification assumptions and safety analyses
- Conducting aircraft maintenance activities
- Collecting and analyzing data, including reporting and feedback mechanisms
- Understanding the role and effectiveness of FAA and industry oversight

The purpose of the CPS was to find process improvement opportunities and not to reinvestigate aircraft accidents or critique airplane designs. References to incidents, accidents, and designs are used solely to highlight potential process improvements in order to increase aviation safety. This is fundamental to understanding and using this report.

The CPS team reviewed the processes associated with US transport airplane certification, from the original type certificate activity through the continued airworthiness processes, and examined how these activities interrelate with in-service maintenance and operations programs, as depicted in Figure 2.

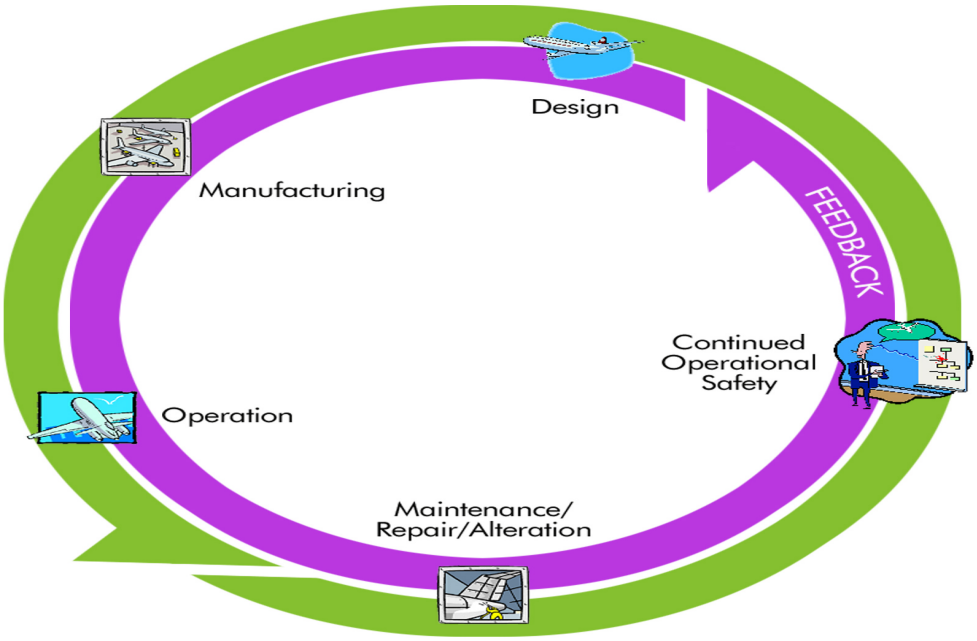

Figure 2. *Life cycle processes associated with US transport airplane certification.*

The CPS also focused on the information paths between certification, operations, and maintenance processes, as depicted in Figure 3. Findings and observations were continuously reviewed against this diagram to ensure they were applicable to the CPS charter.

Figure 3. *Certification process study high-level processes*

Development of Study Focus Areas

The CPS team accepted the challenge of a one-year study of the airplane certification and in-service life cycle processes. While some reference material involved foreign-manufactured airplanes, the study focused primarily on US certificated transport airplanes. During the initial phase of this study, the team analyzed historical reports, accident case studies, numerous briefings by industry subject matter experts, and reviews of applicable regulatory materials.

The CPS team used a top-down and bottom-up analytical approach to better understand the processes related to the certification and life cycle operation of large commercial aircraft. Following a detailed screening activity, five focus areas were identified. These five focus areas formed the basis of the Certification Process Study:

- Airplane Safety Assurance Processes
- Aviation Safety Data Management
- Maintenance, Operations, and Certification Interfaces
- Major Repairs and Modifications
- Safety Oversight Processes

Findings and observations were developed and validated from these focus areas. Findings were defined as those results that can be well substantiated and justified with data. Observations are those items that were not as fully substantiated or justified with data due to time and resource constraints. Nevertheless, observations document areas where opportunities exist for process improvements and are not considered less important than findings. The bottom-up review of reference material, the top-down funneling into focus areas, and the development of findings and observations are depicted in Figure 4.

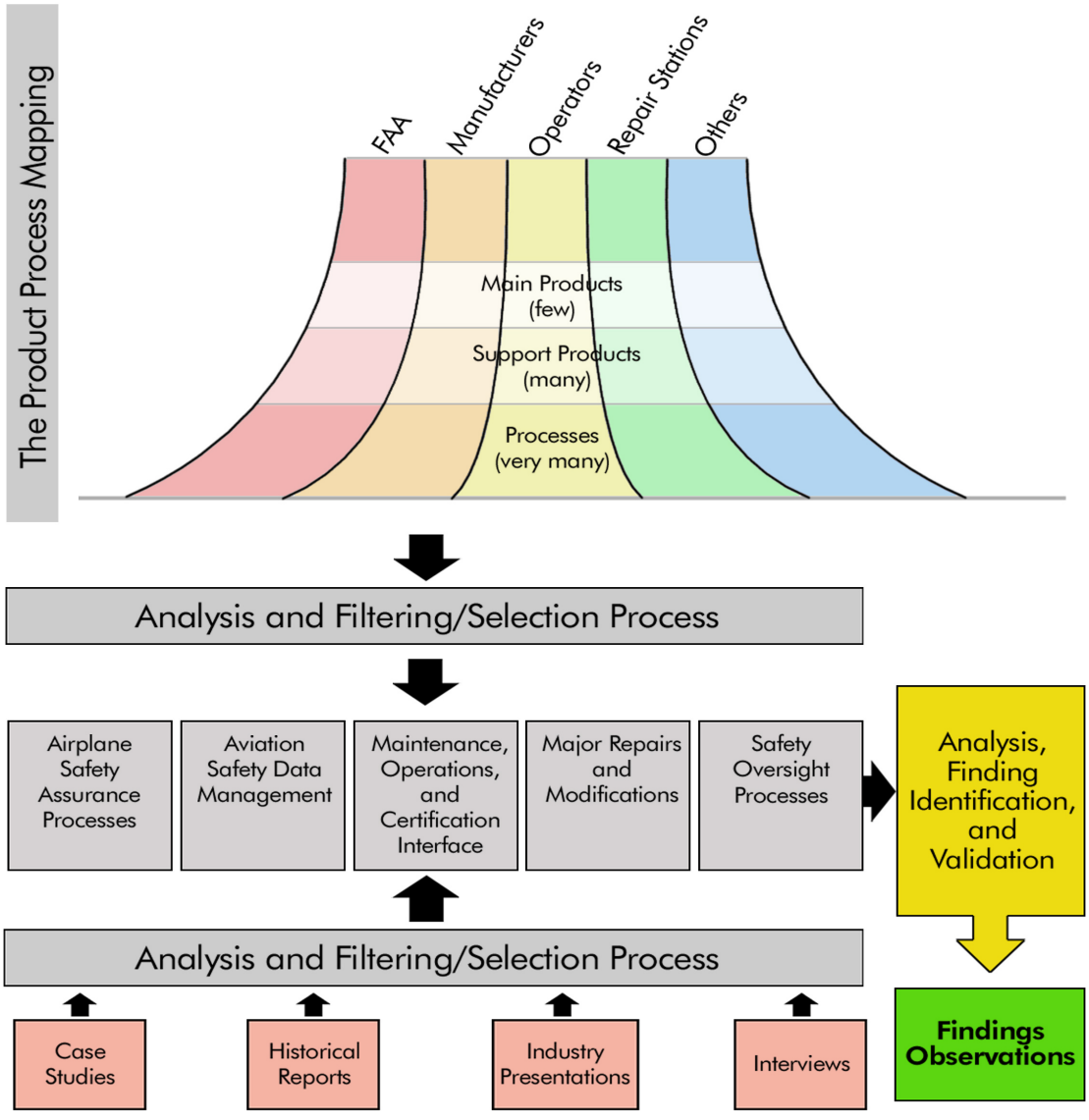

Figure 4. *The CPS methodology for development of findings and observations*

Findings and Observations

The following section of the report contains the findings and observations of the CPS team. They are arranged by chapters, each chapter covering one of the five study topics. The order and numbering of the chapters and findings do not imply any level of importance or priority.

Each chapter also provides a high-level discussion of the processes the CPS team found to be significant to the certification processes in the respective subject area. The reader is cautioned against considering any finding as stand-alone and is encouraged to recognize their interrelationship to other findings and observations in order to gain a better understanding of the certification processes and the areas identified for improvement.

Appendix B provides a summary of the findings and observations that resulted from the study.

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Chapter 1

Airplane Safety Assurance Processes

There are many elements to the safety assurance of commercial airplanes. Included among these are the formal safety assessments performed to support type certification and the continuing adherence to essential operations and maintenance procedures for the life of the airplane. The design team of a new airplane must ensure that all the safety and performance requirements are met. This requires a development assurance process to track the design as it evolves. The airplane safety assessment process can be thought of as a part of this design and development assurance process. As with all design assurance processes, for the safety assessment process to be effective, it must trace through the entire life cycle of the product.

During the development of new airplanes, safety assessments are prepared to ensure that the airplane will meet all the safety standards and requirements imposed by the regulatory authorities and by the manufacturer. These assessments include several related analyses, which should be completed in stages as the development progresses, *i.e.*, they are part of the design and development assurance process. The assessments can be divided into two main functional areas; systems and structures, with propulsion included in both areas.

Over the past 40 years, technologies have changed and systems have become much more interdependent and integrated. Systems now routinely include circuits with microprocessors, programmable logic devices and, in a few cases, fiber optics. With this increasing complexity, it becomes difficult to determine (particularly for the regulatory authorities) the independence of the systems providing critical functions. Therefore, it is imperative to have a sound safety assessment methodology to ensure that failure conditions have been adequately addressed. The certification regulations and associated guidance material have also been in a continual state of development as more is learned about the causes of accidents, and better processes have been identified for conducting the safety assessments.

Although excellent work has been done to improve the quality of the safety assurance processes, there are still some weaknesses that will need attention.

Human error is still listed as one of the most frequent contributors in accidents. There is no single area on which to focus to reduce these errors. It will require attention to all the human interfaces involved in design, operation, and maintenance of an airplane. In the systems area, guidance is provided to the manufacturers in the form of advisory circulars, Radio Technical Commission for Aeronautics (RTCA) documents, and Society of Automotive Engineers Aerospace Recommended Practices (SAE ARPs). SAE ARPs 4761 and 4754 provide excellent guidance to the manufacturers on various topics that need to be addressed in the system safety assessments. However, there are no methods available to evaluate the probability of human error in the operation and maintenance of a particular system design, and existing qualitative methods are not very satisfactory.

Validation and communication of the assumptions that are used during the development of the airplane, relative to the eventual maintenance and operation of the airplane in service, are other problem areas. Some of the assumptions that are critical to flight safety are not always well documented.

A significant problem appears to be the *inadvertent compromise of safety during repair or alteration* of the airplane as a result of the lack of awareness of some of the original design constraints.

Finding 1

Human performance is still the dominant factor in accidents:

- *The processes used to determine and validate human responses to failure and methods to include human responses in safety assessments need to be improved.*
- *Design techniques, safety assessments, and regulations do not adequately address the subject of human error in design or in operations and maintenance.*

Human Factors Issues in Design, Operations, and Maintenance

Human errors continue to dominate as a contributing factor in accidents, being listed in approximately 80% of all transport airplane accidents in the past decade. Flight crew errors are listed as the primary cause in 66% of the accidents [1]. Despite the introduction of protective devices or systems, *e.g.*, Ground Proximity Warning System (GPWS), Traffic Alert and Collision Avoidance System (TCAS), these percentages have remained relatively unchanged. The industry challenge is to develop airplanes and procedures that are less likely to result in operator error and that are more tolerant of operator errors when they do occur.

There are two basic types of human error that can affect the safe operation of an airplane:

- Incorrect response after malfunction
- Incorrect actions with no malfunction

A common assumption in the regulations, advisory circulars, and safety assessments is that single failures, particularly when accompanied with a failure indication, can be detected by the flight crew and, through the use of redundant systems and alternate operating procedures, the flight can be safely continued. In the vast majority of cases, this assumption is correct. However, there are some cases where single failures, which were assumed to cause minor failure effects, have resulted in accidents.

Single Failure Assumed To Cause Minor Failure Effects Resulted In Accident

A recent example is the Boeing 757-200 operated by Birgenair on February 6, 1996 [2]. The plane crashed at night in visual meteorological conditions (VMC), shortly after takeoff from Puerto Plata, Dominican Republic. Data from the cockpit voice recorder (CVR) and flight data recorder (FDR) indicated that the captain's air speed indicator displayed an air speed that was incorrect during

the takeoff roll and the captain recognized this fact. The incorrect airspeed display was consistent with the effects of a blocked pitot pressure sensor. At an altitude of 7000 feet, the captain's airspeed indicator displayed 350 knots and an overspeed warning occurred. This was followed immediately by activation of the stall warning system stick shaker. Although the failed indicator was recognized during the takeoff roll and two other correctly functioning airspeed displays were available to the flight crew, flight crew confusion about airspeed, the proper thrust setting, and the proper pitch attitude resulted in a stall followed by a descent and crash into the Atlantic Ocean. Shortly after this accident, an Aeroperu Boeing 757 crashed [3] after simultaneous overspeed warnings and stall warnings resulting from a failure to remove tape from the static ports after cleaning the airplane. In each accident, errors by both the ground crew and the flight crew were contributory factors.

Failure of Single Attitude Display

The failure of a single attitude display is assumed to be either minor or major depending on the phase of flight and if a failure indication is provided. Accidents are not assumed to occur as the result of minor or major failure conditions. Nevertheless, a number of accidents have occurred following the failure of a single attitude display. For example:

> A Korean Air Lines Boeing 747 crashed 55 seconds after takeoff from Stansted Airport in the UK on December 22, 1999 [4]. The flight crew failed to recognize and correctly respond to faulty roll attitude information displayed on the captain's Attitude Director Indicator (ADI), despite numerous (at least 14) alerts from the Instrument Comparator Buzzer (ICB) and two calls of “bank” by the flight engineer. The airplane impacted the ground in a 90-degree left bank with a 40-degree nose down pitch attitude and all engines operating at takeoff power. On the previous flight with a different flight crew, the captain recognized a problem with his ADI and transferred flying duty to the first officer before selecting the alternate Inertial Navigation System (INS), which corrected the roll attitude display problem. Maintenance was informed of the problem with the captain's ADI, but may not have corrected the problem prior to the next flight.

Incorrect Response After Malfunction

On January 8, 1989, a British Midland Airways Boeing 737-400 suffered a partial fan blade loss in the left engine at flight level (FL) 283 and crashed 19 minutes later, short of a runway at Kegworth, UK [5]. After number one engine failure, a severe vibration was felt accompanied by some engine surges and fumes in the cockpit, but the crew misinterpreted data which was correctly displayed and hastily decided that number two was the faulty engine. After throttling back the number two engine, the vibration seemed to be reduced and then fuel was cut off from the engine. In the non-normal checklist, severe vibration does not necessitate an engine shutdown nor does presence of smoke or fumes in the cockpit. The Air Accidents Investigation Branch (AAIB) made four recommendations relative to the engine instrument displays.

When a thrust reverser deployed during takeoff on TAM flight 402, a Fokker-100, on October 31, 1996, the thrust reverser interlock cable retarded the throttle lever, as intended [6]. The flight crew assumed that this was caused by an autothrottle system failure. The captain forced the throttle lever forward overcoming the interlock and causing the right engine to go to full thrust with the thrust reverser deployed. The resulting asymmetric force caused a loss of control and the airplane crashed.

Other accidents following problems that would not normally be considered catastrophic are referenced here without elaboration:

- Failures of a single attitude indicator or spatial disorientation of the pilot: Air India Boeing 747 (1978) [7], Air Transport International DC-8 (1992) [8], and Zantop International Airline L-188 (1984) [9].
- False stall warning during takeoff roll: TWA L-1011 [10].
- Engine failure during takeoff: Midwest Express Airlines DC-9 [11].

The ability of the flight crew to react correctly to system failures seems to have a large variance, which is difficult to evaluate correctly using currently available safety assessment methods. This also makes it difficult to determine the best display techniques to be used to minimize risk.

Incorrect Actions With No Malfunction

Human error that contributed to accidents of fully functional aircraft or created a fault leading to an accident is a recurring theme and is, in fact, much more common than those following an airplane malfunction. Of particular concern to the airplane designer are the human errors that may be induced by the system design details of a particular model. Some examples include:

> Air Inter 148, an A320, crashed at Strasbourg in 1992 during an approach to landing [12]. The flight crew inadvertently selected 3300 fpm descent rate rather than 3.3 degree flight path angle because of misuse of a switchable controller which allowed selection of either flight path angle or rate of descent. The Bureau of Enquetes-Accidents noted that the display of selected information was ambiguous on the control panel and inconsistent with the displayed information on the primary flight display—a classic human factors issue.
>
> A Delta Airlines Boeing 767 incident occurred shortly after takeoff from Los Angeles in 1987 [13]. The flight crew activated fuel cut-off switches rather than the electronic engine controller (EEC) switches which were adjacent to them. Recovery was accomplished after engine relight at 500 ft. This is another example of design (switch layout) contributing to a nearly catastrophic pilot error.
>
> A China Airlines A300 crashed during approach to Nagoya, Japan, on April 26, 1994 [14]. Go around mode was inadvertently selected and the First Officer tried to continue the approach by overriding the autopilot. The autopilot in this mode did not disconnect as it would have done on most other airplanes. The stabilizer ran to the extreme nose up position resulting in airplane stall and crash.

Another class of human factors accidents is more difficult to categorize because of the broad range of root causes. A few representative examples follow:

> American Airlines Flight 191, a DC-10, crashed at Chicago in 1979 shortly after takeoff [15]. During takeoff rotation the left engine and pylon assembly and part of the wing leading edge separated and fell to the runway. Collateral damage resulted in

loss of the left wing outboard leading edge slats and some warning systems. The cause of the engine separation was traced to an improper procedure used for replacement of the engine which resulted in damage to strut mounts. McDonnell Douglas had specified in its original maintenance procedures and subsequent service bulletins that the engine must be separated from the pylon before the pylon is removed from the wing. However, two major carriers developed procedures to remove the engine and pylon as a single unit using a forklift. This procedure required extreme precision to avoid damage to the spherical support joints, the significance of which was not realized by the maintenance and engineering personnel. Approval was neither sought nor required from the manufacturer or FAA.

Eastern Airlines Flight 855, an L-1011, took off from Miami on May 5th, 1983, after maintenance had replaced the oil chip detector plugs on all three engines without installing the “O” rings [16]. The airplane landed safely but with two engines failed and the third engine in imminent danger of failure.

Federal Express Flight 14, an MD-11, crashed during a landing at Newark, NJ on July 31, 1997, as a result of overcontrol during flare by the captain, which resulted in a bounce and a hard landing that fractured the right wing of the airplane [17].

A Continental DC-9-32 at Houston, TX landed with the landing gear retracted on February 19, 1996, as a result of the failure of the flight crew to follow the check list and turn on hydraulic power to operate the landing gear [18].

Air Canada Flight 646, a Canadair Regional Jet, at Fredericton, Nova Scotia in 1995 [19] crashed when the flight crew initiated a go-around from a destabilized, idle thrust approach in low visibility. The Transport Safety Board of Canada (TSB) noted that the sequential nature of the steps in the go-around procedure, which placed disproportionate emphasis on the flight director, contributed to inadequate monitoring of the airspeed. The flight director's guidance was not appropriate for the low energy state of the aircraft, nor was the aircraft's response from the low energy condition similar to that experienced by the crew during training.

In the case of failed pitot and barometric pressure sensors, particularly if multiple sensors are blocked, a very difficult and confusing condition for the flight crew will exist. There may be multiple warning indications simultaneously indicating underspeed and overspeed conditions in addition to erroneous displays of airspeed, altitude, and vertical speed to both pilots. This condition, which has caused several fatal accidents, is considered to be a catastrophic failure condition. A Northwest Airlines Boeing 727 crashed near Bear Mountain, NY, as a result of ice blockage of all pitot sensors on December 1, 1974 [20]. The airplane encountered icing conditions and the flight crew had not activated pitot heat. Despite rule changes issued because of this accident that require alerting and caution indications for pitot heat failure, on March 2, 1994, a Continental Airlines MD-82 had an accident because of an unsuccessful high speed rejected takeoff (RTO) (initiated at a speed 5 knots above takeoff decision speed V1) as a result of pitot sensors blocked with ice or snow [21]. The flight crew had interrupted the takeoff checklist and did not turn on the pitot heat system. In each of these accidents, the failure of the sensors was the result of flight crew failure to activate pitot heat.

These accidents may point to human factors deficiencies in the design of the flight deck systems or in the various manuals and procedures.

The erroneous response by the flight crew following a malfunction is partially addressed by the regulations in 14 CFR §25.1309 (c), which states:

> *Warning information must be provided to alert the crew to unsafe operating conditions, and to enable them to take appropriate corrective action. Systems, controls, and associated monitoring and warning means must be designed to minimize crew errors which could create additional hazards.*

There is no such regulatory design requirement to minimize errors by maintenance personnel; however, the FAA does have a guidance document, *Human Factors Guide for Aviation Maintenance* [22]. This FAA document contains human factors information and guidance for personnel at various levels of responsibility in aviation maintenance.

One human factors specialist employed by the FAA Transport Airplane Directorate developed a possible approach to improve this situation with a proposed method of ranking system designs for no credit, partial credit, or full credit in safety assessments based on the ease or difficulty of the flight crew to detect, decide, and take action in response to failures of the system [23]. This methodology, or any other similar approach, would require a significant effort to verify its effectiveness before it could be implemented. A tool, appropriately named Procedural Event Analysis Tool (PEAT), has been found useful during development of the flight deck systems and and procedures.

There is very limited guidance, either in the advisory circulars or the SAE ARPs used for initial type certification, to ensure that human performance is adequately considered during the development of the airplane design or for development of the training programs. Draft 12 of SAE ARP 5150 [24], which has not yet been released, refers to two tools available for improvement of performance of flight and ground crews. These are the Maintenance Error Decision Aid (MEDA) and the Flight Operations Quality Assurance (FOQA) tool. However, no mention is made in ARP 5150 of human factors considerations in the design of modified equipment.

The *FAA Human Factors Team Report* [25] included 51 recommendations, many of which also pertain to the issues discussed above. The report focused on the interfaces between the flight crews and modern flight deck systems. The following interrelated deficiencies were identified in the current aviation system:

- Insufficient communication and coordination
- Inadequate processes used for addressing human performance issues in design, training, and regulatory functions
- Insufficient criteria, methods, and tools for design, training, and evaluation
- Insufficient knowledge and skills
- Insufficient understanding and consideration of cultural differences in design, training, operations, and evaluation

If significant strides are to be made in lowering the accident rates, a much better understanding of the issues affecting human performance is required. The airplane designers will be challenged to develop systems which are less error prone. Procedures will also have to be more explicit and more robust with respect to the range of skills and techniques of operations and maintenance personnel. This area would benefit from a better understanding of lessons learned and a sharing of best practices throughout the industry (see Finding 8).

References

1) The Boeing Company, *Statistical Summary of Commercial Jet Accidents Worldwide Operations,1959-2000*, June 2001, pg 21.
2) (a) National Transportation Safety Board (NTSB), Accident Number DCA96RA030, Birgenair Flight 301, Boeing 757, TC-GEN, Puerto Plata, Dominican Republic, February 6, 1996; (b) FAA Flight Standards, *Information Bulletin for Air Transportation 96-15*, September 26, 1996; (c) Correspondence between FAA and NTSB concerning NTSB Recommendation A-96-15.
3) NTSB, Accident Number DCA97RA001B, Air Claims J1996031, Aeroperu 603, Boeing 757 Pasamayo, Peru, October 2, 1996.
4) United Kingdom Air Accidents Investigation Branch (UK AAIB), *UK AAIB Special Bulletin No. S2/2000*, Korean Airlines 8509, Boeing 747-100, Stansted, UK, December 22, 1999.
5) UK AAIB, *Report on the Accident to Boeing 737-400-G-OBME Near Kegworth, Leicestershire on 8 January 1989* (AAIB Aircraft Accident Report No. 4/90, (EW/C1095)), British Midland Airways.
6) NTSB, Accident Number DCA97WA004, TAM 402, F-100, Sao Paulo, Brazil, October 30, 1996.
7) Air Claims J1978001, Air India, Boeing 747-237B, Arabian Sea, January 1, 1978.
8) NTSB, *Aircraft Accident Report-Air Transport International, Inc., Flight 805 Douglas DC-8-63, N794AL Loss of Control and Crash Swanton, Ohio February 15, 1992* (NSTB-AAR-92-05; DCA92MA022; NTIS-PB92-910406), November 19, 1992.
9) NTSB, *Aircraft Accident Report-Zantop International Airlines, Inc., Lockheed L-188A Electra, Chalkhill, Pennsylvania, May 30, 1984* (NTSB-AAR-85-04; DCA84AA024; NTIS-PB85-910404), March 19, 1985.
10) NTSB, *Aircraft Accident Report-Aborted Takeoff Shortly After Liftoff Trans World Airlines Flight 843 Lockheed L-1011, N11002 John F. Kennedy International Airport Jamaica, New York July 30, 1992* (NTSB-AAR-93-04; DCA92MA044; NTIS-PB93-910404), March 31, 1993.

11) NTSB, *Aircraft Accident Report-Midwest Express Airlines, Inc., DC-9-14, N100ME General Billy Mitchell Field, Milwaukee, Wisconsin, Sept. 6, 1985* (NTSB-AAR-87-01; DCA85AA036; NTIS-PB87-910401), February 3, 1987.
12) Bureau Enquetes-Accidents, F-ED920120, Air Inter 148, A320, Strasbourg, France, January 20, 1992.
13) FAA Incident Data System 19870630040879C, DAL, Boeing 767, Los Angeles, CA, June 30, 1987.
14) Aircraft Accident Investigation Commission Ministry of Transport, *Aircraft Accident Investigation Report 96-5* (B 1816, A-300B4-622R), China Airlines, Nagoya, Japan, April 26, 1994.
15) NTSB, *Aircraft Accident Report-American Airlines, Inc., DC-10-10, N110AA, Chicago-O'Hare International Airport, Chicago, Illinois, May 25, 1979* (NTSB-AAR-79-17; NTIS-UB/E/104-017), December 21, 1979.
16) NTSB, *Aircraft Accident Report-Eastern Airlines Inc. Lockheed L-1011, N334EA Miami International Airport Miami, Florida May 5, 1983* (NTSB-AAR-84-04; MIA83AA136; NTIS-PB84-910404), March 9, 1984.
17) NTSB, *Aircraft Accident Report-Crash During Landing Federal Express, Inc. McDonnell Douglas MD-11, N611FE Newark International Airport Newark, New Jersey July 31, 1997* (NTSB-AAR-00-02; DCA97MA055; NTIS-PB2000-910402), July 25, 2000.
18) NTSB, *Aircraft Accident Report-Wheels-Up Landing Continental Airlines Flight 1943 Douglas DC-9 N10556 Houston, Texas February 19, 1996*, (NTSB-AAR-97-01; FTW96FA118; NTIS-PB97-910401), February 11, 1997.
19) Transportation Safety Board of Canada (TSB), *Air Canada Canadair CL-600-2B19, C-FSKI, Fredericton Airport, New Brunswick, December 16, 1997* (Accident Report Number A97H0011), April 15, 1999.
20) NTSB, *Aircraft Accident Report-Northwest Airlines, Inc., Boeing 727-251, N274US, near Thiells, New York, December 1, 1974* (NTSB-AAR-75-13; NTIS-PB-245581/4GA), August 13, 1975.
21) NTSB, *Aircraft Accident Report-Runway Overrun Following Rejected Takeoff, Continental Airlines Flight 795 McDonnell Douglas MD-82, N18835 LaGuardia Airport Flushing, New York March 2, 1994* (NTSB-AAR-95-01; DCA94MA038; NTIS-PB95-910401), February 14, 1995.
22) Galaxy Scientific Corporation, *Human Factors Guide for Aviation Maintenance*, Rev. 1, February, 1998
23) FAA National Resource Specialist presentation on *Human Factors Contribution to Fault Tree Analysis*, Seattle, WA, November 14, 2001.
24) Society of Automotive Engineers Aerospace Recommended Practice (SAE ARP) 5150 Draft 12, *Safety Assessment of Aircraft in Commercial Service.*
25) *FAA Human Factors Team Report*, The Interfaces between Flightcrews and Modern Flight Deck Systems, June 18, 1996.

Finding 2

There is no reliable process to ensure that assumptions made in the safety assessments are valid with respect to operations and maintenance activities, and that operators are aware of these assumptions when developing their operations and maintenance procedures. In addition, certification standards may not reflect the actual operating environment.

Correlation of Safety Assessment Assumptions with Operations and Maintenance Practices

The preparation of a Functional Hazard Assessment and Fault Tree Analysis requires assumptions about the ways in which the airplane will be operated and maintained. The use of such assumptions should be justified by supporting data and should be explicitly stated and effectively disseminated to all operators, maintainers, and modification centers dealing with that aircraft. Assumptions are made relative to:

- Aircraft environmental conditions (ice, wind, lightning, electromagnetic interference, temperatures, bird strikes, *etc.*)
- Air traffic environment (domestic and foreign)
- Operating conditions and procedures
- Maintenance procedures
- Training programs

During the 1990s several examples of inaccurate certification assumptions emerged. The following case studies will illustrate the finding.

Wheel Brake Certification

In the 1990 Special Investigation Report *Brake Performance of the McDonnell Douglas DC-10 During High Speed, High Energy Rejected Takeoffs* [26], the NTSB concluded that:

> *Current Federal regulations do not require setting proper brake wear limits based on the amount of remaining brake friction material necessary to assure continuous brake capability during a maximum energy RTO.*

They found that brake wear limits were determined by tests conducted using new brakes. This procedure ignored the fact that the overwhelming majority of air carrier operations are conducted with less-than-new brake linings. The applicability of data derived from the performance of new brakes to all operations was shown to be deficient. Further, the NTSB found that, in the case of the DC-10, brake performance data for

takeoff considerations were developed by using data from landing tests only. This omitted acceleration effects occurring during reduction from takeoff thrust setting. Although this case has been addressed by changes in the certification criteria, the original criteria which allowed the use of new brakes, and which failed to account for the effects of thrust reduction after brake application during RTO, was not well correlated with actual operating conditions.

In-flight Icing Certification Criteria

Two accidents in recent years have highlighted inconsistencies between the icing certification criteria and the actual operating environment. The Simmons ATR-72 accident at Roselawn, Indiana, in October 1994 [27] involved an airplane that met the most advanced icing certification standard available at that time, yet the design and the standard did not include consideration of the effects of water droplets larger than those defined in the icing standard contained in 14 CFR Part 25, Appendix C. The accident analysis determined that the aircraft encountered a supercooled large droplet environment and that the resulting ice shape led to a loss of control. When Appendix C was developed, such environments were suspected but the measurement equipment to distinguish them did not exist. Subsequent research has confirmed that such environments are more common than previously thought. The NTSB stated:

> *Contributing to the accident were: . . . The FAA's failure to ensure that aircraft icing conditions and FAA published aircraft icing information adequately accounted for the hazards that can result from flight in freezing rain and other icing conditions not specified in 14 CFR 25 Appendix C.*

In the report on Comair EMB-120, an accident that took place at Monroe, Michigan in January 1997 [28], the NTSB stated:

> *The icing certification process has been inadequate because it has not required manufacturers to demonstrate the airplane's flight handling and stall characteristics under a sufficiently realistic range of adverse ice accretion/flight handling conditions.*

These two accidents, as well as a number of well-documented incidents, have raised significant questions about the icing engineering standard itself and about the assumptions used when employing the standard in design and certification. While considerable industry effort is being expended to address these questions (for example, the Ice Protection Harmonization Working Group), both accidents highlight different aspects of certification criteria which did not reflect the actual environment. Further, the investigations suggested that the knowledge of icing certification possessed by operators and flight crews did not include an understanding of what had or had not been accomplished in icing certification.

Low Energy Go-Around Certification

Following the accident involving Air Canada Flight 646 at Fredericton in 1997 [29], the Transportation Safety Board of Canada (TSB) noted some discrepancies between the certification process and the published material available to operators with respect to go-arounds. The aircraft crashed after attempting a low energy (engines at idle power) go-around from an unstabilized instrument approach. The TSB determined that when the go-around was initiated, the aircraft was outside of the flight envelope demonstrated during the certification process. Normally, the certification process evaluates the go-around maneuver from a stabilized approach; in this case, the approach was not stabilized. This difference was not apparent to the operator or flight crew. The TSB found that:

> *The conditions under which the go-arounds are demonstrated for aircraft certification do not form part of the documentation that leads to aircraft limitations or boundaries for the go-around procedure; this contributed to these factors not being taken into account when the go-around procedures were incorporated in aircraft and training manuals.*

The TSB recognized that it might be very difficult for the manufacturer to provide information indicating when a safe go-around could not be expected. Nonetheless, they suggested that:

> *Operators and pilots could be provided with the go-around conditions related to certification so an interpretation of what may not be possible could be made.*

Crosswind Landing Certification

Following the accident involving Transavia Flight 462, a Boeing 757, at Amsterdam Schiphol Airport (1997), an extensive inquiry into crosswind certification and operations was made [30]. The aircraft crashed during landing while experiencing a wind reported by the tower to be 240 degrees at 30 knots, maximum 43 knots, resulting in a crosswind component of 35 knots. The flight management system (FMS) wind reading at 600 feet was 240 degrees at 50 knots. The investigation by Dutch authorities questioned why the flight crew had not considered a go-around. They discovered that the maximum demonstrated crosswind of 30 knots was not considered limiting by Transavia standard operating procedures. The report stated that,

> *By not establishing a clear and definite crosswind limit in the Transavia Operations Manual a defense barrier against unsafe operations was lost.*

An extensive inquiry into crosswind certification and operations was made by the Dutch National Aerospace Laboratory (NLR) [31]. Their report stated that:

> *. . . during this final phase of the approach, the gust of wind coupled with the turbulence induced a significant change in both wind speed and direction resulting in a crosswind in excess of 50 knots. Prior to that the crosswind was 25 to 30 knots.*

When the NLR examined FAR/JAR 25.23, *Wind Velocities*, they pointed out that:

> *When JAR/FAR 25.237 is examined carefully, the following can be noticed:*
>
> - *Only dry runways have to be considered.*
> - *It is not clear if the wind speed includes gusts or not.*
> - *No crosswind limits have to be established, only demonstrated values.*

They further looked at the guidance for certification to FAR 25.237 provided in AC 25-7. They concluded that:

> *There are two possibilities on how to note crosswinds in the AFM. If the demonstrated crosswind is not considered to be a limiting value for aircraft handling characteristics, this demonstrated value can be placed as information in the AFM.*

> *Higher crosswinds are then allowed when the applicable operational requirements and the airline specification allow it. If the demonstrated crosswind is considered to be a maximum limiting value up to which it is safe to operate the aircraft, the demonstrated crosswind value will appear as a limiting value in the AFM. It is not allowed to operate the aircraft beyond this crosswind. For practically all aircraft certified by the FAA the demonstrated crosswind is not regarded as limiting by the FAA test pilots.*

The Dutch authorities noted, in the conclusions section of the Transavia Flight 264 accident report, that:

> *There is a reasonable probability that an actually encountered wind during landing deviates from the reported wind. This uncertainty warrants substantial margins to theoretical wind limitations when operating in crosswind.*

Much as was the case in the Canadian investigation at Fredericton, it appears that what was actually accomplished in certification was not clear to the operator when company procedures were developed. With respect to crosswind, the NLR also pointed out that this weak understanding of crosswind certification also applies to airport authorities when they are establishing preferred runway criteria.

This example leads to the conclusion that the information regarding the boundaries of what was shown during certification may not be adequately communicated to prevent the development and approval of local interpretations, procedures and operating techniques, which imply a basis in certification beyond what was actually accomplished.

Maintenance Procedures

Assumptions about the effectiveness of maintenance practices to protect the safety of the airplane were identified as a problem after the Alaska Flight 261 accident off Point Mugu, CA in January 2000 [32]. The NTSB, in their preliminary report, stated:

> *. . . engineers from the Boeing Commercial Airplane Group testified that wear of the acme nut is normal and expected and is taken into account by its "robust" design. They further indicated that to maintain the horizontal stabilizer*

> *trim system's structural integrity, acme nut thread wear must be managed through; 1) the regular application of lubrication and, 2) an inspection program to monitor the wear. Boeing engineers acknowledged that, without such maintenance intervention, the type design could be compromised and the results could be catastrophic.*

It would appear that better identification (see Finding 4) and tighter monitoring might be required of those maintenance practices which could adversely affect the integrity of flight critical functions. Airplane safety was based on the assumption that regular maintenance would preclude excessive wear of this critical part.

It will always be necessary to make assumptions in the safety analyses; however, where possible, those assumptions may need to be validated by actual experience and periodically revisited to ensure that they reflect the full range of environments and operators of the fleet.

References

26) NTSB, 1990 Special Investigation Report, *Brake Performance of the McDonnell Douglas DC-10 During High Speed, High Energy Rejected Takeoffs* (NTSB/S/R-90/01), February 27, 1990.

27) NTSB, *Aircraft Accident Report-In-flight Icing Encounter and Loss of Control Simmons Airlines, d.b.a. American Eagle Flight 4184 Avions de Transport Regional (ATR) Model 72-212, N401AM, Roselawn, Indiana October 31, 1994;* Volume 1: Safety Board Report (NTSB-AAR-96-01; DCA95MA001; NTIS-PB96-910401), July 9, 1996.

28) NTSB, *Aircraft Accident Report-In-Flight Icing Encounter and Uncontrolled Collision with Terrain, Comair Flight 3272, Embraer EMB-120RT, N265CA, Monroe, Michigan, January 9, 1997* (NTSB-AAR-98-04; DCA97MA017; NTIS-PB98-910404), November 4, 1998.

29) TSB, *Air Canada Canadair CL-600-2B19, C-FSKI, Fredericton Airport, New Brunswick, December 16, 1997* (Accident Report Number A97H0011), April 15, 1999.

30) Dutch Transport Safety Board, *Aircraft Accident Final Report Transavia Boeing 757, PH-TKC, Amsterdam Airport Schiphol, December 24, 1997* (97-75/A-26), November 10, 1999.

31) Federal Aviation Administration, *Safety Aspects of Aircraft Operations in Crosswind* "Roll Upset in Severe Icing," (NLR TP-2001-217), 1995

32) NTSB, *Safety Recommendation A-01-41 through -48*, October 1, 2001.

Finding 3

A more robust approach to design and a process that challenges the assumptions made in the safety analysis of flight critical functions is necessary in situations where a few failures (2 or 3) could result in a catastrophic event.

Robust Safety Assessments and Design for Critical Functions

Safety analyses are accomplished to show that catastrophic events are not expected to occur in the life of an airplane fleet and that lesser events are acceptably unlikely. These analyses are done with the facts and data available at the time, and by making some fundamental assumptions about the behavior of the airplane and its systems, and the people who build, maintain, and operate the airplanes for the life of the fleet. However, a number of events have occurred indicating that the ability to predict correctly all catastrophic failure scenarios is limited. In the early stages of airplane development, designers often have an opportunity to incorporate additional safeguards or use an alternative approach for relatively little added cost in an effort to provide a more robust system.

Catastrophic events such as thrust reverser deployment in flight, and fuel tank explosions, have, as one root cause, an incorrect assumption that made the safety analysis invalid. In the case of the thrust reverser deployment, the assumption was that the airplane was controllable in the event of such a deployment. During the development of the Boeing 767, this was demonstrated in flight, but only at low speed with thrust at idle. This was assumed to be the worst condition, erroneously, as found later in the case of Lauda Air in Thailand (1991) [33]

In the case of fuel tank explosions, the assumption was that the design, operation, and maintenance practices would prevent ignition sources from being present in the tank throughout the life of the fleet. A second assumption was that the tank could be flammable at any time and thus there was no need to examine the probability of the tank being flammable. The combination of these assumptions created a false confidence in the success of the designs. In reality, some fuel tanks are not flammable for considerable portions of the fleet life, preventing explosions but also masking the failure to prevent ignition sources from being present in the tanks. Certain tanks are flammable for much longer periods, and the failure to keep ignition sources out of the tank may have led to three center tank explosions in the last eleven years.

In both of these examples (thrust reversers and fuel tanks), the design was shown to comply with the certification requirements in place at the time of certification, but only because the assumptions were considered to be valid. More in-depth design reviews to question the underlying assumptions may have found these issues. On recent programs, design reviews have included experienced design, operations, and maintenance personnel. These reviews provide an opportunity to challenge the assumptions and determine if a more robust design could be implemented that would provide additional protection. This approach could help to provide protection from failure modes or human actions that were not correctly predicted by analysis.

Joint Aviation Authorities (JAA) issued NPA 25F-281 in October 1998 [34]. This document contains the proposed advisory material for JAR 25.1309 and points out the following, in paragraph 11(h) on page 25 (*Justifications of Assumptions, Data Sources and Analytical Techniques*):

> *Any analysis is only as accurate as the assumptions, data, and analytical techniques it uses. Therefore, to show compliance with the requirements, the underlying assumptions, data and analytic techniques should be identified and justified to assure that the conclusions of the analysis were valid. Variability may be inherent in elements such as failure modes, failure effects, failure rates, failure probability distribution functions, failure exposure times, failure detection methods, fault independence, and limitation of analytical methods, processes, and assumptions. The justification of the assumptions made with respect to the above items should be an integral part of the analysis. Assumptions can be validated by using experience with identical or similar systems or components with due allowance made for differences of design, duty cycle or environment. Where it is not possible to fully justify the adequacy of the safety analysis and where data or assumptions are critical to the acceptability of the Failure Condition, extra conservatism should be built into either the analysis or the design. Alternatively any uncertainty in the data and assumptions should be evaluated to the degree necessary to demonstrate that the analysis conclusions are insensitive to that uncertainty.*

The FAA is currently drafting an update to AC 25.1309 [35] to support harmonization with the JAA document.

Finding 3 suggests that the failure analysis should be examined in much more depth when the consequences of a failure or combination of one, two, or three failures may be an immediate or unavoidable loss of the airplane. The underlying assumptions of the analysis must be examined to determine if the effect of an incorrect assumption is loss of the airplane. Assumptions on future maintenance, such as separation of critical wiring, have also been incorrect. Both versions of the advisory circulars (ACs) essentially suggest that extra caution be taken in the use of data and assumptions during the design and analysis processes.

Every assumption should be examined to understand the sensitivity of the assumption on the results. Where such sensitivity does exist, then the design should be changed to reduce the sensitivity. Similarly, a failure to identify a specific failure mode can occur, particularly when the analysis involves multiple failure paths. One unanticipated failure mode may occur and have a major effect on the airplane safety. In this case it should be addressed by looking at the key protective features and determine if additional safeguards are needed. Reducing fuel flammability is an example of an additional mitigation factor that could reduce the criticality of a failure, which could produce an ignition source in the fuel tanks.

One example of a design that added capability well beyond the 14 CFR §25.1309 requirements is the Boeing 777 flight control system (FCS). The system was designed with several layers of redundancy in the computational paths (both digital and analog), ensuring loss of “get-home” capability would be well beyond extremely improbable. In addition, electrical power for the FCS was protected by use of two dedicated permanent magnet generators on each engine, backed up by the main electrical power buses, the main battery, and a ram air turbine.

Many assumptions are historic in nature, justified by “we’ve always done it this way.” These assumptions tend to be so buried in the analysis that the analyst may not recognize them as

assumptions. Conversely, an assumption based on historical precedent may be entirely valid but is changed simply because the data supporting it have been lost over time. This assumption can be inappropriate if the original assumption was correct. A related finding (see Finding 8) focuses on the failure of industry to carry forward an understanding of historical bases behind regulations, requirements, and best practices.

This finding highlights the need to examine every safety analysis assumption for its impact on the overall safety of the airplane. Where any assumption has a major effect on the outcome, the analysis and design should address the potential for the assumption being wrong. Risk can often be reduced by selection of a relatively conservative design approach with respect to systems with potentially catastrophic failure consequences.

References

33) CAB, Lauda Air NG 004, Boeing 767-300ER, Thailand, May 26, 1991.
34) JAA, NPA 25F-281, October, 1998.
35) Draft AC 25.1309.r1, March 2001.

Finding 4

Processes for identification of safety critical features of the airplane do not ensure that future alterations, maintenance, repairs, or changes to operational procedures can be made with cognizance of those safety features.

Flight Critical Systems and Structures

Airplane design decisions are made with consideration of their impact on both systems and structures. Understanding the design assumptions and the interactions of the safety critical features is essential to maintaining the integrity of the airplane for safe operation. These decisions, assumptions, and interactions must be understood individually and collectively before any subsequent change, modification, or repair is made to the airplane or to its components.

The design of an airplane requires making numerous choices among different design approaches. These choices, from the highest level, such as the number of engines, down to the smallest component level, such as what kind of fastener to use, are made by specialists in the OEMs. Based on their engineering knowledge, experience, and analyses, these design decisions and features allow the airplane to be used safely for its intended purpose.

The final design must meet the requirements of the certification authorities and the design standards of the OEM, but there is no standard means, nor should there be, to design an airplane or its specific components. Different means and various assumptions are made down to the most detailed aspect of the design. These assumptions are typically well documented and maintained in the OEM's internal documents and are well understood by the responsible designers. In recent years many non-OEM changes, modifications, or repairs were made without OEM involvement or data were not available at the time of the change, modification, or repair. This practice could potentially undermine the integrity of the changed, modified, or repaired airplane or the component to a point that might compromise safety.

Two examples where this process failed and allowed new hazards into the original system by the introduction of new wiring are:

- Swissair MD-11 entertainment system installation where the power supply used by the STC installation did not conform to the OEM's design philosophy and resulted in the crew's inability to turn off the system [36]
- Philippine Airlines Boeing 737 fuel tank wiring where the installation of a logo light wire run used the same wire run as for the fuel tank float switch [37]

Structural changes or alterations where the modifying company did not know the specific limitations of the original design have also been an issue. These include:

- Certain passenger-to-cargo modifications by other than OEMs [38]
- The thermal protection of repaired fuel pumps for an operator's MD-11's, where the thermal fuses were incorrectly installed and a subsequent pump failure was not protected by the thermal fuses [39]

Changes developed without OEM involvement and without an understanding of the original certification assumptions add risk because the modifier, maintainer, or operator is not aware of the criticality of the original type design. It is difficult for operators to develop such procedures in accordance with those design constraints because frequently only a few specialists at the OEM may understand the underlying safety issues.

14 CFR §25.981(b), adopted in 2001, addresses the placard issue for fuel systems as follows:

> *Visible means must be placed in the area of the airplane where maintenance, repairs, or alterations may violate the critical design configuration control limitations.*

The objective of this requirement is to provide information to maintenance, repair, or modification personnel to minimize errors that could increase the hazards to the airplane. Protection of other flight critical functions in a similar manner would be beneficial.

An innovative approach is required to ensure that appropriate procedures, manuals, and placards communicate the relevant safety information so that maintenance, operations, alterations, and repairs can be made with cognizance of the safety features of the original design. This approach would have the following potential benefits:

- Provide a method for identification of safety critical features
- Ensure that important safety critical design features are not changed without recognition of the effect on safety.
- Protect safety critical installations from inadvertent degradation during maintenance, alterations, and repair activities.
- Provide a standard for traceability of safety requirements, design constraints, test, and analysis.

This finding has a very strong relationship with Findings 10 and 13.

References

36) FAA presentation to CPS team, *Swissair Flight 111 Accident Overview*, Seattle WA, February 28, 2001.
37) *Philipine Air Lines, B-737*, Manila, Philipines, May 11, 1990, Air Claims J1990014.
38) FAA Transport Airplane Directorate engineer, "Status of STC Cargo Conversion activity, presentation, Seattle, WA, April 5, 2001.
39) FAA National Resource Specialist, "Fuel Pump Issues," presentation, Seattle WA, May 1, 2001.

Endnotes

The following provides some background information on the evolution of Structural Safety requirements, which may be of value to those who are unfamiliar with this very important technical subject.

Structural Safety Assessment

14 CFR §25.571 requirements, which were recodified in 1965 from CAR 4b.270, have evolved throughout the past forty years. This regulation, in part, protects the aircraft structures from the adverse effects of operational conditions. Before 1978, CAR 4b.270 and 14 CFR §25.571 required that airplane structures whose failure could result in catastrophic failure of the airplane be evaluated under the provisions of either fatigue strength or fail-safe strength requirements. If the structure was not demonstrated to withstand the repeated loads of variable magnitude expected in service, it had to be fail-safe. A fail-safe structure is one in which catastrophic failure or excessive structural deformation that could adversely affect the flight characteristics of the airplane are not probable after fatigue failure or obvious partial failure of a single primary structural element (PSE). After these types of failures of a single PSE, the remaining structure must be able to withstand static loads corresponding to the required residual strength loads. If the concept of fail-safe was impractical, structures were certified using the safe-life concept. Most common examples of structures that have been certified to safe-life were landing gear components and structure associated with control surfaces.

The Dan-Air Flight 039 Boeing 707 accident on May 14, 1977 [40], proved that these concepts were inadequate, and on October 5, 1978, Amendment 25-45 of the rule was issued. In this accident, evidence of simultaneous crack nucleation and propagation from colinear holes, which operated at or near the same stress level, linked up and caused the starboard horizontal stabilizer to break off the airplane. Amendment 25-45 added the concept called *damage tolerance* to the rule. Damage tolerance is the attribute of the structure that permits it to retain its required residual strength for a period of use after the structure has sustained a given level of fatigue, corrosion, or discrete source damage. Amendment 25-45 requires that a damage tolerance assessment of the structure be accomplished to determine the most probable location of the damage and to provide an inspection program that requires directed inspections of critical structure. The damage tolerance assessment philosophy essentially replaced the fail-safe and safe-life design philosophies.

In April 1988, a high-cycle Aloha Airlines Boeing 737 experienced an in-flight explosive decompression of the fuselage caused by the undetected presence of widespread fatigue damage (WFD) [41]. This accident increased the concern about the airworthiness of high numbers of aging aircraft, which were otherwise not being inspected for this type of damage. As a result of this accident, several aging aircraft initiatives were launched by the FAA and industry:

- Publication of select service bulletins describing necessary modifications and inspections
- Development of inspection and prevention programs to address corrosion
- Development of generic structural maintenance program guidelines for aging airplanes
- Review and update of supplemental structural inspection documents (SSIDS) that describe programs to detect fatigue cracking
- Assessment of damage tolerance of structural repairs
- Development of program to preclude WFD in the fleet

For large transport airplanes, most of the first five initiatives have been accomplished. The FAA is working on rulemaking currently to mandate the last initiative [42]. Amendment 25-72 removed the words ‘fail-safe’ from the rule. Additionally, the Airworthiness Assurance Working Group (AAWG) recommended that industry

initiate programs to eliminate WFD from all affected airplane models. Amendment 25-96, later mandated, among other things, that manufacturers consider WFD in areas that are prone to this type of damage. This amendment also requires the manufacturer to conduct a full-scale fatigue test of each new airplane to demonstrate that WFD will not occur within the Design Service Goal of the airplane.

References

40) UK AAIB, *Dan-Air Services, Ltd., Boeing 707-321C, G-BEP, near Lusaka International Airport, Zambia, May 14, 1977* (Aircraft Accident Report [EW/A267]) September 1978.

41) NTSB, *Aircraft Accident Report-Aloha Airlines, Flight 243, Boeing 737-200, N73711, Near Maui, Hawaii April 28, 1988* (NTSB-AAR-89-03; DCA88MA054; NTIS-PB89-910404), June 14, 1989.

42) Airworthiness Assurance Working Group, *Recommendations for Regulatory Action to Prevent Widespread Fatigue Damage in Commercial Airplane Fleet,* Rev. A, June 29, 1999

Chapter 2

Aviation Safety Data Management

Numerous interviews with FAA data management personnel were conducted. Because of the CPS one-year charter time constraint, the focus was on FAA data management programs only, rather than on those of the entire industry.

Finding 5 illustrates the primary FAA data management issue: there are too many independent programs without effective inter-departmental coordination or executive oversight. Each program is resource limited, and when asked if programs were focusing on identifying accident precursor events, the answer was generally no. Findings 6 and 7 address data definition and reporting requirements and the need for effective data management methodologies and tools.

The office of the FAA Chief Information Officer (AIO), or an equivalent organization, should coordinate the various FAA data management program activities. The following publications define the FAA's data management and information technology (IT) programs:

- FAA Order 1375.1C, *FAA Data Management* (June 20, 2001)
- *FAA Data Management Strategy* (September 21,1999)
- *FAA Information Technology Strategy*, (September 22, 1999)

These publications are significant and should be implemented promptly before technical or philosophical obsolescence becomes an issue. The FAA's efforts run the risk of falling into the trap noted in *FAA Data Management Strategy:*

> *There is general agreement that the FAA should implement a corporate data management program, but few public or private organizations have successfully done so. Most efforts fail because they are too broad in scope, lack commitment, and grossly underestimate resource requirements.*

Improving Aircraft Safety (The Low Report)[1] identified these same findings over 20 years ago, and they are still relevant today.

Finding 5

Multiple FAA-sponsored data collection and analysis programs exist without adequate inter-departmental coordination or executive oversight.

Coordination of Data Management Systems

Effective data management requires clearly defined lines of business (LOBs) that provide customers with meaningful and timely products to maintain and improve commercial air safety. The complexity and scope of these efforts requires effective program management from the highest levels of the FAA to the field stations. Anything less than a fully integrated and coordinated management structure runs the risk of inefficient resource use and the possibility that intervention opportunities to prevent accidents will be missed.

The following FAA data collection and analysis programs (see Glossary for additional defintions) were reviewed either in person or by teleconference:

- Aviation Safety Action Program (ASAP)
- Aviation Safety Reporting System (ASRS)
- Continued Operational Safety Program (COSP)
- FAA Chief Information Office (AIO)
- Flight Operational Quality Assurance (FOQA)
- Global Aviation Information Network (GAIN)
- National Aviation Safety Data Analysis Center (NASDAC)
- Program Tracking and Reporting System (PTRS)
- Safety Performance Analysis System (SPAS)
- Service Difficulty Reports (SDR)

Several private and industry aviation safety database programs were discussed, but time constraints prevented a thorough enough analysis for the team to arrive at meaningful results or conclusions. For this reason, it was decided to focus on programs with direct FAA involvement.

A fundamental FAA objective is the use of information and knowledge to improve air safety and prevent accidents. This objective led to the creation of numerous FAA data programs to collect and analyze aviation safety data. The primary focus of data collection programs (*e.g.*, the various data collections for which NASDAC provides a user interface) is on data format and metadata collection.

Data analysis efforts (*e.g.*, SPAS), hampered by a lack of quality data, spend an inordinate amount of resources on data collection and integrity. Consequently, data collection and data analysis program activities overlap, hindering data analysis and the creation of meaningful products to enhance aviation safety. A data management objective of "improving air safety" is probably too broad and might be better served if it focused on "creation of products and processes to effectively identify accident precursors and implement intervention techniques."

Data identity and retrieval information (metadata) is crucial, and the existing data provide limited ability to uniquely identify events. For example, data regarding a rejected takeoff (RTO) by an Airbus A340 may be submitted as a rejected takeoff, aborted takeoff, or RTO. The aircraft type may be listed as an A340, Airbus 340, or Airbus A340. On a wide-body aircraft with a flight crew of ten, if every crew member submits an ASAP or ASRS report using slightly different phraseology, this single event will be registered in the databases as ten different events. This inability to standardize data collection formats reduces confidence in the data itself and is an impediment to using the data for analysis, conclusions, and identifying accident precursors using data mining techniques.

The office of the FAA Chief Information Officer (AIO) is mandated to accomplish FAA data management objectives as prescribed in FAA Order 1375.1C [2]:

> *The Assistant Administrator for Information Services and Chief Information Officer (AIO-1) is designated as the focal point and has overall responsibility for the FAA Data Management Program.*

However, there is limited coordination between AIO and the other FAA offices that maintain aviation safety databases and analytical tools such as NASDAC, ASAP, FOQA, and SPAS.

The need for effective oversight is outlined in the *FAA Data Management Strategy* [3]:

> *As with many large public and private organizations, the FAA's information systems have evolved over the past 20 to 30 years to meet specific requirements. This has led to a proliferation of data, much of which is redundant or obsolete. As a result, FAA data is difficult to share, costly to assemble, and hard to assess in terms of integrity and accuracy. At the same time, there is an increasing need to share information externally with domestic air carriers, international civil aviation administrations, Congress, and the flying public.*
>
> *There is general agreement that the FAA should implement a corporate data management program, but few public or private organizations have successfully done so. Most efforts fail because they are too broad in scope, lack commitment, and grossly underestimate resource requirements. The FAA data management program, therefore, needs to be narrowly focused on the areas with the greatest potential benefits for the agency. The process should be evolutionary with emphasis on collaboration where it makes sense, standardization on core data elements, better communication along the information chain, and discrete projects that address the areas of greatest need. The lines-of-business (LOBs) will work with the Assistant Administrator for Information Services and Chief Information Officer (AIO) to implement this Data Management Strategy and subsequent program.*

Lack of FAA data management coordination can be traced in part to the current state of organizational autonomous authority that does not foster a spirit of inter-departmental coordination. This lack of coordination results in a proliferation of fragmented individual data management programs and unnecessary duplication of effort.

Enhancing FAA oversight and a willingness on the part of the FAA offices to cooperate with each other would improve the effectiveness of existing data management programs by

- streamlining resource utilization
- reducing duplication of effort
- enabling prompt product(s) development and delivery.

Other data collection and analysis programs could provide additional safety data and product synergies with FAA programs:

- National Transportation Safety Board (NTSB)
- Department of Defense (DoD)
- International Civil Aviation Organization (ICAO)
- Flight Safety Foundation (FSF)
- American Aviation Safety Information System (AASIS)
- British Airways Safety Information System (BASIS)
- AirClaims
- International Air Transport Association (IATA)
- Boeing
- Airbus
- Component manufacturers

Overlapping objectives, activities, and limited resources indicate FAA data programs are not coordinated (stovepiped). There is minimal intra-FAA data management program coordination and no clearly defined office responsible for coordinating these activities. Significant effort is underway to improve the quality of aviation safety data identification and collection. Implementing an oversight function in accordance with FAA Order 1375.1C, *Data Management* [2[; *FAA Data Management Strategy* [3]; and *FAA Information Technology Strategy* [4], would permit the FAA to streamline resources and programs and expand program capabilities.

References

1) National Resource Council, *Improving Aircraft Safety – FAA Certification of Commercial Passenger Aircraft* (The Low Report), Committee Chairman: George Low, Washington, DC, National Academy of Sciences, 1980.
2) FAA Order 1375.1C, *Data Management*, June 20, 2001.
3) *FAA Data Management Strategy*, September 21,1999.
4) *FAA Information Technology Strategy*, September 22, 1999.

Finding 6

Basic data definition and reporting requirements are poorly defined relative to the needs of analysts and other users.

Data Definition and Reporting Requirements

Quality data are fundamental for meaningful and effective analyses. Data directly influence the effectiveness of the decisions and actions taken to improve safety, not just by the FAA, but also by regulators, operators, manufacturers, and supporting industries.

Poor quality data also hamper the ability to identify accident precursors. Reporting requirements, *e.g.*, 14 CFR §21.3 and 14 CFR §121.703 – 705, alone are insufficient because:

- Mandatory data reporting requirements do not always ensure that adequate or relevant data are collected to reliably identify accident precursor events. Frequently, data are required to be reported only after an accident occurs, which may help explain the preceding accident, but fails to collect the data necessary to identify precursors and help prevent another, possibly different, type of accident.
- Data collection requirements do not adequately consider the resource constraints within the FAA and the user community and industry. Data are frequently collected and submitted without a clear understanding of the purpose for the submission and with no relevant feedback to the organization making the submission.
- Data are being defined and collected without a clear understanding of who the customers are, what analysis tools are available to mine the data, and what end product(s) the data must serve.

Voluntarily reported data (e.g., ASAP, FOQA), while excellent resources, are not always sufficient, reliable, or available to those who need them. Data suppliers may elect not to contribute data out of fear of negative publicity, legal liability, or regulatory enforcement action. It is imperative that data suppliers be provided robust legal and enforcement immunities and incentives to provide data voluntarily (see Finding 9).

A lot of data are collected on component reliability and failure patterns and rates, but there is also a need to capture lessons learned from the human/machine interface. Flight crews and maintenance personnel interface increasingly with the aircraft through computer systems. Knowledge of, and proficiency with, these computer systems is an increasingly more important part of flight crew and maintenance training and line operations.

Human factors issues regarding these interfaces should be captured for analysis and fed back to the aircraft and systems manufacturers. In many flight crew operating manuals, the flight management computer section is thicker than those relating to engine, electrical, hydraulic, and flight controls—a significant change from aircraft manufactured 20 years ago. RTCA Task Force 4 [5] addressed this issue:

> *User feedback, especially regarding errors encountered in the use of new equipment or procedures, is heavily stifled because of fear of retribution or other adverse consequences. Without early and comprehensive user feedback, safety suffers, at least in the inability to identify and correct problems detected through minor incidents, which could have more serious safety related consequences.*

Data may also be skewed based on a unique operating environment. For example, operations in harsh desert or arctic climates might skew the data and any analyses or conclusions from it. A cross sampling of data from multiple operators is needed to ensure the fidelity of the analyses and any conclusions or recommended actions.

Data are being collected in non-standardized formats and stored in multiple, often incompatible, databases. Analysis tools are usually incompatible and narrowly focused on a specific objective or product. As a result, resources are expended on multiple projects and produce separate, yet essentially equivalent products. As a result of multiple unique data collection programs, associated products may not serve the aviation safety needs of government and industry. This further isolates users into unique programs to meet specific needs and perpetuates the problem of stovepiping and database proliferation. Users supporting too many individual database programs are less inclined or able (because of time constraints) to support more broad-based programs.

Data definition and collection, as part of an integrated data management program, are noted in FAA Order 1375.1C [6]:

The guiding principles below represent the vision for the FAA data management program:

- *Data is viewed as a corporate resource used to make informed business decisions.*
- *Data is available in a timely, easily accessible, and understandable format to all users who need it.*
- *Core data is standardized for increased interoperability and increased accuracy.*
- *Maintenance and development costs are reduced by eliminating redundant and obsolete data, and through data reuse.*
- *Data development is coordinated across LOBs using a standardized methodology.*
- *Data is managed throughout its life cycle from creation to disposition.*
- *AIO is the focal point for corporate data management activities.*

The primary goal of the FAA data management program is to make reliable information available quickly.

Figure 5 shows some of the formal and informal information flows among regulators, carriers, and manufacturers.

References

5) Radio Technical Commission for Aeronautics (RTCA) Task Force 4, *Recommendations for Improving the Certification of Communication/Navigation Surveillance/Air Traffic Management (CNS/ATM) Systems* (RTCA Task Force 4 Report), Washington, DC, February 26, 1999.

6) FAA Order 1375.1C, *Data Management*, June 20, 2001.

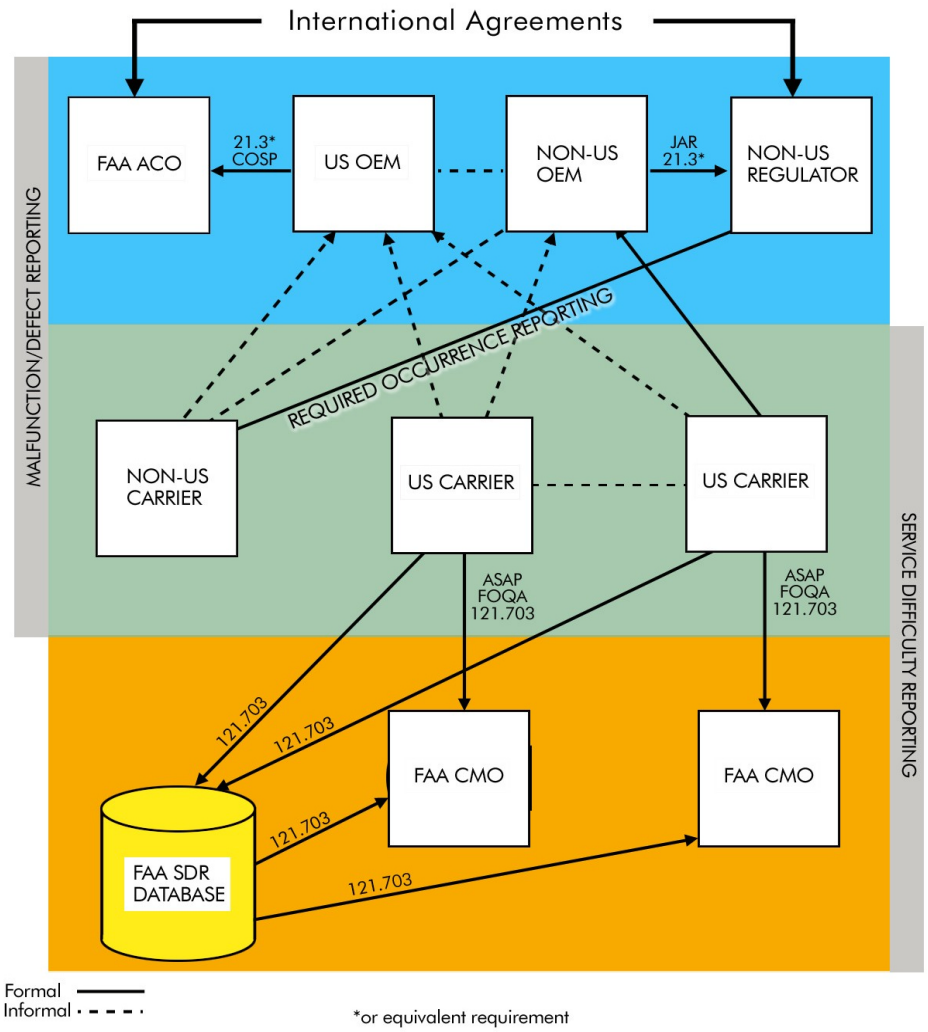

Figure 5. *Generalized formal and informal data flow paths*

Finding 7

There is no widely accepted process for analyzing service data or events to identify potential accident precursors.

Identification of Accident Precursors

Existing data analysis programs are seldom effective at identifying precursors with accident potential. Some non-regulatory processes used by OEMs and airlines are somewhat effective and could be standardized throughout the industry.

Some accidents have precursor incidents that indicated that the actual failure mode, or a similar event, had been experienced at least once prior to the accident. For example, the engine failure on a National Airlines DC-10 [7] was preceded by two similar events on engine test cells.[i] In another example, a Turkish Airways DC-10 cargo door [8] failed in a similar manner to an American Airlines DC-10 [9].

The reporting processes used by the airlines to alert manufacturers and the FAA to in-service events can provide a source of information to search for precursor events. The difficulty is that a precursor event is just another report among many until a post-accident data search finds it. Some OEMs and airlines, in conjunction with the FAA, have developed processes to seek out precursor events and to evaluate the probability of an accident occurring. Integrated FAA and industry safety data management systems should:

- Effectively identify accident precursors
- Provide regulators, operators, and manufacturers information to improve design and operational practices of new and in-service airplanes

The office of the FAA Chief Information Officer (AIO) is mandated to accomplish FAA data management objectives as prescribed in FAA Order 1375.1C [10]as follows:

[i]AAL test cell testing of CF6 on November 15, 1972 and GE test cell testing on January 12, 1973

- *Emphasizes data management as an essential agency program with data being an enterprise resource.*
- *Establishes a comprehensive, corporate Data Management Program rather than strictly data standardization.*
- *Establishes responsibilities for data management within each line of business (LOB) and staff office (SO).*
- *Establishes the key infrastructure necessary to support the Data Management Program.*

The FAA is a data-driven organization. The FAA's Data Management Strategy [11], outlines the agency's approach for the efficient and effective management of data. This order establishes the concepts of the data management strategy as an on-going program for the management of FAA data. This order also supports the information goal of the FAA Information Technology Strategy [12], which is to make reliable information available quickly. Both of these strategies identify data management as essential to the long-term performance of the FAA's mission and functions and the successful implementation of key initiatives to modernize the National Airspace System (NAS) and improve safety, security, and administrative information systems.

The effectiveness of existing FAA data management programs could be enhanced by:

- A better understanding of air transport operations by FAA data management offices that would improve their ability to provide meaningful safety data information and analyses to their customers. These customers can be either internal to the FAA or outside in industry.
- Educating FAA and industry users on these organizations' capabilities, products, or services could lead to FAA data management programs being better appreciated or understood by potential FAA and industry customers. Multiple programs proliferate (FAA and industry) that rely solely on the individual user's data. Stovepiping is also an issue within organizations. For example, maintenance data are often analyzed with maintenance software, and operations data are analyzed by operations software.

Hiring sufficient personnel with unique or specific data management knowledge and skills is critical. The skills required to identify precursor data or events are difficult to train and frequently must be augmented by technical support from OEMs, operators, or maintenance personnel. To avoid over-reliance on outside agencies for technical competency, FAA data management offices must recruit, train, and maintain personnel with requisite technical expertise and skills as noted in *FAA Information Technology Strategy* [12]:

> *People: Acquire and maintain critical IT knowledge, skills, and abilities. The aviation paradigm and information technology are changing so rapidly that keeping the workforce technologically current is daunting. Today, many FAA efforts focus on recruiting, retaining, and training its IT staff, but there is no consensus within the agency as to which are the most important IT knowledge, skills, and abilities, and no corporate program to acquire and develop people with those skills. Over the next three years, that consensus will be built, and programs put in place to acquire and develop people with critical IT knowledge, skills, and abilities, and to maintain those capabilities.*

While the challenges of creating a data management program to identify accident precursors appear daunting, there are a few existing programs that are effectively doing just that:

- The engine OEM/FAA Continued Airworthiness Assessment Methodologies (CAAM),
- FAA/Boeing Continued Operational Safety Program (COSP)
- The airline/FAA Aviation Safety Action Program (ASAP)
- Flight Operational Quality Assurance (FOQA)

All of these programs involve specialists reviewing incident reports for potential safety events, *e.g.*, chafed wiring, sticking controls, operational difficulty with avionics, or operating procedures, and recognizing that an accident could have occurred if events had been just a little different. The process then determines the risk involved with not changing the airplane or procedure, and if the risk is too high, the airplane design or procedure is revised.

Continued Airworthiness Assessment Methodologies (CAAM)

The Continued Airworthiness Assessment Methodology (CAAM) was developed in the early 1990's by an Aircraft Industries Association/European Aerospace Industry Association (AIA/AECMA) Propulsion Sub-Committee in response to the need for industry and the FAA Engine and Propeller Directorate to more effectively manage engine, propeller, and auxiliary power unit (APU) unsafe conditions. CAAM is a data-driven process, which sets a limit for accident risk and provides the time allowed to correct an unsafe condition and still remain within the risk limit. CAAM has been applied most frequently to engine, propeller, and APU problems, but the concepts have potential application to airframe continued airworthiness as well.

CAAM has identified several incident and accident precursors.

- PW4000 HPC Front Drum Rotor (AD 2001-20-13) and HPT (AD 2001-20-02) cracking
- AE3007 HPT 1-2 Spacer (AD 2001-19-03) with higher stresses than predicted
- AE2100 HPT wheel (AD 2001-17-31) cracking
- JT8D compressor disks (AD 2001-15-58) delivered with machining damage
- CF34 bearing system (AD 2001-12-06) report of compartment over-temperature and excessive disk growth

CAAM is a living process that continues to expand and improve. The process was updated in 1996 and is now in another update phase under the direction of the AIA Propulsion Committee. It is the basis of the FAA's draft Advisory Circular AC39-xx which applies to propulsion-related transport airplane potentially unsafe conditions [13].

Continued Operational Safety Program (COSP)

In 1999, the FAA-Boeing Partnership for Safety Plan working agreement on Continued Operational Safety Program (COSP) was developed, based on the principles and practices to be followed in reporting, analyzing, and resolving safety events and issues related to the Boeing transport airplane fleet. Recent problems worked through this process included [14]:

- Accelerated electrical connector corrosion, mostly on Boeing 737NG wheel wells, related to use of potassium phosphate runway de-icing fluid, mostly in Northern Europe
- A miscalibrated angle-of-attack (AOA) vane that caused a high speed RTO. An airline was using a multi-mode shop rigging tool and erroneously set a Boeing 757 vane to Boeing 727 settings.
- During a routine inspection of a Boeing 747, the primary nut on the engine strut midspar fuse pin was found backed out to the secondary retention feature. After an extensive investigation, an AD was issued to address the unsafe condition.

Flight Operational Quality Assurance (FOQA)

The Flight Operational Quality Assurance (FOQA) program in use by several US and international airlines captures and analyzes flight data recorder information to assist the FAA and airlines to identify unsafe trends and improve flight crew training and maintenance programs and to provide feedback to OEMs. Collection of FOQA data enables operators to focus on specific operational problem areas such as unstabilized final approaches that can result in aircraft departing the runway or a hard landing or tail strike.

Aviation Safety Action Partnership (ASAP)

In 1992, American Airlines implemented the Aviation Safety Action Partnership (ASAP) program, a voluntary incident reporting system. This program is viewed as a prototype for future operational data sharing partnerships between the airlines and the FAA. ASAP is part of a growing effort by the airlines and the FAA to collect and analyze airline operational data. The correlation of ASAP trend information with objective data from FOQA program can provide a valuable means to evaluate historical data and try to prevent accidents before they happen.

The NRC Low Report [15] (1980) noted:

> *A properly employed information system is indispensable to providing clues to, and early warning of, potential accidents. Critical to the effectiveness of such a system are the following elements:*
>
> *1) Information should be gathered and processed quickly, and the system should be capable of highlighting those items having possible consequences for safety.*
>
> *2) Additional information, beyond what is now available,should be obtained, wherever possible. The FAA needs to devote more attention to the safety information passing between and among the airlines and manufacturers that is now largely outside its purview.*
>
> *3) Analysis of the data should be made by well-qualified users.*
>
> *4) The users of the system must be disciplined to determine the cause of every incident, failure or accident, to require that corrective action be taken, and to provide feedback to all concerned parties.*

This position is also supported by recommendations made in the 1998 Continuing Airworthiness Risk Evaluation (CARE) Report [16, Chapter 2.3.6]. Implementation of these recommended processes from the Low and CARE reports, as well those from RTCA Task Force 4 [17], could consolidate data collection efforts and focus on the needs of data analysts examining data for safety and reliability improvement opportunities.

Data management programs must create products and services that effectively identify accident precursors. The focus needs to be on interventions to prevent the next accident by implementing lessons learned from previous accident and incident investigations. Data collection, data mining, and analysis with automated tools must be developed to alleviate resource constraints and human error. Resources for these efforts are available by integrating existing data management programs.

As a result of the unique requirements of regulators and industry, it is probably impossible to create a one-size-fits-all program. In the short term, the FAA should coordinate resource utilization and review and implement best practices. Expediency is important since natural and man-made hazards continue to threaten the safe and efficient transportation of the traveling public.

References

7) NTSB, *Aircraft Accident Report-National Airlines DC-10, N60NA, near Albuquerque, New Mexico, November 3, 1973* (NTSB-AAR-75-2), January 15, 1975.
8) NTSB, *Aircraft Accident Report-American Airlines, Inc., DC-10-10, N103AA, near Windsor, Ontario, June 12, 1972* (NTSB-AAR-73-2), February 28, 1973.
9) Turkish Air Lines DC-10 Paris on March 3, 1974.
10) FAA Order 1375.1C, *Data Management*, June 20, 2001.
11) FAA Data Management Strategy, September 21,1999.
12) FAA, *FAA Information Technology Strategy*, September 22, 1999.
13) FAA AC39-xx (draft), *Continued Airworthiness Assessments of Powerplant and Auxiliary Power Unit Installations on Transport Category Airplanes.*
14) Subject Matter Expert presentation CPS team, *Boeing Safety Process Overview*, February 27, 2001.
15) National Resource Council, *Improving Aircraft Safety – FAA Certification of Commercial Passenger Aircraft* (The Low Report), Committee Chairman: George Low, Washington, DC, National Academy of Sciences, 1980.)
16) Enders, Dodd, and Fickeisen, *Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE): An Exploratory Study* (The CARE Report), Flight Safety Foundation, September-October 1999.
17) Radio Technical Commission for Aeronautics (RTCA) Task Force 4, *Recommendations for Improving the Certification of Communication/Navigation Surveillance/Air Traffic Management (CNS/ATM) Systems* (RTCA Task Force 4 Report), Washington, DC, February 26, 1999.

Chapter 3

Maintenance, Operations, and Certification Interfaces

The sharing of information between manufacturers, airlines, and regulatory agencies is an essential element in the certification process and in maintaining the airworthiness of in-service airplanes. Of the many communication interface issues reviewed, four were identified that were of special concern:

- Capturing the lessons learned from design, manufacturing, maintenance and operating experience
- Constraints on the sharing of safety information
- Maintenance and operational safety recommendations and feedback between operators and OEMs
- Communication and coordination between aircraft certification and flight standards services

Preparation of these findings was based on reviews of relevant requirements and advisory material, case studies, historical reports, presentations by and discussions with operators, OEMs, Principal Maintenance and Operations Inspectors, FAA Aircraft Certification, Flight Standards, Aircraft Evaluation Group (AEG) personnel, and CPS team members.

Finding 8

Adequate processes do not exist within the FAA or in most segments of the commercial aviation industry to ensure that the lessons learned from specific experiences in airplane design, manufacturing, maintenance, and flight operations are captured permanently and made readily available to the aviation industry. The failure to capture and disseminate lessons learned has allowed airplane accidents to occur for causes similar to those of past accidents.

Capturing the Lessons Learned from Design, Manufacturing, Maintenance, and Operating Experience

Understanding the mistakes of the past and the lessons learned from them is an important step in assuring that those mistakes are not repeated. The investigation of accidents and incidents is one of the most effective ways to identify these mistakes and the lessons derived from them. While the experiences of the past are a valuable source of improved knowledge in all aspects of commercial aviation, maximum benefit has not always been derived from these experiences. Too often, lessons are not learned or adequately captured. This increases the risk that such knowledge will be lost with time. Regardless of the reasons, failure to capture adequately the important lessons of the past sets the stage for the repetition of past errors.

Historically, FAA regulations, guidance, and commonly accepted good aviation practices are based in large part on the lessons learned from past experience and, in particular, from past accidents. There is no requirement for a permanent and commonly available repository of experiences from which FAA regulatory and guidance material and industry best practices are derived. Additionally, there is no requirement to familiarize personnel in positions with safety responsibilities in the relevant experiences and mistakes of the past. Exacerbating this problem is the natural, and sometimes rapid, turnover of personnel in all segments of the commercial aviation industry. Capturing the knowledge these individuals have gained during their careers is as important as capturing the lessons of past accidents. Without processes in place to capture and communicate this information, institutional and individual memories fade and important lessons may be lost.

Historical perspective is an essential element in educating regulators and certificate holders to justify the need for regulatory change. A major source of the historical rationale for a regulation is contained in 14 CFR preambles. This material is often incomplete and difficult to research. Past preambles are

often less comprehensive than those published today and may contain only the disposition of public comments to an FAA proposal. A review of existing 14 CFR preamble materials indicates that there are no consistently applied processes under which regulatory preamble material is developed.

The Final Report of RTCA Task Force 4 Certification [1] also addressed this issue. Finding 11 of the RTCA report states in part:

> *The authorities should correct the improper application of rules, guidance, and policy by educating agency specialists about the conceptual basis for regulatory material.*

There are many examples in the history of commercial aviation to illustrate the importance of capturing and remembering lessons learned, as the following three case studies will illustrate.

Fuel Line Certification Criteria

On November 11, 1965, a Boeing 727 crashed on approach to the airport at Salt Lake City, Utah [2]. During the accident, the right main landing gear severed fuel lines resulting in a cabin fire. Following the investigation, the Civil Aeronautics Board recommended specific design changes to the FAA. As a result, 14 CFR §25.993(f) was revised to state that, “Each fuel line within the fuselage must be designed and installed to allow a reasonable degree of deformation and stretching without leakage.” However, detailed discussion of the rationale of what constituted a suitable design was contained only in internal FAA communications and the revised airplane design requirements of the affected OEM. As a result, recent interpretations of this regulation appear to conflict with the original intent of this revision. This has led to airplane designs that appear to meet the requirement but not the intent of the 1965 revision to this regulation. These airplane designs address the flight loads, ground loads, and pressurization cycle issues specified in the regulation but not the more stringent requirements of partial fuselage break up that were derived from the Salt Lake City accident. Follow-on airplanes of the original manufacturer, who had more detailed information about the rationale behind the rule, have installations that meet the intent of the rule.

However, changes in 14 CFR Part 25 regulatory material and industry guidance material to adequately reflect the original intent have never been made.

In-flight Fire

On November 3, 1973, a Boeing 707 cargo airplane crashed short of the runway at Boston-Logan airport with a seriously deteriorating smoke and fire condition that the flight crew was unable to control [3]. On June 2, 1983, a DC-9 landed in Cincinnati after an uncontrollable fire was discovered on board [4]. The NTSB reports on both of these accidents indicated that the flight crews underestimated the severity of their emergencies and did not land the airplanes as soon as possible. On September 2, 1998, an MD-11 crashed near Halifax, Nova Scotia following an uncontrollable fire inboard. Although a final report has not been issued, the investigation is evaluating the timeliness of the diversion and landing decision [5]. It appears that the operational lessons of both the Boeing 707 and the DC-9 accidents may not have been adequately learned by industry.

Automated Propeller Response in the Event of Powerplant Failure

In the 1980s, the development of several new turboprop commuter airplanes resulted in proposals for certification that would allow multiple engine autofeather following engine failure. Accidents involving multiple engine autofeather events had occurred in the 1950s and 1960s and guidance material to understand and eliminate this as an accident cause had been incorporated into the Civil Aeronautics Manual. This requirement was not captured in the Civil Air Regulations (CAR) nor was it carried forward to the Federal Aviation Regulations in the mid-1960s. It was the past experience of an FAA specialist who understood the relevance of those earlier events and was able to provide the guidance to the various manufacturers regarding these earlier lessons. The current 14 CFR Part 25 does not address this issue, so tomorrow's designers may not understand the lessons that should have been learned from previous autofeather related accidents.

Regulations and related guidance materials are often revised as a result of accident and incident investigations. The processes

intended to improve these materials cannot be effective without ensuring a permanent and ongoing understanding of the rationale for the change, as well as a method for retention of the costly lessons that may not have been incorporated into the standards. Without this additional insight, safety improvement efforts may not be fully understood by future designers.

The knowledge of experienced individuals may well be passed in one form or another. This can be accomplished either formally in documentation required by policy or informally by word of mouth. However, no requirement currently exists in the FAA or in the commercial aviation industry to ensure that the important lessons of the past are memorialized and shared. Without such a process, industry's memory fades and critical lessons may be painfully re-learned.

References

1) Radio Technical Commission for Aeronautics (RTCA) Task Force 4, *Recommendations for Improving the Certification of Communication/Navigation Surveillance/Air Traffic Management (CNS/ATM) Systems* (RTCA Task Force 4 Report), Washington, DC, February 26, 1999, page 6.
2) US Civil Aeronautics Board, *Aircraft Accident Report – United Air Lines, Inc. Boeing 727, N7030U, Salt Lake City, Utah, November 11, 1965*, June 7, 1966.
3) NTSB, *Aircraft Accident Report-Pan American World Airways, Inc. Boeing 707-321C, N458PA* (NTSB-AAR-74-16), *Boston, Massachusetts, November 3, 1973*, December 2, 1974.
4) NTSB, *Aircraft Accident Report-Air Canada Flight 797, McDonnell Douglas DC-9-32, C-FTLU, Greater Cincinnati International Airport, Covington, Kentucky, June 2, 1983* (NTSB-AAR-86-02), January 31, 1986.
5) TSB, *Interim Aviation Safety Recommendations – In-flight Firefighting–Occurrence Number A98H0003,* (TSB A 15/2000), Recommendation 3.

Finding 9

There are constraints present in the aviation industry that have an inhibiting effect on the complete sharing of safety information.

Constraints on the Sharing of Safety Information

The primary goal of the airline industry is to provide safe transportation to the traveling public. To achieve this goal, considerable human and economic resources are dedicated to analyzing collected safety data in an effort to identify accident precursors or potentially unsafe trends. Properly collected and analyzed operational and maintenance information can be a powerful accident prevention tool. However, some of this information may be proprietary and can provide a significant economic benefit in a competitive environment. If used improperly, this information may cause extensive economic and public relations harm. Although this harm is often thought to relate to legal liability only, enforcement action and public disclosure of safety information are equally significant factors. For a safety data collection program to be timely and effective, protection of the data from all these issues is required.

Safety information is collected by government agencies, manufacturers, and operators. Most safety information gathered by the government is available to the public through the Freedom of Information Act (FOIA). However, litigation is often required to release safety information gathered by manufacturers or operators.

Concerns for legal liability, enforcement action, and public disclosure of safety information hamper the collection and analysis of safety data and impede its free exchange, thereby impacting aviation safety.

The legal liability issue is of primary concern since court judgments can result in significant monetary and punitive awards. Frequently, a major segment of litigation is based on tracing exchanged safety information to its source. There are several FAA safety reporting programs where operators are required to contribute data. Most of these data are de-identified to protect confidentiality. While this technique has frequently addressed the legal liability and disclosure issues, it has diminished the value of the exchanged safety information.

Legal Liability

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Protecting safety information collected by operators and manufacturers from litigating parties is difficult. One approach observed was to collect, analyze, and retain the information for a specific time. This, however, limits the amount of data collected and its usefulness for analyses. Some operators simply elect not to collect safety data to discourage litigation. Manufacturers have developed elaborate informal processes to gather safety information for internal use. Formal requirements also exist for the exchange of safety information with the FAA. Regardless of which processes the operators and manufacturers use, the threat of litigation to seek safety information exists.

Several courts have ruled inconsistently on the confidentiality of safety information used in litigation. Until such time as complete confidentiality of all formally or informally collected safety information is guaranteed, some operators or manufacturers may be reluctant to share safety information.

Public Disclosure of Safety Information

There is a reluctance to report or share safety data if it is not protected from public disclosure since it can be misinterpreted or misquoted if reported in the media. The White House Commission on Aviation Safety and Security [6] also recognized the protection issue by stating:

> *. . . people and companies will not provide or assemble safety data . . . if it can in any way cause them a liability.*

For example, a major US airline willingly cooperated in an FAA sponsored Flight Operations Quality Assurance (FOQA) reporting program and provided large amounts of data. Less data were provided by other airlines in the same program. Subsequently, the data were publicly disclosed and quoted in the media. The inference was that the airline providing large amounts of data was less safe than the others. This airline subsequently withdrew from the FOQA program.

In the Federal Aviation Reauthorization Act of 1996 (Section 40123), Congress recognized the importance of gathering and analyzing safety data to, ". . . spot trends before they result in accidents" and directed the FAA to, ". . . issue regulations to carry out this section." This would prevent the public disclosure of voluntarily provided safety or security information under most conditions. In June 2001, the FAA issued 14 CFR Part 193, *Protection of Voluntary Submitted Information* [7]. The FAA issued the FOQA rule on November 30, 2001 [8]. The two rules complement each other. The former provided for the protection of voluntarily submitted information except under limited circumstances while the latter established a voluntary safety data collection program using flight data recorder information. These rules are a major step forward in addressing the legal concerns of operators, but they only apply to voluntarily supplied data and only to data provided to the FAA. Occasionally, there is a need to exchange safety information with other operators or manufacturers. However, 14 CFR Part 193 does not protect this information. All safety data must be completely protected to ensure the effective and timely identification of safety issues.

Enforcement Action

The fear of enforcement action against a manufacturer, operator, or individual for disclosing safety violations also exists. The FAA has made efforts to diminish this form of action against an individual by establishing the Aviation Safety Action Program (ASAP) [9] and the Aviation Safety Reporting Program (ASRP) [10]. The *Voluntary Disclosure Reporting Program* [11] was established to provide the operator a process to disclose apparent violations. One of the prime reasons for establishing these programs was to

encourage voluntary reporting of safety issues and events. All of these programs have specific requirements for compliance designed to eliminate the threat of enforcement action.

There are a number of international actions that attempt to address these issues:

- IATA recently set up the Safety Trend Evaluation, Analysis and Data Exchange System (STEADES). This initiative appears to have the potential to become a useful process for the free exchange of safety data.
- ICAO currently recommends the collection of FOQA data and will require this under Annex 6 in January 2005. This recommends that the program be non-punitive and that adequate safeguards be in place to protect the suppliers of data.
- There are many years of experience in Europe with the use of non-punitive exchange of data. In spite of the different legal systems, this experience may help to resolve some of the US problems.
- The UK Civil Aviation Authority (CAA) issued, in March 2000, Airworthiness Notice Number 71, *Maintenance Error Management Systems (MEMS),* covering the voluntary submittal of safety critical maintenance error data.

The FAA has made considerable progress in reducing the constraints of legal liability, enforcement action, and public disclosure of safety information. However, the operator or manufacturer may be reluctant to fully disclose all safety information in a timely manner until complete confidentially is guaranteed. Until this is achieved, the operator or manufacturer may elect not to contribute data out of concern for these potential consequences.

References

6) White House, *The White House Commission on Aviation Safety and Security.* February 12, 1997, page 13.
7) FAA, *14 CFR Part 193, Protection of Voluntarily Submitted Information,* June 25, 2001.
8) FAA, DOT FAA 14 CFR Part 13 Docket No. FAA-200-7554, Amendment No. 13-30, *Flight Operations Quality Assurance Program,* November 30, 2001.

9) FAA, Advisory Circular 120-66A, *Aviation Safety Action Programs* (ASAP), March 17, 2000.
10) FAA, Advisory Circular 00-46D *Aviation Safety Reporting Program*, February 26,1997.
11) FAA, Advisory Circular 00-58 *Voluntary Disclosure Reporting Program*, May 4, 1998.

Finding 10

There are currently no industry processes or guidance materials available which ensure that:

- *Safety related maintenance or operational recommendations developed by the OEM are evaluated by the operator for incorporation into their maintenance or operational programs; and*
- *Safety related maintenance or operational procedures developed or modified by the operator are coordinated with the OEM to ensure that they do not compromise the type design safety standard of the airplane and its systems.*

Maintenance and Operational Safety Recommendations and Feedback Between Operators and Original Equipment Manufacturers (OEMs)

When an operator first introduces an airplane model into service, there is a tremendous amount of coordination that takes place to ensure that the operator is aware of and considers the OEM's recommendations on how the airplane should be operated and maintained. This communication and coordination is in many ways enhanced by the processes administered by the FAA (e.g., the Maintenance Review Board (MRB) and the Flight Operations Evaluation Board (FOEB)). After the initial approvals are granted, there are no known formal industry processes or requirements to ensure that operators review the OEM's safety related recommendations. There is also no requirement for operators to include these recommendations in appropriate procedures and manuals.

Similarly, there is no requirement or process to ensure that operator changes to operations or maintenance programs are coordinated with the OEM to prevent adverse impact on the safety of the type design produced by the OEM and approved by the FAA. Both OEMs and operators want the flow of safety related communications to be robust and efficient. However, a review of accident case studies and interview sources indicates that this is not always the case.

There is a large amount of information flowing from OEMs to operators that could be considered safety-related. However, the only mechanism available that ensures that the OEM's or the FAA's recommendations are implemented by an operator is the Airworthiness Directive (AD) process described in 14 CFR Part 39. Airworthiness Directives are an appropriate correction process when:

- An unsafe condition exists in a product; and
- That condition is likely to exist or develop in other products of the same type design.

Although some of these recommendations involve safety deficiencies that are addressed with the AD process, other recommendations may or may not be reviewed and considered for incorporation in the operator's manuals. Examples of these recommendations include Operations Manual Bulletins, Maintenance Manual procedural changes, and Warnings/ Cautions included in both the maintenance and operations manuals. For example, following a September 2, 1998 accident of an MD-11 aircraft accident en route from New York to Geneva, Switzerland, the OEM issued an Operations Manual Bulletin [12] to all MD-11 operators clarifying the crew's role in reacting to on-board smoke and fire events. The Operations Manual Bulletin discussed a safety issue that could not be addressed by an AD since an unsafe condition had not been identified.

Equally important, there is no requirement that ensures that operators who make changes to their operations or maintenance programs coordinate them with the OEM. This is not a new issue. The National Research Council's report on Improving Aircraft Safety [13] recommended that the manufacturer should have:

> *. . . continuing knowledge of an operator's maintenance procedures by obtaining the manufacturer's formal review prior to authorizing any significant deviation from the approved maintenance program.*

Several accident examples can be cited which address the safety communication breakdown that sometimes occurs between operator and OEM:

- On May 25, 1979, a DC-10 aircraft departing from Chicago-O'Hare International Airport, Illinois, crashed shortly after takeoff following the separation of the left engine and pylon assembly. Although there were numerous findings identified by the NTSB [14] involving the manufacturer, the airlines, and the FAA, a number of them concerned a procedure developed by two airlines that involved removing and reinstalling DC-10 wing-mounted engines as a single unit. The OEM had recommended in their original maintenance procedures and in follow-on service bulletins that the engine be separated from the pylon before removing the pylon from the wing. Apparently, the airlines were not aware of the safety concern that the OEM had for engine-pylon removal. Neither of the airlines requested that the OEM review their revised procedures.
- On January 9,1997, an Embraer EMB-120 aircraft approaching Detroit crashed near Monroe, Michigan. The NTSB determined the probable cause to be a premature stall because of ice accretion [15], and noted in the report's findings that:

  > *Had the pilots ... been aware of the specific airspeed, configuration and icing circumstances of the six previous EMB-120 icing-related events and of the information contained in Operational Bulletin 120-002/96 and revision 43 to the EMB-120 airplane flight manual, it is possible that they would have operated the airplane more conservatively with regard*

> *to airspeed and flap configuration or activated the deicing boots when they knew they were in icing conditions.*

Finding 30 of the NTSB report noted:

> *The current Federal Aviation Administration policy allowing air carriers to elect not to adopt airplane flight manual operational procedures without clear written justification can result in air carriers using procedures that may not reflect the safest operating practices.*
>
> *In this case, the flightcrew of the accident aircraft did not have the latest operational guidance that had been provided by the OEM.*

- On September 2, 1998, an MD-11 aircraft en route from New York to Geneva, Switzerland, crashed in the Atlantic Ocean near Peggy's Cove, Nova Scotia, Canada, following an in-flight fire. Although the TSB report has not been released, the results of an FAA Special Certification Review Team report [16] were released in June 1999. Finding 1 of that report stated that

  > *. . . the current design of the IFEN [In-flight Entertainment] system electrical power switching is not compatible with the design concept of the MD-11 airplane with regard to the response by the flightcrew to a cabin or flight deck smoke/fumes emergency.*

  In particular, the OEM's design concept removed power from all main cabin systems when the CAB BUS switch is engaged during a smoke/fumes emergency. This design, implemented by a Supplemental Type Certificate (STC), violated that concept by connecting the in-flight entertainment system to a power source that was not de-energized when the CAB BUS switch was activated. Although it cannot be stated at this time the exact role this may have played in the accident, there is no indication in the report that the operator (responsible for the operating procedures) or the STC applicant coordinated or consulted with the OEM on this proposed

installation. This may have resulted in the emergency fire and smoke checklist procedures provided by the OEM and those in use by the operator to be inconsistent with the configuration of the aircraft at the time of the accident.

- On January 31, 2000, an MD-83 aircraft traveling from Puerto Vallarta, Mexico, to Seattle, Washington, crashed into the Pacific Ocean near Point Mugu, California, following a catastrophic horizontal stabilizer jackscrew assembly failure. Although the NTSB investigation is not complete and a report has not been published, a set of recommendations released on October 1, 2001, by the Safety Board [17] provides some insights pertinent to this CPS finding. One example concerns the ". . . potential adverse effects caused by mixtures of inappropriate grease types or incompatible mixtures of grease types." In an attempt to standardize the grease used across its entire fleet, the operator elected to change from Mobilgrease 28, which used a clay-based thickening agent, to Aeroshell Grease 33, which used a lithium-based agent. The NTSB found that the OEM had previously expressed concern about mixing grease types and had provided the operator with a "no technical objection" to the grease change as long as the operator monitored the areas where Aeroshell 33 grease was to be used and obtained FAA approval as required by their Principal Maintenance Inspector. While the relevance of Aeroshell 33 grease or the mixing of grease types in this accident has not been determined by the NTSB, it appears that a safety related recommendation developed by the OEM was either not clearly communicated as a safety recommendation by the OEM or not adequately evaluated by the operator for incorporation into their maintenance program.

Addressing this finding will not be straightforward. Requiring operators to get OEM approval for every change made to their operations or maintenance programs is not realistic. The OEMs are not staffed to review all potential changes to their customers' programs. Likewise, requiring operators to review every recommendation or suggestion made by OEMs for possible inclusion in their programs may also not be realistic. An additional disincentive to the operators from coordinating changes with the OEM is the cost and possible program delays.

A particular challenge exists in defining “safety related” recommendations or changes in a manner that is clearly understood by the operator and OEM. This is not an easy issue to resolve and was discussed in the National Research Council report on May 25, 1979, Improving Aircraft Safety [13] in 1980.

> *The committee recognizes that this recommendation introduces the need to define “significant” in a way that will make it clear which items require a review by the manufacturer-designer. Such items should be confined strictly to those involving the continuing integrity and safety of the design.*

The existing ATA-100 Alert Service Bulletin concept and the FAA Airworthiness Directive process do not address all safety related recommendations – nor should they. These processes are for communicating information on and correcting unsafe conditions. The process of identifying the remaining safety related recommendations and changes and communicating these in an adequate manner between OEM and operator needs improvement. Striking a balance between onerous intrusion and the addressing of true safety issues will be a difficult task. Unique airline operating conditions and alternative operating methods complicate this matter even further. This issue of identifying and communicating safety related information is also addressed by Findings 4 and 13.

In conclusion, the potential exists for OEM operational or maintenance recommendations not to be fully considered by operators. The potential also exists for operators to modify operations or maintenance procedures and practices that could impact the safety of the type design. The challenge will be to identify the additional communication and reviews required to achieve a real safety benefit versus an onerous communication requirement. The solution to this problem does not appear to be achievable simply with additional regulation or requirements. Indeed, it appears that this communication problem may best be solved by an industry partnership – both manufacturers and operators – with the FAA monitoring the progress and effectiveness of the solutions identified.

References

12) The Boeing Company, *Supplemental Information to MD-11 Flight Crews on Inflight Smoke/Fire Procedures* (Operations Manual Bulletin No. MD-11-99-04), June 2, 1999.

13) National Resource Council, *Improving Aircraft Safety – FAA Certification of Commercial Passenger Aircraft* (The Low Report), Committee Chairman: George Low, Washington, DC, National Academy of Sciences, 1980, page 63.

14) NTSB, *Aircraft Accident Report-American Airlines, Inc. DC-10-10, N110AA, Chicago-O'Hare International Airport, Chicago Illinois, May 25, 1979* (NTSB-AAR-79-17; NTIS-NTISUB/E/104-017), December 21, 1979.

15) NTSB, *Aircraft Accident Report In-flight Icing Encounter and Uncontrolled Collision with Terrain, Comair Flight 3272 Embraer EMB-120RT, N265CA, Monroe, Michigan January 9, 1997* (NTSB-AAR-98-04; NTIS-PB98-910404), November 4, 1998.

16) FAA, *Special Certification Review (SCR) Team Report on Santa Barbara Aerospace STC ST00236LA-D Swissair Model MD-11 Airplane In-flight Entertainment System*, June 14, 1999, page 17.

17) NTSB, *Safety Recommendation A-01-41 through –48*, October 1, 2001.

Finding 11

The absence of adequate formal business processes between FAA Aircraft Certification Service and Flight Standards Service limits effective communication and coordination between the two that often results in inadequate communications with the commercial aviation industry.

Communication and Coordination Between Aircraft Certification Service and Flight Standards Service

The NTSB has often cited lack of adequate FAA oversight as a contributing factor when accidents occur or when other significant safety problems are identified. Interviews with FAA personnel and a review of case histories revealed that this lack of oversight was due in part to the absence of formal processes that would ensure the communication of safety information between the Aircraft Certification Service and Flight Standards Service. This results in existing FAA work programs not being adequately coordinated on matters concerning oversight findings, safety issues, and allocation of oversight

resources. The lack of formal processes also impedes the coordination and dissemination of safety related information and control of guidance material intended for use by both the FAA and industry, allowing potentially unsafe aircraft configurations or operations.

Examples of these breakdowns in communication and coordination between the two services are illustrated by the following case studies.

Icing Related In-service Events

Interviews with FAA and former FAA personnel [18] involved with analyzing icing events stated that Flight Standards had information concerning potentially hazardous flight characteristics of airplanes under heavy ice buildups that was not promptly communicated to Aircraft Certification Service. As a result, actions by Aircraft Certification to correct airplanes and their systems were delayed.

Alteration of Maintenance Programs:

The FAA review of the Alaska Airlines maintenance program for the MD-83 indicates that the operator substantiated the escalation of their C-check program through their maintenance reliability program [19]. Within the operator's escalated C-check program, there were critical systems inspections. The PMI was aware of his operator's program escalation. However, there was no documented process that would have recommended coordination with the increased inspection intervals of critical systems with the AEG or ACO responsible for the MD-80 type design.

A process designed to ensure a formal exchange of safety related data between Aircraft Certification and Flight Standards and its subsequent coordinated distribution to commercial airplane operators would provide a more effective and proactive use of safety data and oversight resources. Formally defined coordination between these two offices would facilitate the development of potential accident precursor information. Aircraft Certification and Flight Standards Services personnel perform safety oversight functions usingseparate uncoordinated methodologies to determine resource needs, deployment, and inspection requirements. For example, the National Program Guidelines (NPG) was

established in Flight Standards as a method of accomplishing oversight. In 1996, Flight Standards Service developed the Air Transportation Oversight System (ATOS). ATOS links the oversight functions and the ability to target resources to the areas needed. Existing automated programs, such as the Aircraft Certification System Evaluation Program (ACSEP) and the Flight Standards Safety Performance Analysis System (SPAS) are in place to support aviation safety oversight functions and data gathering, but they are not always adequate to coordinate resources and exchange pertinent safety information between Flight Standards and Aircraft Certification. As a consequence, day-to-day surveillance data or safety information of interest to specialties within Aircraft Certification and Flight Standards may not be passed along or coordinated. Further, available resources may not always be assigned or used to support the planned overall safety oversight objective.

In the field, links between the two organizations are very limited and have not been thoroughly developed to assure optimum communication between them. The AEG was created to resolve this communication deficiency and serves as the liaison organization between Aircraft Certification and Flight Standards. However, there remains a lack of adequate formal guidelines that define the interface between Aircraft Certification and Flight Standards. Without such protocols, there is an ongoing risk that important safety data and precursor information may not be communicated in a way that assures proper analyses and appropriate action. While efforts have been initiated to address this issue, it remains unresolved.

At the FAA Headquarters level, both Services are authorized to publish regulations, advisory circulars (ACs), internal FAA orders, notices, and policy memos. However, no formal business process requires Aircraft Certification and Flight Standards to communicate and coordinate the issuance of these documents. Given the lack of these formal processes, there exist many informal, uncoordinated practices, based primarily on established personal relationships, used by the two services to

communicate. These practices frequently are inadequate and inconsistent and have resulted in multiple documents being produced by both services that either contradict or duplicate each other. This situation increases the challenges faced by Aviation Safety Inspectors and Aviation Safety Engineers in their oversight roles. The effect on the industry is a variety of individual operator interpretations and uncertainty as to adequate compliance. Worse, it compromises the industry's perception of FAA coordination and technical competence.

No process exists for archiving past policy and guidance material in order to determine what the FAA's position has been in the past. Such a database of past policy and guidance would benefit both the FAA and industry. It would promote greater consistency on the part of the FAA when issuing policy and guidance material and greater understanding and improved consistency of industry compliance. Without an effective archival process, the likelihood for duplicating or contradicting past notices, policy letters, and memos exists. Currently, notices, draft notices and handbook bulletins are posted on the FAA website; however, this is not a complete archival system. For example, document termination dates are poorly controlled and may not be adhered to at all. This promotes internal confusion and a proliferation of advisory materials in various forms.

It is common practice by some FAA inspectors and certification personnel to interpret and enforce guidance material as regulatory. This has only added to the confusion and in some instances creates a less than positive working relationship with industry. There are many examples of these occurrences as evidenced by the number of formal complaints from industry and congressional representatives. A recent example is the attempts of Flight Standards maintenance safety inspectors to enforce the 14 CFR Part 145 *Notice of Proposed Rulemaking (NPRM)* [20], which proposed updates and changes to domestic repair stations, before the proposed rule was final and in effect.

There are informal processes that have evolved between Flight Standards and Aircraft Certification but they are neither consistent nor complete. The lack of documented formal business processes between these offices compromises effective communication and coordination that may affect the FAA's ability to address industry safety issues effectively and industry's ability to fully comply with FAA regulations and requirements.

References

18) CPS Team Interview with the FAA Flight Standards and Aircraft Evaluation Group, January 8, 2002.

19) CPS Team Interview with the Alaska Airlines Principal Maintenance Inspector and the Partial Program Manager for the MD-80 Fleet, January 15, 2002.)CPS Team Interview with the FAA Flight Standards and Aircraft Evaluation Group, January 8, 2002.

20) FAA Notice of Proposed Rulemaking (NPRM), Repair Stations, Docket No. FAA-1999-5836; Notice No. 99-09.

Chapter 4

Major Repairs and Modifications

Once the manufacturer releases an aircraft to an operator, the operator is responsible for maintaining its continued airworthiness. Maintaining continued airworthiness involves routine maintenance, as well as repairs and alterations to the aircraft. For all of these activities, an approved configuration must be maintained. Maintenance, repair, and alteration work is accomplished using either FAA approved or accepted data, including operator and manufacturer (user) documents.

14 CFR §43.13 states:

> *Each person performing maintenance, and alterations, or preventative maintenance on an aircraft, engine, propeller, or appliance shall use the methods, techniques, and practices prescribed in the current manufacturer's maintenance manual, or instructions for continued airworthiness prepared by its manufacturer, or other methods, techniques, and practices acceptable to the Administrator.*

These findings were based on reviews of relevant requirements and advisory material, case studies, historical reports, presentations by and discussions with operators, personnel from large and small maintenance, repair, and alteration companies, Principal Maintenance Inspectors, and team member.

Improvements in the areas of repair and alteration classification, quality of the implementation of repairs and

alterations, and the process to provide accurate and timely information into user manuals are needed in order to assure continued airworthiness of the aircraft.

Finding 12

The airline industry and aircraft repair organizations do not have a standardized process for classifying repairs or alterations to commercial aircraft as "Major" as prescribed by applicable Federal Aviation Regulations (FARs)

Classification of Repairs and Alterations

There is no standard process used across the commercial aviation industry or regulatory authority to determine and classify repairs or alterations to commercial aircraft as *Major* [1] as prescribed by applicable FARs [2]. The result of misclassifying a repair or alteration is the lack of adequate review, validation, and reporting of the sufficiency of repairs or alterations developed for commercial aircraft.

Consistency is needed in the major or minor repair decision processes. A major repair or alteration should use a controlled process requiring record keeping, reporting requirements and FAA approved data [3]. The lack of a consistent process can lead to a tendency of operators and repair stations to avoid use of the Major category for repairs and alterations. Repairs and alterations that are classified as *Minor* generally result in less paperwork and reduced inspection requirements for the maintenance activity.

The reason for this inconsistency is that FARs and guidance material lack clear and unambiguous decision logic that would allow consistent and proper classification of a repair or alteration as Major. Some operators have developed a detailed decision logic process that more adequately address the *Major/ Minor* classification requirement than those of other operators. Repair stations may develop their own major or minor decision process or default to the customer's decision process.

Interviews with repair station [4], FAA [5,6], and air carrier personnel [7] revealed that there is continuing concern that the lack of a standardized process for the appropriate classification

of repairs and alterations can have an adverse impact on the continued airworthiness of aircraft. Rather than a uniform industry-wide process, each airline operator or FAA certificated repair station has the responsibility for the determination and classification of repairs or alterations to commercial aircraft in accordance with applicable FARs such as 14 CFR Part 43, Appendix A and B.

An Aviation Rulemaking Advisory Committee (ARAC) working group, the Clarification of Major/Minor Repairs or Alterations Working Group, was established in 1994 to examine this issue [8]. The existence of this activity indicates the FAA and industry have recognized this subject as a significant concern in aviation safety.

The result of a standardized classification process for major repairs and alterations to aircraft will be to enhance aircraft safety by assuring that all 14 CFR Part 121 operators and 14 CFR Part 145 repair stations use an appropriate level of decision logic. This will maintain the focus on safety and continued airworthiness when addressing repairs or alterations to commercial transport aircraft.

References

1) 14 CFR Subchapter A Part 1: *Definitions and Abbreviations*
2) 14 CFR Part 43 Appendix A and B, FARs 121.380, 121.379(b), and 121.707.
3) General Accounting Office, GAO/RCED-98-21 Aviation Safety, *FAA Oversight of Repair Stations Needs Improvement,* October 1997, page 30.
4) CPS Team Interview with FAA Repair Stations, BF Goodrich Aero Controls, August 14, 2001.
5) CPS Team Interviews with PMIs, BF Goodrich, Aero Controls, July 18, 2001.
6) FAA Northwest Mountain Region Technical Standards Branch, ANM230 briefing.
7) CPS Team Interview with United Airlines Personnel, August 2, 2001.
8) Aviation Rulemaking Advisory Committee (ARAC), Clarification of Major/Minor Repairs or Alterations Working Group (59 FR 1583), January 11, 1994.

Finding 13

Inconsistencies exist between the safety assessments conducted for the initial Type Certificate (TC) of an airplane and some of those conducted for subsequent alterations to the airplane or systems. Improved FAA and industry oversight of repair and alteration activity is needed to ensure that safety has not been compromised by subsequent repairs and alterations.

Quality of Alterations and Repair Processes

Processes for the design and accomplishment of repairs and alterations, including oversight, have not always ensured the continued airworthiness of the airplane. Safety assessments prepared for certification of alterations to the airplane or systems may not meet the same standards as those for the original type certificate, although the FARs require they do so. Cases exist where the modification station or company did not have the appropriate expertise or access to original certification data to conduct adequate safety analyses. Two case studies revealed a lack of design expertise or the use of pertinent OEM design data, which may have contributed to an accident or significant non-airworthiness condition. In the Boeing 727 passenger-to-freighter conversion, the FAA found no, or limited, structural analysis for the pressure deck, wing-box beams, and the lateral floor restraint in the Supplemental Type Certificate (STC) file [9]. In later analysis the FAA determined that the margins of safety calculated for the floor beams in the STC did not comply with CAR 4.b requirements [10].

After the Swissair Flight 111 accident, the FAA conducted a Special Certification Review (SCR) of the In-flight Entertainment System (IFE) [11]. The review was to evaluate the design, installation, and certification process of the approved IFE system. The SCR team determined that the IFE system electrical power switching was not compatible with the OEM design concept of the MD-11. The Transportation Safety Board of Canada (TSB) is leading the investigation for this accident and has not completed its work or established a probable cause.

The consistency of FAA and industry oversight varies greatly, which has resulted in some repairs and alterations being non-compliant with the FARs. Published historical reports [12,13,14,15] and CPS team interviews with commercial airline operators [16, 17] and FAA certificated repair station personnel [18] have confirmed there has been, and can continue to be, an adverse impact on commercial aviation safety when there is insufficient oversight.

There is no requirement for a facility approved to perform major repairs and alterations [19], or for an STC applicant, to consult with the FAA ACO and AEG offices involved in the original TC approval, the OEM, or holders of other STCs applicable to that work. Cases exist where failure to do this has had an adverse impact on the continued airworthiness of the aircraft. The *STC Process Review Final Report* [12] has also cited this concern.

The lack of clear requirements for repairs and alterations, combined with inadequate FAA and Industry oversight, result in the potential for insufficient repairs or alterations of commercial transport aircraft. The subject of this finding is closely linked to Finding 4 and 10 in this report.

References

9) FAA presentation to CPS Team on Boeing 727 Passenger to Freight conversion program, April 5, 2001.
10) Civil Aeronautics Regulations (CAR 4b).
11) FAA presentation to CPS team, *Swissair Flight 111 Accident Overview*, Seattle WA, February 28, 2001.
12) *STC Process Review Final Report*, May 31, 2000.
13) General Accounting Office, *FAA Oversight of Repair Stations Needs Improvement* (GAO/RCED-98-21 Aviation Safety), October 1997.
14) Gore Commission, *White House Commission on Aviation Safety and Security* (The Gore Report) Chairman: Vice President Al Gore, February 12, 1997, Chapter 3.
15) Radio Technical Commission for Aeronautics (RTCA) Task Force 4, *Recommendations for Improving the Certification of Communication/Navigation Surveillance/Air Traffic Management (CNS/ATM) Systems* (RTCA Task Force 4 Report), Washington, DC, February 26, 1999.
16) CPS Team Interview with United Airlines Personnel, August 2, 2001.
17) Federal Express Briefing, Seattle, WA, October 22, 2001.
18) CPS Team Interview with FAA Repair Stations, BF Goodrich, Aero Controls, August 14, 2001.
19) 14 CFR Subchapter A Part 1: Definitions and Abbreviations.

Observation 1

OEM and Operator maintenance manuals, illustrated parts catalogs (IPC), wiring diagrams, and other documents needed to maintain aircraft in an airworthy configuration after incorporation of service bulletins (SB) and Airworthiness Directives (AD), are not always revised to reflect each aircraft's approved configuration at the time the modifications are implemented.

Airworthiness Directive/ Service Bulletin Information Flow into Field Reference Materials

Maintenance manuals, illustrated parts catalogs (IPCs), wiring diagrams and other FAA accepted or approved manuals are required for continued airworthiness. Incorrect data as a result of delayed revisions to user manuals can result in the release of aircraft into service in a non-airworthy configuration.

Airworthiness directives [20] and service bulletins are not stand-alone documents. These documents usually refer to other documents to provide detailed instructions for accomplishment. Most ADs rely on Service Bulletins, which in turn may reference maintenance manuals, wiring diagrams, or illustrated parts catalog (IPC) information to accomplish the work. This information, which may be referenced in the AD or SB, may not have been revised to the standard assumed in the AD or SB. When SBs are incorporated into an aircraft, the instructions in the SB should be considered for information necessary for the continued airworthiness of the aircraft. During CPS team interviews, it was observed that there is risk that information needed for this continued airworthiness is not always incorporated into the user documents within a reasonable time.

During an interview [21], a situation was cited where a mechanic had used an IPC that had not been revised to reflect the requirements of an AD and resulted in the use of a component not authorized by the AD. The mechanic performing this work used the latest published manual information available. The information did not reflect the AD requirements and there was nothing to alert the mechanic to the fact that this action dealt with an AD modified configuration. This missing information resulted in an installation that was not in compliance with an AD; therefore, the airplane could be considered non-airworthy.

A concern also exists with STC configuration management. An STC approved for incorporation on a fleet type may not consider the wide range of actual aircraft configuration differences within that fleet. The information for continuing airworthiness should be provided for incorporation into the user accepted or approved manuals to assure STC and AD configurations are not altered during routine maintenance.

A process is needed to adequately assure that proper repairs and modifications are implemented and that mandated configurations are not altered. All manuals and documents that are affected by ADs, AMOCs (Alternative Methods of Compliance), STCs, or other authorized documents must be revised to reflect the mandated aircraft design configuration in order to assure continued airworthiness.

This problem has been recognized as critical in the development and acceptance of Extended Range Operations with Two-Engine Aircraft (ETOPS) operations. As a result, for ETOPS aircraft the Configuration, Maintenance, Procedures (CMP) document is a controlling document that is FAA approved. The procedure used for ETOPS operations and maintenance is recognized as an improvement in the ability of an operator to maintain an approved configuration on the aircraft.

Configuration control problems associated with the use of equivalent or substituted parts to AD or AMOC mandated configurations can exist. There are instances of inadvertent parts substitutions within the manufacturer's or operator's material management systems that may result in unapproved configurations being implemented into the aircraft. An improved process is needed for a mandating document to specify areas where manufacturer and operator flexibility is allowed and areas where no flexibility is allowed.

The consequence of a lag in introducing continuing airworthiness information into user manuals is the risk of an aircraft being released into service in a non-airworthy configuration, or an AD or STC required configuration being altered during future maintenance activity.

References

20) 767 Center Fuel Tank Pumps ADs and associated SBs.
21) CPS Team Interviews with PMIs, BF Goodrich Aero Controls, July 18, 2001.

Chapter 5

Safety Oversight Processes

FAA and Industry oversight of the design, manufacture, and operation of commercial aircraft involves a large number of tasks. These oversight tasks are often the basis for the discovery of information used to establish safe practices and processes. Oversight also serves as a means to assess the adequacy of existing standards and requirements.

The FAA's Aircraft Certification Service provides oversight of the continued airworthiness of in-service aircraft. These oversight responsibilities include engine and aircraft certification, the development and management of the Designated Engineering Representative (DER) system, rule making, the validation of foreign engine and aircraft certifications, and, when necessary, the development and issuance of airworthiness directives. FAA's Flight Standards Service oversight responsibilities include the certification of airlines, airmen, mechanics, and repair stations. They also provide continuing oversight of airline operations, training, and maintenance activities.

Industry oversight includes programs used by manufacturers, airlines, and repair stations to review and assess existing processes. Regulatory requirements drive some of the industry oversight processes. However, there are examples of organizations in the industry that have quality assurance programs that exceed those required by the regulations.

Strong and effective industry and FAA oversight processes can be used to identify potential safety problems and accident precursors. The present exceptional commercial aviation safety record can be further enhanced by making improvements in these areas. The DER system, detection of single-point human failures, and industry's internal oversight processes are the subject of findings or observations in this chapter.

Preparation of these findings was based on reviews of relevant requirements and advisory material, case studies, historical reports, presentations by and discussions with operators, the contributions of personnel from large and small maintenance, repair, and alteration companies, FAA Principal Maintenance and Operations Inspectors, and CPS team members.

Finding 14

Consultant Designated Engineering Representative (DERs) have approved designs that were deficient or non-compliant with FAA regulations.

People and Process for Oversight of DERs

The DER system is generally working well. This system has been enhanced by the addition of new processes for selection and annual review of DERs. However, some consultant DER project approvals, which do not require FAA review, combined with the lack of DER and FAA technical expertise in certain specialized fields, have resulted in designs that were deficient or non-compliant with FAA regulations. Contributing to this is the reluctance of some FAA DER advisors to recommend disciplinary action when DERs are found to be working below acceptable standards.

The release of the FAA's Designee Management Handbook, Order 8100.8A in January 2001, provides guidance for the appointment, annual review, and renewal of DERs [1]. The new guidance is a considerable improvement over past practices. It provides a standard structure for appointing and overseeing DER activity, including detailed instructions for termination of DERs. Two categories of DERs exist: company

DERs working for airline, manufacturing, and design organizations; and consultant DERs, working independently. While problems do occur with company DERs, they are usually discovered because the larger engineering pool in place, and by subsequent peer review. Additionally, field service experience is reviewed by these DERs, so they are familiar with problems associated with the design. Consultant and company DERs who work for smaller manufacturers not having large engineering staffs do not have these peer review or field experience processes.

Some consultant DERs have approved designs and data for modifications and alterations that are non-compliant with the regulations. For example, a DER approved passenger-to-freighter conversion was found to be non-compliant with FAA regulations after the aircraft had returned to service [2]. In this instance, the independent DER consulted with an FAA advisor about the STC. However, based on presentations and interviews with experienced FAA engineers involved in the investigation of this conversion, neither the DER nor the advisor had the technical knowledge to make a proper compliance finding.

DERs who have been granted approval authority need not submit their designs to an ACO for review. In the case of the Swissair MD-11 accident, it was a preliminary finding of an FAA Special Certification Review (SCR) team [3] that an independent DER approved a passenger entertainment system that violated the design criteria used by the manufacturer [4]. In this case, the IFE power source was from a bus other than the one that the flight crew would expect, thereby possibly contributing to confusion when trying to isolate a smoke or fumes source using the emergency checklist. It should be noted that the TSB is leading the investigation for this accident and has not completed its work or established a probable cause. In the case of a Boeing 737-900 after market antenna installation, errors were discovered in the analysis assumptions when a review was conducted by aircraft certification engineers [5].

These errors resulted in a DER approved design that did not meet damage tolerance requirements.

The perception of some DER advisors is that disciplining DERs is difficult because of fear of litigation. This misperception has resulted in little, if any, disciplinary action being taken when it may be warranted. A senior FAA attorney interviewed by the CPS team stated that disciplinary action could readily be taken when appropriate.

FAA DER advisor competence is affected by a number of factors. These include experience, education, workload, and the requirement to supervise and review work outside their areas of expertise. In some cases, this may require experience in and detailed knowledge of a subject to do an adequate review, which the DER advisor may not possess. In the case of the passenger-to-freighter conversion cited, the DER advisor did not properly assess the adequacy of the design data when consulted by the DER. As a result, the FAA was not aware that an unsafe condition existed [6].

The commercial aerospace industry could not function effectively or efficiently without DERs. Critical to this system is the assurance, through the FAA's oversight process, that DER approved designs will maintain airworthiness compliance. The experience levels of FAA Aviation Safety Engineers (ASEs) is an important factor in determining the effectiveness of this oversight function. The adequacy of FAA technical competency has been the subject of two previous studies; the National Research Council (NRC) study of 1980 [7], and, more recently, a General Accounting Office (GAO) report in 1993 [8]. A central theme in the NRC study was concern for technical capabilities of the FAA specialists overseeing safety of the commercial fleet. Several recommendations concerned this central issue and concluded that the FAA ". . . must improve the expertise and quality of the technical staff. . . ."

The 1993 GAO report commented on the high turnover rate and low experience level of FAA ASEs in the two FAA ACOs responsible for the majority of commercial transport airplane oversight (Long Beach and Seattle). The turnover rate in ASEs

between 1982 and 1993 was 107%, and in 1993 more than 50% had less than five years FAA experience. To update this information, the turnover rates and experience levels for the Seattle ACO and the New England Engine Certification Office were surveyed during the CPS review. Data gathered for the period from 1993 through 2001 showed that the combined turnover rate remains high at 115%, and, presently, over 50% of the ASEs still have less than five years of FAA experience.

Turnover rates and experience levels are not the only indicators of an organization's technical competence. However, this particular engineering subject area requires years of interdisciplinary exposure to understand the increasingly complex interrelated systems and human factors interfaces of modern aircraft, and to learn from past mistakes that led to accidents. The consistently high turnover rate and associated low experience levels are indicators of the limited time available for ASEs to acquire the necessary experience and to understand and apply accident precursor information.

Enhancing the expertise of the FAA ASEs acting as DER advisors and establishing criteria for accomplishing adequate review of DER approvals has the potential for making significant improvements in the FAA's oversight of all aspects of commercial transport aircraft design, operations, and maintenance.

References

1) Federal Aviation Administration Order 8100.8A, *Designee Management Handbook*, January 30, 2001.
2) FAA presentation to CPS Team on Boeing 727 Passenger to Freight conversion program, April 5, 2001.
3) FAA presentation to CPS team, *Swissair Flight 111 Accident Overview*, February 28, 2001.
4) Swissair passenger entertainment system STC ST00236LA-D.
5) 737-900 after market antenna design STC.
6) AD 98-26-21.
7) National Resource Council, *Improving Aircraft Safety – FAA Certification of Commercial Passenger Aircraft* (The Low Report), Committee Chairman: George Low, Washington, DC, National Academy of Sciences, 1980.
8) GAO Report, GAO/RCED-93-155 Aircraft Certification, *New FAA Approach Needed to Meet Challenges of Advanced Technologies*, September 1993.

Finding 15

Processes to detect and correct errors made by individuals in the design, certification, installation, repair, alteration, and operation of transport airplanes are inconsistent allowing unacceptable errors in critical airworthiness areas.

Detection of Single Point Human Error

For some certification activities there are well-ordered and effective processes; for others, no formal process exists, or existing processes may be ineffective. When effective processes do not exist, individuals working independently have made errors in critical airworthiness areas; some of these errors have resulted in accidents.

The FAA has based safety requirements for transport airplanes on fail-safe, redundant, and damage tolerant design concepts. An important aspect of the fail-safe concept is to eliminate, as far as possible, the dependence on any single system or structural element, the failure of which would cause a hazardous or catastrophic condition (14 CFR §25.1309 and 14 CFR §25.571, and Section 5 of Advisory Circular 25.1309-1A.).

The fail-safe concept is well established and is intended to protect the airplane from single failure; it extends to provide protection from human errors in some areas of airplane design and operation. For example, one reason transport airplanes require two pilots is to allow continued safe operation if one pilot is incapacitated. Criteria for the development of the software used in the most critical aircraft systems (RTCA/DO-178B) recommend that software verification be accomplished by someone other than the software designer.

14 CFR §121.369(b)(2)) requires an independent review or verification of maintenance and alterations by a second qualified person, to ensure the work has been correctly accomplished in areas where a ". . . failure, malfunction, or defect [that could] endanger the safe operation of the aircraft," (hereafter referred to as critical airworthiness areas in this finding).

However, the requirement that these critical airworthiness areas are fail safe from a human error perspective is not well defined; it is

generally not required in the design area, and may not be consistently applied in the maintenance and alteration areas. In commercial aircraft and engine design, where adequate engineering staff exists, redundancy in the oversight of the design generally happens as a result of company policy or organization. However, this redundancy is not required and is not always found when design changes, maintenance, repairs, or alterations involving critical airworthiness areas are accomplished.

An example of where lack of redundancy has adversely affected safety is the Japan Airlines Boeing 747 accident involving improper repair of the aft pressure bulkhead [9]. The engineering drawings for the repair were properly done and the parts were properly manufactured. When difficulty was experienced in installing a part, that part was altered in a manner that did not maintain the integrity of the design. There was no requirement to inspect the work as it was being accomplished or after the repair was complete. A post work inspection could not have detected that a part was altered. The result was a repair that did not maintain the airworthiness of the aircraft and an accident resulted.

Two Boeing 747 aircraft accidents were caused when engines were mounted to their pylons without fuse-pin retaining devices [10,11,12]. The pins worked loose during flight, causing separation of the engine from the airplane in such a manner as to cause an accident.

The British Civil Aviation Authority method of delegating design approval under Joint Aviation Authority Regulation (JAR) 21 has the effect of reducing the chances of single-point human error by delegating authority to organizations, instead of to individuals. The expected result is that having a group responsible for design and certification will be more likely to provide adequate redundancy, reducing the instance of failures as a result of single-point human errors.

Establishing such redundant verification requirements or practices for all work in critical airworthiness areas would improve the overall safety of commercial air carrier operations.

It is very important that such requirements specify that inspections or verifications be accomplished at a time and in a manner when errors can still be detected and corrected. If critical inspection sequences are not specified, improper maintenance work may not be detected.

14 CFR §43.13(b) requires all work be performed to ensure an airplane is returned, after repair, maintenance, or modification, to its original or properly altered configuration. The rule does not specify how this quality of work is to be met or assured. 14 CFR §121.371(c) specifies no person may perform a required inspection if they performed the item of work required to be inspected. Yet, although post-work verification inspection requirements are addressed in a general manner, no specific guidance or definition of the type of work requiring inspection is available. The only requirement is that each airline provide, upon request, a list of the items that have been designated as needing such inspection. The OEM does not participate in developing this list.

For DER approved type design data the same individual that designs the change can approve the change. These DER approved data are submitted to the ACO, but there is no requirement they be reviewed by ACO engineers. DER approval of data used for field approvals (FAA Form 337, *Major Alteration and Major Repairs*) or major repairs, are not required to be submitted to the ACO for review. In this case, the DER creating the design data can also approve the design data.

The FAA and industry have long accepted that single point failures in the design of transport airplanes should be avoided in critical airworthiness areas. The human element (DERs, engineers, maintenance personnel, *etc.*) also affects critical airworthiness areas. By applying the same single point failure philosophy to human error as is applied to aircraft design, the occurrence of accidents caused by the mistakes of a single individual can be reduced.

There are linkages between this finding and Findings 3, 4, and 14.

References

9) Aircraft Accident Investigation Commission Ministry of Transport, *Aircraft Accident Investigation Report (Tentative Translation from Original in Japanese) Japan Air Lines Co., Ltd. Boeing 747 SR-100, JA8119, Gunma Prefecture, Japan, August 12, 1985*, June 19, 1987.
10) FAA-Boeing Briefing, *Pylon to Wing Attachment*, May 2001
11) NTSB, *Northwest Airlines Fuse Pin Accident, NWA 18, Boeing 747, Tokyo, Japan, 9/94* (NTSB DCA94RA037).
12) Air Claims JI990013, Air India Fuse Pin Accident, New Delhi, May 7, 1990 (NTSB SIS-94/02)

Observation 2

Some air carriers do more extensive oversight than others of their in-house and outsourced flight operations and maintenance activities, with major safety and economic benefits.

Oversight Processes and Resources: Industry

Briefings provided by large 14 CFR Part 121 certificated air carrier personnel indicated that when voluntary quality assurance and technical analysis processes are used, significant safety and economic benefits could be realized [13,14]. The effectiveness of these processes was substantiated in interviews with FAA principal inspectors with maintenance and operations oversight responsibilities [15].

14 CFR §121.373, Continuing Analysis and Surveillance System (CASS) mandates one of these quality assurance processes. This regulation requires each certificate holder to establish and maintain a program to monitor the performance and effectiveness of its inspection and maintenance activities and to correct any deficiencies in those activities. The CASS process encompasses organizational, procedural, performance, and record keeping requirements for maintenance and alteration of air carrier aircraft.

Airlines that are the most rigorous in developing and vigorous in applying quality assurance programs get results and, therefore, are the most effective. The Flight Operations Quality Assurance (FOQA) and the Aviation Safety Analysis Program (ASAP) are

examples of air carrier voluntary quality assurance processes that were briefed to the CPS team. Again, operators with these programs and FAA officials responsible for their oversight reported enhanced safety based on the use of information obtain from these programs.

The FAA should encourage all segments of the air carrier industry to enhance their internal analysis processes. It has been suggested that FAA incentives could be considered to influence others in the aviation community to enhance internal and external quality assurance and technical analysis activities.

References

13) Federal Express Briefing, Seattle, WA, October 22, 2001.
14) CPS Team Interview with United Airlines Personnel, August 2, 2001.
15) CPS Team Interview with FAA Principal Maintenance Inspectors (Asian American Airlines PMI and United Airlines PMI), August 15, 2001.

Conclusions

The Certification Process Study evaluated processes associated with the certification, operations, and maintenance of commercial transport airplanes. Particular attention was given to the processes associated with the interfaces between the certification, operations, and maintenance functions as depicted by the arrows in Figure 6.

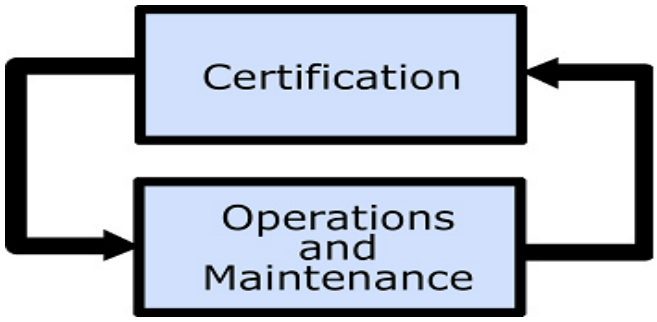

Figure 6. *Certification process study high-Level processes.*

The study identified fifteen findings and two observations in the following categories:

- Safety Assurance Processes
- Aviation Safety Data Management
- Maintenance/Operations/Certification Interfaces
- Major Repairs and Modifications
- Safety Oversight Processes

The team identified four areas of commonality in the findings and observations (this list is not all-inclusive):

Information Flow

Critical information may not be available to those that could act upon it. Organizational barriers to communication, failure to recognize the need to communicate, information overload, and language differences, may all contribute to information flow breakdowns.

Human Factors

Failure to account for the human element is a common thread in accidents. Faulty assumptions, incomplete understanding of tasks, and poor feedback of actual human responses may all contribute to mistakes or failures in the human/machine interface.

Lessons Learned

Significant safety issues learned through accidents are sometimes lost with time and must be re-learned at a very high price. The absence of a comprehensive lessons learned database, general or non-existent requirements, constraints on information sharing, and loss of corporate knowledge may all contribute to problems being repeated.

Accident Precursors

Awareness that certain service incidents are effective indicators of the need for intervention measures requires airplane level safety awareness acquired through both training and experience. Risk management tools and understanding of lessons learned are vital in developing the skills necessary to consistently recognize accident precursor events and initiate corrective actions.

Figure 7 indicates how various other perspectives may be useful in identifying the commonalities among the findings and observations. It must be stressed that the findings and observations in this study are clearly interrelated and should not be addressed in isolation.

Safety Awareness at the Airplane Level

Many of the accidents reviewed during this study followed one or more previous incidents that were not acted upon because those involved in industry and government were unaware of the significance of what they had observed. Often the reason for this lack of awareness was failure to view the significance of the event at the *airplane level*, rather than at the system or subsystem level. This airplane level perspective allows the interface areas to be most apparent, such as human factors considerations of a maintenance task, specific flight crew

procedures necessary for system failure intervention. This is also the attribute of a safety specialist that is most difficult to attain, as it depends to a very large extent on experience of the individual combined with technical capability.

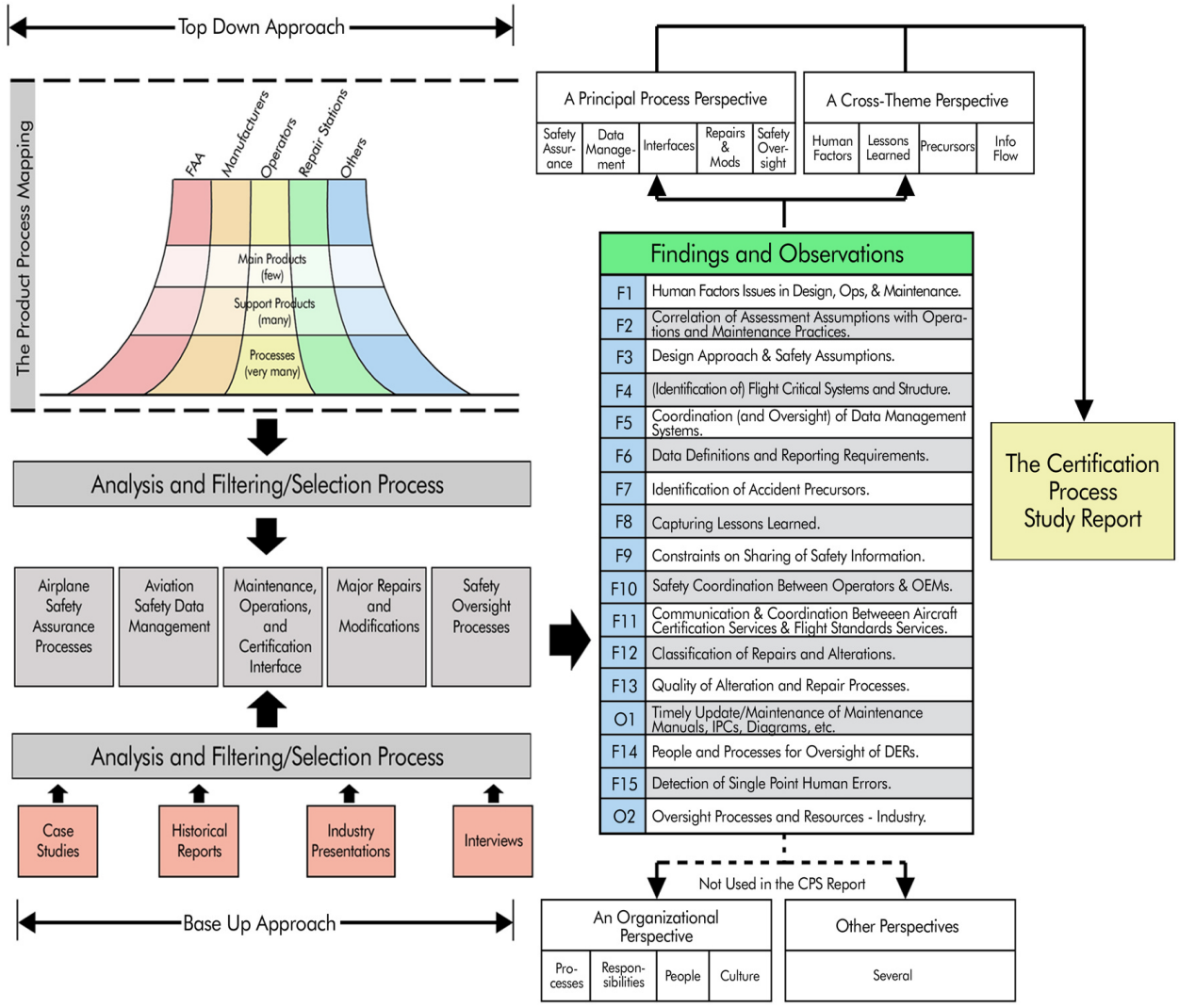

Figure 7. *Other perspectives may provide additional insights.*

Safety awareness at the airplane level is needed for all key safety specialists regardless of their organization, and is achieved by both proper training and adequate experience, as illustrated in Figure 8. Safety initiatives could be better coordinated and more effective if the operator, manufacturer, and FAA could achieve and maintain this level of safety awareness.

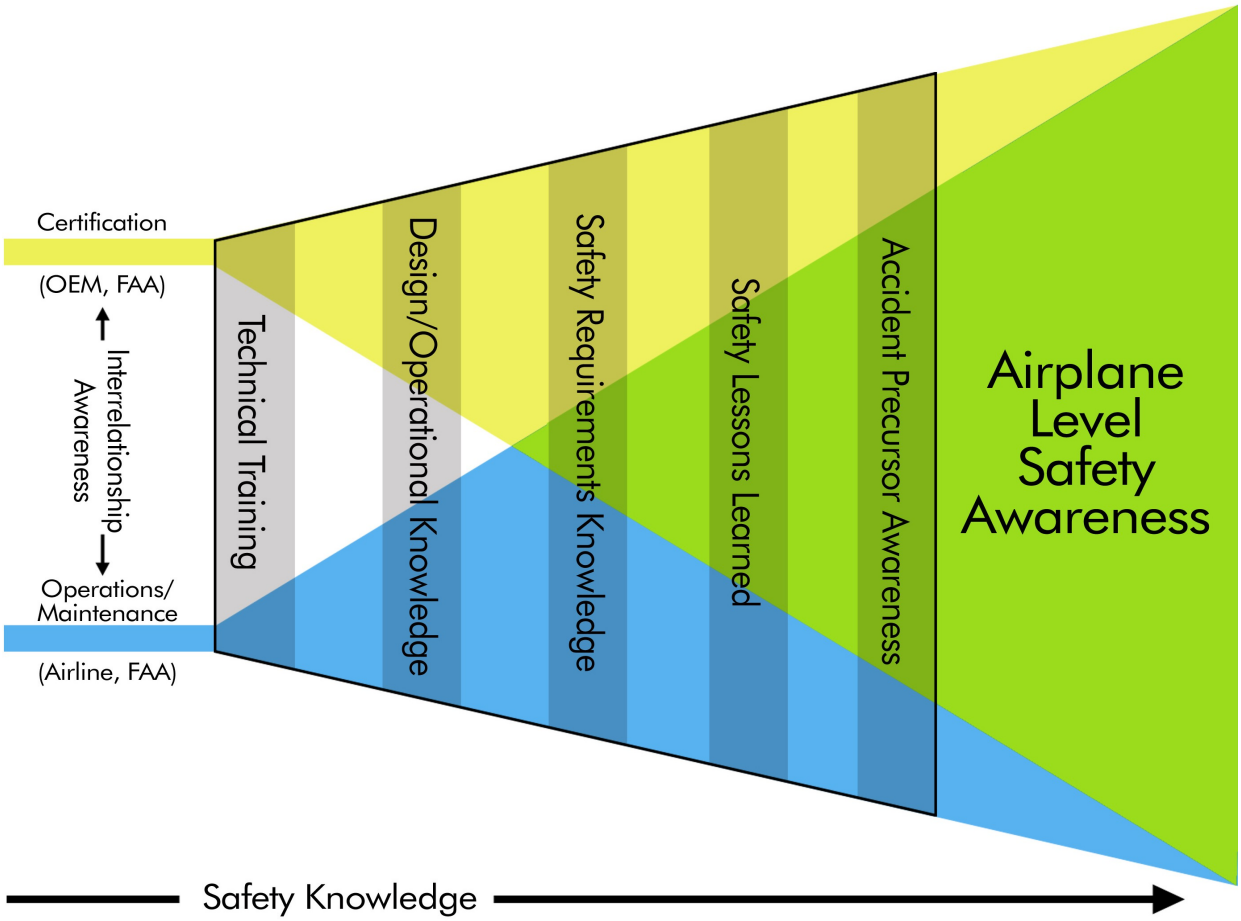

Figure 8. *Evolution toward airplane level safety awareness ideal state*

Cultural Change

Traditional relationships among the regulators and industry have inherent constraints that have, in some cases, limited the ability to effectively identify and act on accident precursors. Further safety improvements will require significant intra- and inter-organizational cultural changes to facilitate a more open exchange of information. Regulatory solutions alone cannot achieve the desired results.

Solutions are Interrelated Among Manufacturer, Operator, and FAA

Improvements to the safety processes identified in this study will require the manufacturer, operator, and FAA to work together with coordinated initiatives (see Figure 9). It will be necessary for each organization to enlist the support of a workforce with the necessary safety knowledge and experience, including expanding knowledge in the major interface areas such as those identified in this study.

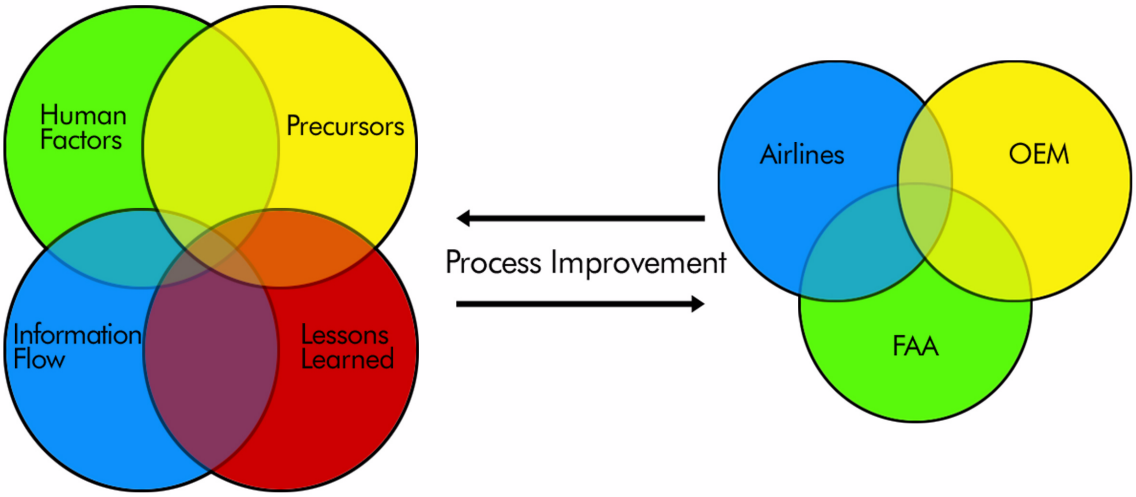

Figure 9. *Solutions are interrelated among manufacturer, operator, and FAA*

From the information gathered during this study, it is clear that process improvements could be applied in certain key areas, particularly those interfaces with safety implications. Process improvements alone will not improve safety unless regulators and industry work together towards this goal. It will require personnel with special skills, knowledge, and experience to recognize lessons learned and accident precursors, and to properly apply risk management tools and techniques.

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Appendices

Appendix A	Study Charter
Appendix B	Summary of CPS Findings and Observations
Appendix C	Historical Reports, Case Studies, Interviews, and Presentations
Appendix D	Study Team

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Appendix A

Study Charter

Team Sponsor Associate Administrator for Regulation and Certification

Background The safety of large transport airplanes operating in commercial service throughout the world has steadily improved over the last several decades. Currently, commercial air travel within the US is the safest form of mass transportation available, annually moving millions of passengers with a convenience never imagined even a generation ago. Nevertheless, although rare, accidents still occasionally occur. When they do occur, it is important to identify the cause(s) of these accidents so that appropriate steps may be taken to reduce the risk of their reoccurrence. One major safety initiative is Safer Skies, whereby past accident types are reviewed for root cause analysis, future safety hazards are identified, and specific safety interventions are identified and implemented. The FAA also considers that it is important to periodically examine the overall processes that are being applied during the airplane's certification activities, and evaluate how these activities interrelate to the in-service operation and maintenance of the airplane. The FAA believes that periodic review of these processes is necessary in order to maintain and continuously improve upon the high level of safety now achieved by commercial aviation in the US. This review, intended as a separate but complimentary effort to Safety Skies, will study the processes and procedures that are currently being applied during the various activities associated with the airplane certification programs, and to examine how these activities interrelate to the maintenance and operation programs that are being applied in service.

Objective

The team is being formed to conduct a comprehensive review of the processes and procedures associated with the aircraft certification activities of transport airplanes from the beginning of the original type certificate activity through the continued airworthiness certification processes intended to maintain the safety of the airplane fleet. Special emphasis will be placed upon analyzing how the various major certification processes in the airplane's life cycle relate to each other, and to evaluate the relationship between these certification processes and the maintenance and operating processes being applied in service. This will include a review of the certification methods, analytical tools, and policies being applied during the various stages of the airplane certification programs that are intended to establish and maintain the safety of the airplane throughout its operational life. Processes for assessing the effects of single, multiple, common cause, and cascading failure modes will also be evaluated during the study. The objective of this effort is to assess the adequacy of the various certification processes that are currently in place throughout the airplane's service life, and, if appropriate, to identify opportunities for process improvements.

Team Tasks

The study will involve three major phases:

Phase One– Information Gathering

This portion of the study will involve the identification and assembling of all of the major processes, procedures, and policies that are being applied during the aircraft certification activities throughout the various stages of the service life of a commercial transport airplane. This "mapping out" phase will begin by the identification and review of certain relevant aviation studies that were previously conducted which evaluated various aspects of commercial aircraft certification processes and procedures. This historical review will be followed by the identification and assembly of the major certification processes being applied during the original airplane certification activities, initial introduction into service, initial maintenance and operation programs, and how these programs and processes evolve throughout the airplane's service life. Special emphasis will be given to those processes and policies that concern the safety analysis methods, and the processes currently being used to

establish initial and ongoing maintenance and operating programs. The objective of this activity will be to identify all of the various processes currently being applied during the certification programs in order to permit their later analysis in determining how these various elements of the aircraft certification processes "fit together". Additionally, phase one will conclude by the identification and assembling of information involving several (five or six) incidents or accidents, which are selected for their significance relative to processes involving aircraft certification, maintenance and operational interrelationships.

Phase Two– Information Analysis

This portion of the study will involve the analysis of the information that is gathered in phase one. The objective of this analysis is to evaluate the various processes, how they interrelate from a functional and objective standpoint, and to identify areas where process improvements may be justified. In the cases where processes have measurable outcomes, metrics for determining their effectiveness will be applied and analyzed where appropriate. The previous historical studies that were identified during phase one will be analyzed for their relevance to current processes and practices. Findings from these studies will be evaluated relative to current processes and practices that have been implemented since the earlier studies were conducted. Finally, the accident and incident "case studies" identified in phase one will be analyzed with respect to their process significance. Areas involving process issues will be evaluated against current processes and practices in order to identify possible opportunities for improvement. Throughout the "case study" analysis activity of phase two, the team will continue to consider any relevant findings contained in the corollary certification studies which were identified during phase one for additional guidance or insight in assessing the overall certification processes. Similar to the objective of phase one of this study, the purpose of the historical review and case study activity of phase two is to assess the certification processes being applied, and to evaluate their effectiveness.

Phase Three– Report Writing

This portion of the study will involve documenting the analysis, observations and findings of the first two phases into a final report. Included in this report will be the analysis, findings, and

observations associated with the certification processes being applied during the current transport airplane “life cycle”, and to evaluate how these various processes “fit together” in the area of design, maintenance and operation throughout the service life of the airplane.

Product

The deliverable is a report, to be submitted to the FAA Administrator, documenting the analysis, findings, and observations of the team's review.

Membership

The Commercial Airplane Certification Process Study team will include representatives with appropriate technical background from the US aviation industry, NASA, DoD, ALPA, and academia. Also represented will be a major non-US manufacturer and a non-US independent airworthiness consultant with experience of certification in foreign countries as well as in the USA. The FAA will serve as chairman of the study team and will functionally report to the Manager of the Transport Airplane Directorate and administratively report to the Manager of the Seattle Aircraft Certification Office.

Oversight

The direction, activity, and progress of the study team will be monitored by an Oversight Board, with membership from appropriate executive positions within industry, government, and academia.

Schedule

The team will commence their study in January 2001, and will deliver its final report to the FAA Administrator by January 2002.

Approval of Charter

Tom McSweeny
Associate Administrator
for Regulation and Certification

4-19-2001
Date

Mac Armstrong

Bob Davis

John Goglia

Lou Mancini

Daniel Schrage

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Appendix B

Summary of CPS Findings and Observations

Focus Area	Category	Findings and Observations	
Airplane Safety Assurance Processes	Human Factors Issues in Design, Operations, and Maintenance	**Finding 1**	*Human performance is still the dominant factor in accidents:* • *The processes used to determine and validate human responses to failure and methods to include human responses need to be improved.* • *Design techniques, safety assessments, and regulations do not adequately address the subject of human error in design or in operations and maintenance.*
	Correlation of Safety Assumptions with Operations and Maintenance Practices	**Finding 2**	*There is no reliable process to ensure that assumptions made in the safety assessments are valid with respect to operations and maintenance activities, and that operators are aware of these assumptions when developing their operations and maintenance procedures. In addition, certification standards may not reflect the actual operating environment.*
	Robust Safety Assessments and Design for Critical Functions	**Finding 3**	*A more robust approach to design and a process which challenges the assumptions made in the safety analysis of flight critical functions is necessary in situations where a few failures (2 or 3) could result in a catastrophic event.*
	Flight Critical Systems and Structure	**Finding 4**	*Processes for identification of safety critical features of the airplane do not ensure that future alterations, maintenance, repairs, or changes to operational procedures can be made with cognizance of those safety features.*
Aviation Safety Data Management	Coordination of Data Management Systems	**Finding 5**	*Multiple FAA-sponsored data collection and analysis programs exist without adequate inter-departmental coordination or executive oversight.*
	Data Definition and Reporting Requirements	**Finding 6**	*Basic data definition and reporting requirements are poorly defined relative to the needs of analysts and other users.*
	Identification of Accident Precursors	**Finding 7**	*There is no widely accepted process for analyzing service data or events to identify potential accident precursors.*

Focus Area	Category	Findings and Observations	
Maintenance/ Operations/ Certification Interfaces	Capturing the Lessons Learned From Design, Manufacturing, Maintenance, and Operating Experience	**Finding 8**	*Adequate processes do not exist within the FAA or in most segments of the commercial aviation industry to ensure that the lessons learned from specific experiences in airplane design, manufacturing, maintenance, and flight operations are captured permanently and made readily available to the aviation industry. The failure to capture and disseminate lessons learned has allowed airplane accidents to occur for causes similar to those of past accidents.*
	Constraints on the Sharing of Safety Information	**Finding 9**	*There are constraints present in the aviation industry that have an inhibiting effect on the complete sharing of safety information.*
Maintenance/ Operations/ Certification Interfaces (Cont.)	Maintenance and Operational Safety Recommendations and Feedback Between Operators and OEMs	**Finding 10**	*There are currently no industry processes or guidance materials available which ensure that:* • *Safety related maintenance or operational recommendations developed by the OEM are evaluated by the operator for incorporation into their maintenance or operational programs; and* • *Safety related maintenance or operational procedures developed or modified by the operator are coordinated with the OEM to ensure that they do not compromise the type design safety standard of the airplane and its systems.*
	Communication and Coordination Between Aircraft Certification Service and Flight Standards Service	**Finding 11**	*The absence of adequate formal business processes between FAA Aircraft Certification Service and Flight Standards Service limits effective communication and coordination between the two that often results in inadequate communications with the commercial aviation industry.*

Focus Area	Category	Findings and Observations	
Major Repairs and Modifications	Classification of Repairs and Alterations	**Finding 12**	*The airline industry and aircraft repair organizations do not have a standardized process for classifying repairs or alterations to commercial aircraft as "Major" as prescribed by applicable Federal Aviation Regulations (FARs).*
	Quality of Alterations and Repair Processes	**Finding 13**	*Inconsistencies exist between the safety assessments conducted for the initial type certificate (TC) of an airplane and some of those conducted for subsequent alterations to the airplane or systems. Improved FAA and industry oversight of repair and alteration activity is needed to ensure that safety has not been compromised by subsequent repairs and alterations.*
	Airworthiness Directive/Service Bulletin Information Flow to Field Reference Materials	**Observation 1**	*OEM and operators' maintenance manuals, illustrated parts catalogs (IPC), wiring diagrams, and other documents needed to maintain aircraft in an airworthy configuration after incorporation of service bulletins (SB) and airworthiness directives (AD), are not always revised to reflect each aircraft's approved configuration at the time the modifications are implemented.*
Safety Oversight Processes	People and Process for Oversight of DERs	**Finding 14**	*Consultant DERs have approved designs that were deficient or non-compliant with FAA regulations.*
	Detection of Single Point Human Error	**Finding 15**	*Processes to detect and correct errors made by individuals in the design, certification, installation, repair, alteration, and operation of transport airplanes are inconsistent allowing unacceptable errors in critical airworthiness areas.*
	Oversight Processes and Resources: Industry	**Observation 2**	*Some air carriers do more extensive oversight than others of their in-house and outsourced flight operations and maintenance activities, with major safety and economic benefits.*

Appendix C

Historical Reports, Case Studies, Interviews, and Presentations

Historical Reports

Special Subcommittee on Investigations of the Committee on Interstate and Foreign Commerce, *Air Safety: Selected Review of FAA Performance* (The Staggers' Report), Committee Chairman: Harley O. Staggers, Washington DC, U.S. Government Printing Office, January 1975.
National Resource Council, *Improving Aircraft Safety - FAA Certification of Commercial Passenger Aircraft* (The Low Report), Committee Chairman: George Low, Washington, DC, National Academy of Sciences, 1980.
Dr. McLucas, Drinkwater III, Fred J., and LtGen Leaf, Howard W., *Report of the President's Task Force on Aircraft Crew Complement*, Chairman: Dr. John L. McLucas, July 2, 1981.
GAO Report, GAO/RCED-92-179 Aircraft Certification, *Limited Progress on Developing International Design Standards*, August 1992.
GAO Report, GAO/RCED-93-155 Aircraft Certification, *New FAA Approach Needed to Meet Challenges of Advanced Technologies*, September 1993.
GAO Report, GAO/RCED-96-193 Aviation Safety, *FAA Generally Agrees With But Is Slow In Implementing Safety Recommendations*, September 1996.
GAO Report, GAO/RCED-98-21 Aviation Safety, *FAA Oversight of Aviation (Delete) Repair Stations Needs Improvement*, October 1997.
National Resource Council, *Improving the Continued Airworthiness of Civil Aircraft - A Strategy for the FAA's Aircraft Certification Service*, Committee Chairman: James G. O'Connor, Washington, DC, National Academy Press, 1998.
Enders, John H., Dodd, Robert S., and Fickeisen, Frank, Flight Safety Foundation, *Continuing Airworthiness Risk Evaluation (CARE): An Exploratory Study* (The CARE Report), Flight Safety Foundation, September-October 1999.
Radio Technical Commission for Aeronautics (RTCA) Task Force 4, *Recommendations for Improving the Certification of Communication/Navigation Surveillance/Air Traffic Management (CNS/ATM) Systems* (RTCA Task Force 4 Report), Washington, DC, February 26, 1999.

Table 2. Accident/Incident Case Study List

Airline	Airplane	Location	Date	Event Report No.
UAL 266*	Boeing 727	Los Angeles, CA	1-18-69	NTSB SA 413-1-0004 AAR-70-06
ComAir 3272	Embraer-120RT	Monroe, MI	1/09/97	NTSB/AA98-04 DCA97MA017
Air India 855	Boeing 747-237B	Arabian Sea	1/1/78	AirClaims J1978001
Air Florida 90*	Boeing 737-200	Washington, DC	1/13/82	NTSB/AAR-79-17 AAR-82-8
Air Inter 148	A320	Strasbourg	1/20/92	Bureau Enquetes-Accidents F-ED920120
Alaska Air 261	MD-83	Pt. Mugu, CA	1/31/2000	NTSB Safety Recommendation A-01-41 to 48, 10/1/01
British Midland Airways 92	Boeing 737-400	Kegworth, UK	1/8/89	AAIB Report No. 4/90 (EW/C1095)
Aeroperu 603	Boeing 757	Pasamayo, Peru	10/02/96	DCA97RA001
TAM 402	F-100	Sao Paulo, Brazil	10/13/96	NTSB DCA97WA004
Simmons 4184	ATR 72-212	Roselawn, IN	10/31/94	NTSB/AAR-96-02 DCA95MA001
El Al 1862	Boeing 747	Amsterdam, Netherlands	10/4/92	AirClaims J1993008
UAL 277*	Boeing 727	Salt Lake City	11/11/65	CAB SA-388 File No. 1-0032

*Denotes an accident for which a presentations was made to the CPS team.

Codes used in Event Report No. column:
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Airline	Airplane	Location	Date	Event Report No.
National Airlines 27*	DC-10-10	Albuquerque, NM	11/3/73	NTSB/AAR-75-2
PAA 160	Boeing 707-321C	Boston, MA	11/3/73	NTSB/AAR-74-16
NWA 6231	Boeing 727	Thiells (Near Bear Mountain), NY	12/1/74	NTSB/AAR-75-13
Air Canada 646	CL600-2B19 Regional Jet	Fredericton, New Brunswick, Canada	12/16/97	TSB Canada Report A97H0011
AAL 965	Boeing 757-200	Cali, Columbia	12/20/95	NTSB DCA96RA020
China Air 358	Boeing 747	Taiwan	12/21/91	Air Claims J1992042
Korean Airlines 8509	Boeing 747-100	Stansted, UK	12/22/99	UK AAIB Special Bulletin No. S2/2000
Transavia HV 462	Boeing 757-200	Amsterdam, Netherlands	12/24/97	Dutch Transportation Safety Board Final Report 97-75/A-26
America West	Boeing 737-200	Tucson, AZ	12/30/89	NTSB LAX90FA061
PAA 214*	Boeing 707-121	Elkton, MD	12/8/63	CAB SA-376 File No. 1-0015
Pacific Western Airlines 314*	Boeing 737-200	Cranbrook, British Columbia, Canada	2/11/78	TSB Canada A78H0001
Air Transport International 805	DC-8-63	Swanton, OH	2/15/92	NTSB DCA92MA022
Continental Airlines 1943	DC-9-32	Houston, TX	2/19/96	NTSB FTW96FA118
Birgenair 301	Boeing 757	Dominican Republic	2/6/96	NTSB DCA96RA030

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Airline	Airplane	Location	Date	Event Report No.
NWA 710*	L-188	Cannelton, IN	3/17/60	CAB SA 354 File No. 1-0003
Continental 795	MD-82	Flushing, NY	3/2/94	NTSB DCA92MA038 AAR-95-01
THY 981*	DC-10	Paris, France	3/3/74	ICAO Circular 132-AN/93 (116-125)
UAL 585	Boeing 737	Colorado Springs, CO	3/3/91	NTSB/AAR-01-01 DCAP1MA023
JAL 46E	Boeing 747	Anchorage, AK	3/31/93	NTSB DCA93MA033
NWA 18	Boeing 747	Tokyo, Japan	3/94	NTSB DCA94RA037
China Airlines B1816	Airbus A300B4-622R	Nagoya, Japan	4/26/94	Accident Investigation Commission of Japan Report 96-5, July 19, 1996, Translation from University of Beilefeld, FRG, by Peter Ladkin and Hirshi Sogame
Aloha 243	Boeing 737-200	Maui, Hawaii	4/28/88	NTSB DCA88MA054
China Eastern Airlines 583	MD-11	Aleutians	4/6/93	NTSB/AAR-93-07 DCA93MA037
Philippine Airlines PR143	Boeing 737	Manila, Philippines	5/11/90	AirClaims J1990014
Valujet 592	DC-9	Miami, FL	5/11/96	NTSB DCA96MA054
Dan-Air	Boeing 707	Lusaka, Zambia	5/14/77	AAIB Report 9/78 (EW/A267)
AAL 191*	DC-10	Chicago, IL	5/25/79	NTSB/AAR-79-17
Lauda Air NG 004	Boeing 767-300ER	Thailand	5/26/91	Report issued by the Aircraft Accident Investigation Committee of Thailand, CAB approved July 21, 1993

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Airline	Airplane	Location	Date	Event Report No.
Zantop International Airlines 931	L-188	Chalkhill, PA	5/30/84	NTSB DCAA84AA024
EAL 855	L-1011	Miami, FL	5/5/83	NTSB/AAR-84-04
Air India 132*	Boeing 747-200 (Strut Issue)	New Delhi, India	5/7/90	AirClaims J1990013
Air Canada 797	DC-9	Cincinnati, OH	6/2/83	NTSB/AAR-86-02
Delta	Boeing 767	New York	6/25/96	NTSB NYC961A131
DAL	Boeing 767	Los Angeles, CA	6/30/87	FAA Incident Data System 19870630040879
AAL 96*	DC-10	Detroit, MI	6/72	NTSB/AAR-73-2
TWA 800	Boeing 747-100	East Moriches, NY	7/17/96	NTSB/AAR-00-03 DCA96MA070
UAL 232	DC-10	Sioux City, IA	7/19/89	NTSB DCA89MA063 AAR-90-06
TWA 843	L-1011	JFK Airport, NY	7/30/92	NTSB DCA92MA044 AAR-93-02
FedEx 14	MD-11	Newark, NJ	7/31/97	NTSB/AAR-00-02 DCA97MA055
JAL 123	Boeing 747SR	Gunma Prefecture, Japan	8/12/85	Presentation to CPS team on 4/27/01 AA1 Report 6/19/87 (Tentative translation from Japanese)
British Airtours KT28M*	Boeing 737-200	Manchester, UK	8/22/85	AAIB Report 8/88
Fine Air 101	DC-8	Miami, FL	8/7/97	NTSB/AAR-98-02

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Swissair 111	MD-11	Peggy's Cove Halifax, Nova Scotia, Canada	9/2/98	briefing to CPS on 3/1/01
Braniff 542*	L-188	Buffalo, TX	9/29/59	CAB SA-348
Midwest Express Airlines 105	DC-0-14	Milwaukee, WI	9/6/85	NTSB DCA85AA036
US Air 427	Boeing 737-300	Aliquippa, PA	9/8/94	NTSB/AAR-99-01 DCA94MA076

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TSB = Transportation Safety Board
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Interviews and Presentations

Interviews

CPS Team Interview with FAA, *ANM230 Briefing*, July 18, 2001.
CPS Team Interview with FAA SEA FSDO, *Principal Maintenance Inspector for Small Repair Station*, July 18, 2001.
CPS Team Interview with FAA SEA FSDO, *Principal Maintenance Inspector for Large Repair Station*, July 18, 2001.
CPS Team Interviews with United Airlines Personnel, August 2, 2001.
CPS Team Interview with FAA AFS-230, *Aviation Safety Action Program (ASAP) and Flight Operations Quality Assurance (FOQA) Program*, August 6, 2001.

CPS Team Interview, *National Aviation Safety Data Analysis Center (NASDAC)*, August 7, 2001.
CPS Team Interview with FAA Repair Stations BF Goodrich, Aero Controls, August 14, 2001.
CPS Team Interview with United Airlines Principal Operations Inspector, *Discussion of Oversight Function*, August 15, 2001.
CPS Team Interview with FAA Principal Maintenance Inspectors, August 15, 2001.
CPS Team Interview with Senior Engineer in FAA Certification Office, *DER Oversight*, August 15, 2001.
CPS Team Interview with FAA ATL ACO, August 17, 2001.
CPS Team Interview, *SPAS*, September 20, 2001.

Presentations

Certification of Aircraft and Aircraft Products, February 27, 2001.
FAA Seattle Aircraft Certification Office Continued Operational Safety Program, February 27, 2001.
Boeing Safety Process Overview, February 27, 2001.
Advanced Avionics Certification Process & Future Directions - Communication, Navigation, Surveillance (CNS), February 27, 2001.
Alaska Flight 261 Accident Overview, February 28, 2001.
SwissAir Flight 111 Accident Overview, February 28, 2001.
FSB/FOEB/MRB Process, March 1, 2001.
Flight Operations Programs, March 1, 2001.
Maintenance Review Board Process, March 1, 2001.
Maintenance Program Philosophy & Policy - MSG-3, March 1, 2001.
Improved Safety Through Coalescence of Operations and Certification Realities, April 3, 2001.
USAir Flight 427 Accident Overview, April 4, 2001.
TWA 800 Accident and Certification Lessons, April 4, 2001.

Air Carrier Accident Data Review: A Review of Pilot Ability to Assess Inflight Icing Hazards, April 5, 2001.
Air Carrier Accident Data Review: Certification Section, ALPA Submission to NTSB on the Investigation of TWA 800, April 5, 2001.
Status of STC Cargo Conversion Activity, April 5, 2001.
Airline Maintenance Process—MRB/MPD Processing, April 6, 2001.
Japan Airlines Flight 123 Accident Overview, April 30, 2001.
Air Transport Association Specification 111 "Airworthiness Concern Coordination Process" *and* "Enhanced Airworthiness Program for Airplane Systems," April 30, 2001.
*Fuel Boost Pump Issue*s, May 1, 2001.
Boeing 747 Strut to Wing Attachment, May 1, 2001.
Flight Standards Audit Programs, May 22, 2001.
Safer Skies - A Focused Agenda, June 25, 2001.
FAR 25/33 Safety Presentations, Flight: Airplane Performance, Stability and Control, Related Support, June 26, 2001.
FAR 25/33 Safety Presentations, Structures: Loads, Design and Construction, June 26, 2001.
FAR 25/33 Safety Presentations, Equipment: General, Mechanical, June 26, 2001.
FAR 25/33 Safety Presentations, Equipment: Electrical, Avionics, June 26, 2001.
FAR 25/33 Safety Presentations, Propulsion: Engine/APU, June 26, 2001.
FAR 25/33 Safety Presentations, Propulsion: Engine Installation, June 26, 2001.
FAR 25/33 Safety Presentations, Cabin Safety, June 26, 2001.
FAR 25/33 Safety Presentations, Human Factors, June 26, 2001.
Delegation Processes, July 17, 2001.
National Aviation Safety Data Analysis Center (NASDAC), July 19, 2001.
Global Aviation Information Network, August 7, 2001.

FAA Data Systems, August 14, 2001.
Status of FAR Part 145, August 14, 2001.
FAA Databases on Continued Operational Safety, August 14, 2001. *Certification Oversight Safety Program (COSP)*, August 15, 2001.
Boeing Safety Process Overview, August 15, 2001.
Boeing Safety Philosophy, August 15, 2001.
FAA Legal Overview, August 16, 2001.
American Airlines ASAP Program, August 16, 2001.
FedEx Air Operations Division Aircraft Quality Assurance, October 22, 2001.

Appendix D

CPS Study Team

Oversight Board Members

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Alan Gurevich	*FedEx Pilots' Association*
David Harrington	*Airbus*
Dick Innes	*Air Line Pilots' Association*
Rod Lalley	*Federal Aviation Administration*
John Lapointe	*Federal Aviation Administration*
Hals Larsen	*Federal Aviation Administration*
Chet Lewis	*Federal Aviation Administration*
Dale Mason	*Airbus*
Jim McWha	*Boeing Consultant*
Thomas Morgan	*Department of Defense*
Tom Newcombe	*Federal Aviation Administration*
Lee Nguyen	*Federal Aviation Administration*
Brian Perry	*International Airworthiness Consultant*
John Powers	*United Airlines*
Brian Prudente	*Federal Aviation Administration*
Patrick Safarian	*Federal Aviation Administration*
Mike Smith	*Delta Air Lines Consultant*
Ivor Thomas	*Federal Aviation Administration*
James Treacy	*Federal Aviation Administration*
Randy Wallace	*Delta Air Lines Consultant*
Paul Werner	*Sandia National Laboratories*
Brian D. Will	*American Airlines*
Julie Zachary	*Federal Aviation Administration*

Glossary

Definitions

Aviation Safety Action Program (ASAP)

These programs are intended to provide air carriers with the opportunity to identify and report safety issues to management and the FAA for resolution without fear of punitive legal enforcement action being taken. These programs are designed to encourage participation from employee groups such as flight crewmembers, mechanics, flight attendants, and dispatchers. For example, a partnership between American Airlines, the pilots' union, and the FAA encourages pilots to anonymously disclose safety problems for the purpose of sharing information. It is designed to identify and to reduce or eliminate possible flight safety concerns, as well as minimize deviations from the regulations.

Aviation Safety Reporting System (ASRS)

Administered by NASA for the FAA, the ASRS receives, processes, analyzes, interprets, and reports safety data provided voluntarily by pilots, controllers, flight attendants, mechanics, and other users of the national airspace system. Reports may not be used for enforcement action by the FAA. The database information may be considered for making systemic safety changes.

Continued Operational Safety Program (COSP)

FAA-Boeing partnership initiative that implement the *COS Working Agreement* on October 1, 1999, to accomplish the following:

- In-service events are screened by Boeing service engineering for reportable events. The list of events to be reported goes beyond FAR 21.3 requirements in accordance with the *COS Working Agreement*.

- Event reports are submitted by Internet file transfer and loaded into ACO database daily. The events are distributed and tracked within the FAA from event to closure or AD issuance.

FAA Chief Information Office (AIO-1)

The FAA operates or develops over 640 information systems as part of carrying out its mission. The FAA must decide which information systems to buy off the shelf, which to develop and build, which to retire, and which to upgrade, and then smartly execute those decisions. The main focus of this office is to implement new management techniques to improve these critical investment decisions, and help manage them more effectively so as to receive maximum value for our scarce investment dollars.

Damage Tolerance

The attribute of the structure that permits it to retain its required residual strength for a period of use after the structure has sustained a given level of fatigue, corrosion, or discrete source damage.

Flight Operational Quality Assurance (FOQA)

FOQA programs would give the FAA access to in-flight recorded data collected by airlines to improve safety in the following areas: flight crew performance; training; air traffic procedures; airport maintenance and design; and aircraft operations and design. Airline participation is voluntary. The FAA, labor, and industry are working with NASA Ames on research and development. A model program has been initiated with some major airlines.

Global Aviation Information Network (GAIN)

GAIN is designed to help the aviation industry prevent accidents by making safety information available to aviation professionals worldwide who can use it to improve safety. By learning more about potential problems, the GAIN participants can use the information to address problems proactively. Actions could include pilot training, procedural changes to manuals, modifications to air traffic control procedures, changes to maintenance or manufacturing procedures, and design changes. The privately owned and operated international system will draw from various worldwide aviation information sources.

Metadata

Metadata is the information that provides the unique identification of the data itself, a data fingerprint, and is used to

facilitate data retrieval.

National Aviation Safety Data Analysis Center (NASDAC) — The NASDAC is an automated support capability that enables users to apply powerful state-of-the-art analysis tools to an integrated database containing safety data from multiple sources. The NASDAC database currently includes data from over 20 source systems. A walk-in NASDAC facility is open in the FAA Headquarters building.

Program Tracking and Reporting System (PTRS) — The PTRS system is a database management tool that is designed to record certain work activities in the Aviation Safety Program to assist program analysis and future planning. It provides a database to indicate geographic areas, organizations, and operators who have supported or have been supported by the safety program within the previous three years.

Safety Performance Analysis System (SPAS) — SPAS is a computer-based system designed to help inspectors identify potential safety risks by tracking the performance of operators, aircraft, and personnel.

Service Difficulty Reports — Title 14 Code of Federal Regulations requires that holders of certificates issued under part 121, 125, 127, or 135 submit reports on certain specified failures, malfunctions, or defects of specific systems and on all other failures, malfunctions, or defects that, in the opinion of the certificate holder, have endangered or may endanger the safe operation of an aircraft. Certificated domestic and foreign repair stations are also required to report defects or recurring unairworthy conditions on any aircraft, powerplant, propeller, or any component thereof to the FAA.

Stovepiping — The concept of stovepiping is derived from a factory setting, where separate ovens are burning fuel and emitting smoke and heat. Each stovepipe is a separate and distinct operation from the beginning of its process until the work cycle has been completed. In the context of this report, stovepiping is a euphemism for holding onto information or the absence or lack of coordination and communication among various functional lines of business.

Acronyms

AAIB	Air Accidents Investigation Branch
AAL	American Air Lines
AASIS	Aviation Safety Information System
AAWG	Airworthiness Assurance Working Group
AC	Advisory Circular
ACO	Aircraft Certification Office
ACSEP	Aircraft Certification System Evaluation Program
AD	Airworthiness Directive
ADI	Attitude Director Indicator
AECMA	European Aerospace Industry Association
AEG	Aircraft Evaluation Group
AFM	Airplane Flight Manual
AFS	FAA Flight Standards Service
AIA	FAA Office of International Aviation; Aircraft Industries Association
AIO	FAA Office of Information Services/Chief Information Officer (CIO)
AIR	FAA Aircraft Certification Service
ALPA	Air Line Pilots' Association
AMOC	Alternative Method of Compliance
AOA	Angle of Attack
AOM	Airplane Operating Manual
APU	Auxiliary Power Unit
ARAC	Aviation Rulemaking Advisory Committee
ARM	FAA Office of Rulemaking
ARP	Aerospace Recommended Practice
ASA	Alaska Airlines
ASAP	Aviation Safety Action Program
ASRS	Aviation Safety Reporting System
ASY	FAA Office of System Safety
ATA	Airline Transport Association
ATC	Air Traffic Control
ATR	Automatic Thrust Restoration; Avions de Transport Regional
ATS	Air Traffic Services
BASIS	British Airways Safety Information System
BMA	British Midland Airways
CAA	Civil Aviation Authority
CAAM	Continued Airworthiness Assessment Methodologies
CAB	Civil Aeronautics Board
CAB BUS	Cabin system electric bus

CACPS	Commercial Airplane Certification Process Study
CAR	Civil Air Regulation
CARE	Continuing Airworthiness Risk Evaluation
CAS	Continuing Analysis and Surveillance
CCA	Common Cause Analysis
CFR	Code of Federal Regulations
CIO	Chief Information Officer
CMP	Configuration Maintenance Program
CNS/ATM	Communication/Navigation/Surveillance/Air Traffic Management
COSP	Continued Operational Safety Program
COTS	Commercial Off-the-Shelf
CPS	Commercial Airplane Certification Process Study
DAL	Delta Air Lines
DAR	Designated Airworthiness Representative
DBMS	Database Management System
DER	Designated Engineering Representative
DoD	Department of Defense
DOT	Department of Transportation
DSG	Design Service Goal
EEC	Electronic Engine Control
EIA	Evergreen International Airlines
ETOPS	Extended Range Operations with Two-Engine Aircraft
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FCOM	Flight Crew Operating Manual
FCS	Flight Control System
FHA	Functional Hazard Assessment
FL	Flight Level
FMEA	Failure Modes and Effects Analysis
FMS	Flight Management System
FOCA	Switzerland Federal Office for Civil Aviation
FOEB	Flight Operations Evaluation Board
FOIA	Freedom of Information Act
FOQA	Flight Operational Quality Assurance
FSAT	FAA Flight Standards Information Bulletin for Air Transportation
FSF	Flight Safety Foundation
FSM	Flight Standards Manual
FTA	Fault Tree Analysis

GAIN	Global Aviation Information Network
GAO	General Accounting Office
GPWS	Ground Proximity Warning System
HBAW	FAA Handbook for Airworthiness
HIRF	High Intensity Radiated Field
HPC	High Pressure Compressor
HPT	High Pressure Turbine
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICTS	Ice Contaminated Tailplane Stall
IFE	In-flight Entertainment
IFEN	In-flight Entertainment
INS	Inertial Navigation System
IPC	Illustrated Parts Catalog
IT	Information Technologies
JAA	Joint Aviation Authorities
JAL	Japan Airlines
JAR	Joint Airworthiness Requirements
KAL	Korean Air Lines
KIAS	Knots Indicated Airspeed
LOB	Line of Business
MDR	Metadata Repository
MEDA	Maintenance Error Decision Aid
MEL	Minimum Equipment List
MRB	Maintenance Review Board
MEMS	CAA Maintenance Error Management System
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NASDAC	National Aviation Safety Data Analysis Center
NPA	JAA Notice of Proposed Amendment
NRC	National Research Council
NRS	FAA National Resource Specialist
NTSB	National Transportation Safety Board
NWA	Northwest Airlines
OEM	Original Equipment Manufacturer
PEAT	Procedural Event Analysis Tool
PMA	Parts Manufacturer Approval

PMI	FAA Principal Maintenance Inspector
POI	FAA Principal Operations Inspector
PSE	Primary Structural Element
PSSA	Preliminary System Safety Assessment
PTRS	Program Tracking and Reporting System
RTCA	Radio Technical Commission for Aeronautics, Inc.
RTO	Rejected Takeoff
SAE	Society of Automotive Engineers, Inc.
SAS	Scandinavian Airlines
SB	Service Bulletin
SCR	Special Certification Review
SDR	Service Difficulty Report
SFAR	Special Federal Aviation Regulation
SO	Staff Office
SPAS	Safety Performance Analysis System
SSID	Supplemental Structural Inspection Document
STC	Supplemental Type Certificate
STEADES	Safety Trend Evaluation, Analysis and Data Exchange System
SSA	System Safety Assessment
TC	Type Certificate
TCAS	Traffic Alert and Collision Avoidance System
TOGA	Takeoff/Go-Around
TP	Telecommunication Processor
T/R	Thrust Reverser
TSB	Transportation Safety Board of Canada
TSO	Technical Standard Order
TWA	Trans World Airlines
UA	United Air Lines
UAL	United Air Lines
WFD	Widespread Fatigue Damage

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