



**Federal Aviation
Administration**

DOT/FAA/AM-12/16
Office of Aerospace Medicine
Washington, DC 20591

Technical Documentation Challenges in Aviation Maintenance: A Proceedings Report

Katrina Avers
Bill Johnson
Joy Banks
Brenda Wenzel

Civil Aerospace Medical Institute
Federal Aviation Administration
Oklahoma City, OK 73125

November 2012

Final Report

NOTICE

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents thereof.

This publication and all Office of Aerospace Medicine technical reports are available in full-text from the Civil Aerospace Medical Institute's publications Web site:
www.faa.gov/go/oamtechreports

Technical Report Documentation Page

1. Report No. DOT/FAA/AM-12/16		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Technical Documentation Challenges in Aviation Maintenance: A Proceedings Report				5. Report Date November 2012	
				6. Performing Organization Code	
7. Author(s) Avers KB, Johnson B, Banks J, Wenzel B				8. Performing Organization Report No.	
9. Performing Organization Name and Address FAA Civil Aerospace Medical Institute P.O. Box 25082 Oklahoma City, OK 73125				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No.	
12. Sponsoring Agency name and Address Office of Aerospace Medicine Federal Aviation Administration 800 Independence Ave., S.W. Washington, DC 20591				13. Type of Report and Period Covered	
				14. Sponsoring Agency Code	
15. Supplemental Notes Work was accomplished under approved task AM-A-08-HRR-521					
16. Abstract The 2012 Technical Documentation workshop addressed both problems and solutions associated with technical documentation for maintenance. These issues are known to cause errors, rework, maintenance delays, other safety hazards, and FAA administrative actions against individuals and organizations. The report describes the group processes and data collection technique used to identify the top ten industry action items for addressing documentation issues: 1. Quantify financial loss related to documentation issues. 2. Develop/apply methods for evaluating quality of technical documentation. 3. Leverage voluntary reporting to identify specific problems with documentation. 4. Improve/create guidance for FAA personnel working documentation issues, especially Instructions for Continued Airworthiness (ICA). 5. Expand incident investigation to identify details associated with documentation issues. 6. Improve integration and linkage of content across maintenance documents – maintenance manuals, task cards, and illustrated parts catalogs. 7. Delegate approval from FAA to industry using established Organization Designation Authorization (ODA). 8. Improve usability of manual format, accessibility of manual, and training on manual use. 9. Initiate industry mandate requiring users to address known documentation issues. 10. Improve coordination of document professionals from industry segments and government.					
17. Key Words Maintenance, Technical Documentation				18. Distribution Statement Document is available to the public through the Internet: www.faa.gov/go/oamtechreports	
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 32	
				22. Price	

ACKNOWLEDGMENTS

Dr. Bill Johnson and Dr. Katrina Avers co-chaired the workshop for international attendees, including key official Aviation Safety (AVS) personnel, industry leaders (Maintenance, Repair, and Overhaul organizations, airlines, and manufacturers), scientists, and data management providers. The administration of the Chief Scientific and Technical Advisor Program, the Aircraft Certification Workshop Program, the Atlanta Flight Standards District Office, the Human Factors Research and Engineering Group (ANG), and the Human Factors Research Division of the Civil Aerospace Medical Institute provided all of the necessary support to ensure the success of the workshop.

High-value workshops are much more than an agenda and a technical report. Behind the scene are hours of concept development; proposal preparation, submission, and approval; selection of attendees; invitations to speakers; and logistics. The success of this workshop was dependent on excellent speakers and active participation from attendees. We thank the workshop speakers, small group leaders, and attendees for their engagement in the issue and responsiveness to coordination requests. Their contributions will advance the implementation of technical documentation solutions in the maintenance industry.

Special thanks to Keith Frable for facility coordination, Tara Bergsten for pre-workshop support, Joy Banks for logistical and administrative support across all phases of the workshop, Brenda Wenzel for analytic support, Brittney Goodwin for travel and purchasing support, and Janine King, Suzanne Thomas, and Mike Wayda for final proofing and formatting of the workshop report.

The outcomes reported here from the collaborative effort among 28 attendees at the workshop are intended to help ensure continuing aviation safety as it applies to the challenges of technical documentation in aviation maintenance.

ATTENDEE	AFFILIATION
Bill Johnson	AIR-100
Doug Dalbey	Cavok
Bill Collieran	Gulfstream
Edward Garino	AIR-110
Bill Norman	TIMCO
Guy Minor	AWP-204
Bill Rankin	Boeing
John Goglia	JDA Aviation Technology Solutions
Brad Shelton	Delta
John Hall	US Airways
Brenda Wenzel	AAM-510
Joy Banks	AAM-510
Brockford Tubbs	Boeing
Katrina Avers	AAM-510
Caroline Daniels	ATP
Keith Frable	ASO-27
Colin Drury	Applied Ergonomics
Lynn Pierce	AEG-15
Dave Latimer	TIMCO
Maggie J. Ma	Boeing
David J. Giustozzi	American Airlines
Paul Mingler	GE Aviation
David K. Hopson	AFS-330
Philippe Barthas	Airbus
David Snider	AEG-25
Rayner Hutchinson	AAR CORP.
Dominic Marshall	Pratt & Whitney
Stephen P. Boyd	ANM-111

EXECUTIVE SUMMARY

For three consecutive years, the Federal Aviation Administration's (FAA's) Office of Aviation Safety (AVS) Chief Scientific and Technical Advisory (CSTA) program, and the Human Factors Division of the Civil Aerospace Medical Institute (CAMI) have conducted an annual workshop dedicated specifically to maintenance and engineering. The 2012 workshop reported here addressed both problems and solutions associated with technical documentation for maintenance.

Twenty-eight invited attendees came from government, research and development, manufacturing, airlines, and maintenance, repair, and overhaul organizations. The first CSTA workshop on maintenance human factors issues, in 2010, identified technical documentation as the number one human factors challenge in aviation maintenance (Johnson, 2010; Avers, Johnson, Banks, & Nei, 2011). At the 2012 workshop, one attendee noted "...it is known that the technical documentation challenge is the greatest risk in the aviation industry – it will take more than a scientist's workshop to fix the issues, but this is a good start." Issues associated with technical documentation are known to cause errors, rework, maintenance delays, other safety hazards, and FAA administrative actions against individuals and organizations. In National Aeronautics and Space Administration (NASA) studies of Aviation Safety Reporting System (ASRS) reports, 45 to 60% of incidents were procedure related or involved technical documentation (Kanki & Walter, 1997). These instances threaten safety and cost the industry millions of dollars.

The workshop format combined key presentation topics, followed by structured discussion and small group exercises. It began by clarifying issues regarding technical documentation for maintenance and ended with extensive lists of challenges and corresponding short-term and long-term solutions, rank-ordered by priority. The report describes the group processes and data collection technique used to identify the top ten industry action items for addressing documentation issues:

1. Quantify financial loss related to documentation issues.
2. Develop/apply methods for evaluating quality of technical documentation.

3. Leverage voluntary reporting to identify specific problems with documentation.
4. Improve/create guidance for FAA personnel working documentation issues, especially Instructions for Continued Airworthiness (ICA).
5. Expand incident investigation to identify details associated with documentation issues.
6. Improve integration and linkage of content across maintenance documents — maintenance manuals, task cards, and illustrated parts catalogs.
7. Delegate approval from FAA to industry using established Organization Designation Authorization (ODA).
8. Improve usability of manual format, accessibility of manual, and training on manual use.
9. Initiate industry mandate requiring users to address known documentation issues.
10. Improve coordination of document professionals from industry segments and government.

The workshop design reflected the importance of government and industry working together in a concerted effort to prioritize solutions for improving maintenance documentation. Attendees acknowledged, on day 1 of the workshop, that more of the same "talking about the challenges" is insufficient action. All segments of industry and government must make an organizational and financial investment to address documentation problems.

The technical documentation challenge is complex due to organizational and regulatory processes, technological innovations, and design quality, to name a few. This makes solution implementation difficult. Fixing the problems means changing a culture. The question remains: Is the aviation industry ready to tackle these challenges?

The development of viable solutions is a shared responsibility that requires open communication from all of the stakeholders—aviation maintenance technicians (AMTs), AMT supervisors, corporate executives, manufacturers, suppliers, and government. Without a collective effort, technical documentation issues will continue to be a safety risk. This workshop and report are important first steps to taking action.

CONTENTS

TECHNICAL DOCUMENTATION CHALLENGES IN AVIATION MAINTENANCE: A PROCEEDINGS REPORT	1
Section 1.0 Workshop Proceedings	1
1.1 Background on technical documentation issues	1
1.2 Workshop attendees	2
1.3 Workshop format	2
1.4 Workshop – Day 1	3
1.4.1 Welcome session	3
1.4.2 Keynote address “Why are we talking about technical publications?”	3
1.4.3 Workshop introductions	3
1.4.3.1 Proposed problems	4
1.4.3.2 Proposed solutions	4
1.4.4 Day 1 presentations	4
1.4.4.1 Session 1: Summarizing government and industry challenges	5
1.4.4.2 Session 2: Creating and delivering technical documents	7
1.5 Workshop – Day 2	11
1.5.1 Day 2: Presentations	11
1.5.1.1 Session 3: Evidence-based practices	11
1.5.2 Day 2: Small group event	14
1.5.2.1 Workgroup task	14
1.5.2.2 Prioritization of workgroup challenges and solutions	15
1.5.2.3 Evaluation of the workshop	15
Section 2.0 Workshop results	15
2.1 Prioritized challenges	15
2.1.1 FAA consistency	15
2.1.2 Content accuracy	15
2.1.3 Culture of noncompliance with documentation	15
2.1.4 Lack of appropriate business case for document issue improvement	16
2.1.5 Industry standards	16
2.2 Prioritized Solutions	16
2.2.1 Quantify financial loss related to documentation issues	17
2.2.2 Develop/apply methods for evaluating quality of technical documentation	18
2.2.3 Leverage voluntary reporting to identify specific problems with documentation	19
2.2.4 Improve/create guidance for FAA personnel working documentation issues	19
2.2.5 Expand incident investigation to identify documentation issues	20
2.2.6 Improve integration and linkage of content across maintenance documents	20
2.2.6.1 Providing the right access	20
2.2.6.2 Providing the right tools	20
2.2.6.3 Providing the right solutions	20
2.2.7 Delegate approval from FAA to industry	21
2.2.8 Improve usability of manual format, accessibility of manual, and training on manual.	21
2.2.9 Initiate industry mandate requiring users to address known documentation issues	21
2.2.10 Improve coordination of professionals from industry segments and government.	22
2.2.11 Challenges and action item summary	22
2.2.12 References	22

TECHNICAL DOCUMENTATION CHALLENGES IN AVIATION MAINTENANCE: A PROCEEDINGS REPORT

SECTION 1.0 WORKSHOP PROCEEDINGS

1.1 Background on Technical Documentation Issues

“The technicians failed to follow the written procedures ...”

This statement is often found in descriptions of minor maintenance errors in National Transportation Safety Board (NTSB) reports of major aircraft accidents. *Written procedures* refer to a variety of manufacturer publications, specific company job cards, or the rule in Code of Federal Regulations (CFR) 14 Part 43 Section 43.13(a) entitled, “Acceptable Methods, Techniques, and Practices—Aircraft Inspection and Repair.” The rule states that:

...each person performing maintenance, alteration, 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, or practices acceptable to the Administrator...

The rule is clear: Use a manual for all work. It should be easy, but it is not straightforward. Figure 1 represents the volume of manuals or data delivered to operators of

multiple aircraft types in support of in-service operations and maintenance. Even carrying the documentation for a single task may become unwieldy when maintenance is performed in a restricted space or at night on the ramp. While the pile of paper could be very high, most airlines receive and use the majority of their documentation in digital format.

The volumes of documentation make it easy to understand how documentation problems compound in Maintenance, Repair, and Overhaul organizations (MROs) where each aircraft must be maintained by maintenance documentation specific to the aircraft owner and registry number. This means that an MRO is likely to have different work instructions for each aircraft in the shop, even though they are the same type of aircraft. Most air carrier operations supplement manufacturer’s manuals with company instructions, checklists, job cards, and more; and some companies use computer-based maintenance documents with varying degrees of user friendliness.

The maintenance documentation issues extend to the smaller general aviation (GA) aircraft and to all aircraft components but can manifest in different ways. GA operators often lack some of the standardization and documentation that is required in air carrier operations.



Copyright 2012 The Boeing Company. All rights reserved. Reproduced courtesy of The Boeing Company.

Figure 1. The technical documentation for Boeing aircraft model.

GA technicians report there is not enough technical documentation for some aircraft. Regardless, all technicians are responsible for integrating maintenance instructions from multiple sources (e.g., manufacturer manuals, service bulletins, and airworthiness directives) – a situation that can make documentation a significant challenge for those who maintain aircraft.

Before presenting details of the workshop, here are examples (Giustozzi, 2009) of the scope of the technical documentation issue:

In 2000, an FAA study looked at maintenance error. The study focused on major malfunctions that occurred within 90 days of a heavy maintenance check. Failure to comply with maintenance documentation was the number one reason for malfunction (Johnson & Watson, 2001).

In 2004, the NTSB accident report of the Charlotte USAir Express Accident (AAR-04-01) stated that the FAA should: “...require 14 CFR Part 121 air carriers to implement a program in which carriers and aircraft manufacturers review all work card and maintenance manual instructions for critical flight safety systems and ensure the accuracy and usability of these instructions so that they are appropriate to the level of training of the mechanics performing the work...”

In 2007, a report by the Confidential Human Factors Incident Reporting Programme (CHIRP) from the United Kingdom (www.chirp-mems.co.uk) indicated the top two most frequently occurring errors reported were: (1) information not used and (2) procedures not followed.

Their recommendation was to simplify the procedures and align company task cards with the aircraft maintenance manual (Rankin, 2008).

A 2012 analysis of the FAA enforcement database for actions taken against mechanics regarding 14 CFR Part 43 Section 43.13(a) showed that technical documentation is a challenge. Of nearly 900 “closed” cases from 2010, more than 850 actions were taken against mechanics. Over one-third of the violations (36%) were associated with not using the proper technical documentation. The data revealed this is the number one cause for Enforcement Investigation Reports (S. Hodges-Austin, personal communication, April 4, 2012).

A 2012 analysis of the NASA ASRS maintenance reports from 2001 to 2011 (14,267 reports) showed that nearly 64% (about 9,000) of safety incidents coded in the reporting system were related to technical documentation or procedural challenges or both (J. Moya, personal communication, March 29, 2012).

1.2 Workshop Attendees

The workshop planners invited participants who had a stake in the issue of technical documentation for aviation maintenance. All 28 attendees possessed considerable expertise from either operations or science, including MROs, Original Equipment Manufacturers (OEMs), airlines, FAA offices, research and development (R&D), and third-party data management providers (See Figure 2).

1.3 Workshop Format

The workshop format fostered participant interactions, application of analytical methods, and a multi-disciplinary approach to addressing problems associated with technical documentation in the aviation maintenance industry. The format employed individual, small-group, and large-group participative techniques. There were 12 formal presentations divided into session topics, following the keynote speaker and individual attendee introductions. (See presentation slides in Appendix B.) Select attendees led a solution-oriented group discussion at the end of each session. Following all presentations, five working groups were formed to identify technical documentation challenges and corresponding short-term and long-term solutions within one of the designated focus areas: (1) document quality, (2) measurement, (3) user/mechanic, (4) government, and (5) industry/management. Each working group presented their lists of challenges and solutions to the full workshop group. At the end of the workshop, attendees provided an evaluation of the workshop.

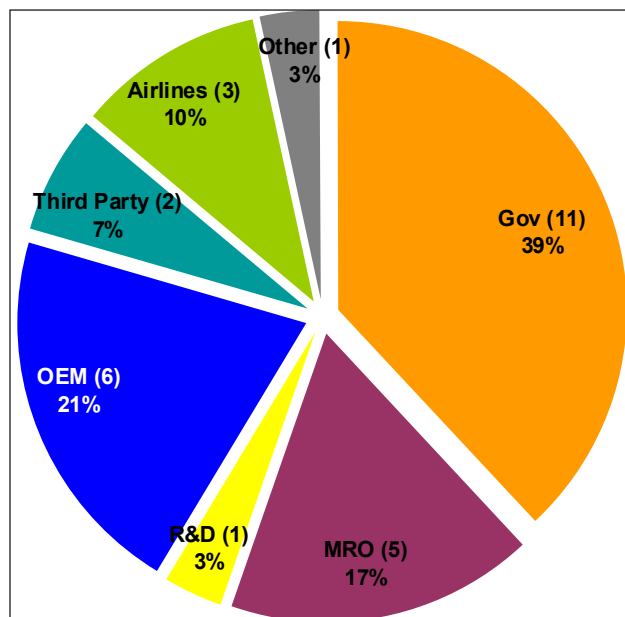


Figure 2. A depiction of attendee affiliation (count and percentage).

1.4 WORKSHOP – DAY 1

The two-day workshop was held in Atlanta at the Flight Standards District Office (see Figure 3). The following subsections summarize the workshop presentations and activities.



Figure 3. Dr. Bill Johnson thanks Mr. Keith Frable for hosting the workshop location.

1.4.1 Welcome Session

Dr. William (Bill) Johnson, CSTA for Maintenance Human Factors, opened the meeting and welcomed the attendees. He summarized the accomplishments of the last maintenance human factors workshop and identified four objectives for the current meeting. He asked workshop attendees to:

- Identify, summarize, and prioritize the technical documentation problems in operational terms,
- Estimate the affect of technical documentation issues on aviation safety and efficiency,
- Identify and differentiate short-term and long-term solutions for technical documentation problems, and
- Create actionable guidance for the FAA, research and development community, and industry.

1.4.2 Keynote Address “Why are we talking about technical publications?”

Caroline Daniels – Aircraft Technical Publishers

Ms. Caroline Daniels, Chairwoman of the Board and Chief Executive Officer of Aircraft Technical Publishers (ATP), is widely recognized as a pioneer of safety information management systems. Her company is involved in issues surrounding technical documentation in aviation maintenance. In her opening statement, she asked attendees to consider technical documentation a shared responsibility. As an industry, we all have the responsibility to document and inform, mitigate risk, establish processes, and meet regulatory requirements pertaining to

technical documentation. To do this effectively, we must consider the complete lifecycle of technical publications. She went on to say that each maintenance organization must make its own unique set of technical documentation requirements, considerations, and decisions. At each point in the development process, decisions have to be made regarding authoring (tools), printing (media), and distribution (type of reader). These decisions are critical and can produce very different results for the end user, depending on the authoring tools and formatting selected.

Cost influences document development. Costs determine how a company creates the complete technical publication lifecycle to support its company strategy. There are low cost resources available (e.g., Microsoft® Word for authoring and Adobe® pdf for delivery), but they are not cost-effective in the long term because the content is unstructured and difficult to search and maintain. Based on the experience of ATP, structured authoring and well-crafted document architecture produce the best results for the money. This is not easily accomplished; it requires oversight and administration, strict discipline among the authors, and extensive information technology structure and support.

Currently, there is no regulatory specification regarding media, format, turn-around times, or distribution technology for technical documentation. We are at a point where we can utilize next-generation technologies and provide new opportunities for presenting and accessing technical information (e.g., 3D modeling, embedded video training, and voice recognition). Even with these new technological capabilities, we, as an industry, have to focus on “delivering the right form and right pieces of information into the right hands, at the right time and place.”

1.4.3 Workshop Introductions

Next, attendees introduced themselves to the group and presented what they considered as the most important problem relating to technical documentation in aviation maintenance and offered three viable solutions to overcome the problem. Some attendees provided multiple problems and corresponding solutions, while others provided one of each. We had requested each attendee submit problem and solutions, prior to the workshop.

The content analysis conducted on the problems and solutions included input from 28 attendees. They submitted 79 problems and 80 solutions, which were independently analyzed based on coding protocols developed for each (Sutton, 2010; Walker, 2011). Three raters separately applied the protocols and then met to address coding discrepancies before coming to an agreement. Their results were presented to the group on the second day of the workshop.

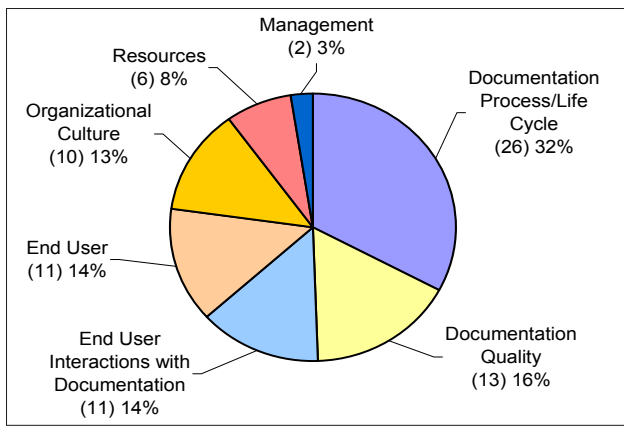


Figure 4. Distribution of identified problems within categories (count and percentage).

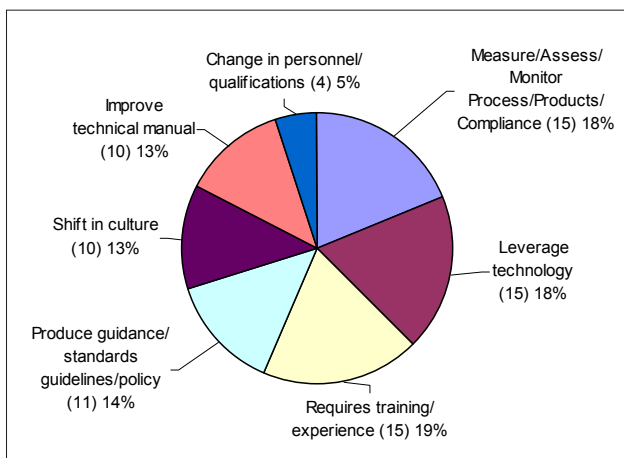


Figure 5. Distribution of proposed solutions within categories (count and percentage).

1.4.3.1 Proposed Problems

Results of the problem content analysis (Figure 4), reveal that prior to the workshop nearly half (48%) of the identified problems with technical documentation are attributable to the processes involved in producing and sustaining quality end-products. Twenty-eight percent of the problems reveal issues AMTs, as end users, face with low-quality documentation. The remaining 24% of problems reveal features of an organization that contribute to documentation issues. Figure 4 emphasizes the broad range of problems associated with technical documentation improvement.

1.4.3.2 Proposed Solutions

Results of the *solutions* content analysis (Figure 5), reveal that prior to the workshop, 36% of the proposed solutions would involve changes in processes (incorporation of analytics and leveraging technology), 37% in people (qualifications, training, and cultural shift), and 27% in products (standards and guidelines, and technical manuals). Again, this shows many solutions were proposed, but a silver bullet is unlikely.

1.4.4 Day 1 Presentations

The two presentation sessions (Figure 6) conducted the first day of the workshop were entitled: “Summarizing Government and Industry Challenges” and “Creating and Delivering Technical Documents.”



Figure 6. Workshop presentations - Day 1.

1.4.4.1 Session 1: Summarizing Government and Industry Challenges

Keith Frable – Federal Aviation Administration

Mr. Keith Frable, Principal Maintenance Inspector for Delta Air Lines, Certificate Management Office, was involved with the merger between Delta and Northwest Airlines and has been employed by the FAA for more than 15 years. Mr. Frable offered a detailed overview of the Air Transportation Oversight System (ATOS). Under ATOS, the FAA's primary responsibilities are to 1) continually validate the performance of an air carrier's approved and accepted programs for the purpose of continued operational safety, and 2) conduct performance assessments to confirm that the air carrier's operating systems produce intended results. Aviation Safety Inspectors (ASIs) use other data to assess the air carrier's operational health, including the Voluntary Disclosure Reporting Program (VDRP), the Aviation Safety Action Program (ASAP), and the Safety Management System (SMS). These program databases provide the opportunity to identify and address operational safety issues without punitive damages. In the operations overseen by Mr. Frable, the majority of disclosures reported are categorized as a failure to follow or adhere to approved documentation or procedures. He noted the documentation was seldom incorrect and resulted in a failure. When there are slight errors, the mechanic often recognizes the issue and triggers an engineering change to the document.

The challenge for many ASIs is the magnitude of data. Inspectors receive data from many sources, and it is difficult to absorb all of the data points and develop a "silver bullet" approach. The principal maintenance inspectors are consistently trying to answer the question, "How do we fix this problem?" and "What regulatory solutions can be provided?"

Bill Norman – TIMCO Aviation Services

Mr. Bill Norman, President of MRO services for TIMCO Aviation Services, is responsible for TIMCO's Airframe, Engine and Line Care Maintenance businesses. Mr. Norman offered insight into the issues repair stations and air carriers struggle with regarding technical data for aviation maintenance. Technical data are rarely all in one place. Technicians must assimilate information from multiple parts of a manual and even multiple manuals. Moreover, they are required to pull all reference data for a given task and wade through the data to determine exactly what is and is not applicable to the maintenance task.

Mr. Norman shared an example of an accident where an A-320 departed the runway due to a cross-wired anti-skid transducer connector. In this accident, technical documentation played a significant role. The technical

data required to perform work on the anti-skid transducer connector included one airworthiness directive reference, 11 service bulletin (SB) references, and 62 customer task card AMM (Aviation Maintenance Manual) references. This resulted in 73 references total and 6.25 pounds of reference data the technician had to go through to complete the task. In addition to the quantity of technical data tied to this task, the Airbus diagram did not follow aviation norms. The air carrier developed the job card using the "do per AMM XX-YY-ZZZ" approach. "Do per" is a shortened instruction to follow a reference listed elsewhere in the documentation or associated company job card. Instead of usable stepped work instructions, the job card sequencing was reverse-ordered in places, the transducer electrical connectors were not uniquely keyed, and the final test of the anti-skid system was inadequate. All of these issues (minus aircraft design for the connectors) could be addressed with improved guidance from the manufactures and improved Instructions for Continued Airworthiness (ICAs).

Clear and easy-to-understand ICAs are needed now and will continue to be needed as the industry experiences significant changes in the type of technicians (non-certificated) available for hire and the type of aircraft being repaired and maintained.

John Hall – International Association of Machinists

Mr. John Hall, lead mechanic and Director of the International Association of Machinists and Aerospace Workers (IAMAW) Flight Safety Committee, serves on numerous industry and regulatory committees involving aviation maintenance safety. Mr. Hall reviews not only the technical documentation problems as they relate specifically to the mechanic user but also the process that is followed for corrective action. Once a mechanic commits an identifiable error, that mechanic receives a letter of investigation from the FAA. The mechanic notifies the company's field safety representative and meets to establish the facts. The flight safety representative then calls the principal maintenance inspector and requests an informal meeting to discuss the issue with the ASI. When a violation is identified, the field safety representative presents any factors involved in the commission of the error and seeks remediation for the mechanic. Some of the contributing factors identified in this process include confusing or conflicting paperwork and issues with equipment and shop procedures.

Mr. Hall noted that technical documentation continues to be a problem for mechanics. At U.S. Airways in the last 10 months, approximately 35% of the ASAP reports were paperwork related (e.g., failure to follow, confusing, and conflicting) and 10% of the reports resulted in changes to paperwork. He identified some possible solu-

tions as including recurrent training, crew briefings, alert bulletins, employee involvement in changes to technical publications, and user-friendly electronic publications. In ASAP InfoShare meetings, many carriers suggest that paperwork issues contributes to as much as 70% of the reports.

Brad Shelton – Delta Air Lines

Mr. Brad Shelton, the Managing Director of Engineering, Quality, Technology and Training for Delta Air Lines, is responsible for fleet and propulsion engineering, maintenance programming, reliability, publications, and technical records. Mr. Shelton opened his presentation by stating, “We are ultimately responsible for the work accomplished on our aircraft.” This responsibility is directly influenced by the document usability and technical accuracy. To appropriately mitigate and eliminate technical documentation issues, we all (industry, OEMs, and regulators) must work together.

Delta pursues four key objectives relating to documentation: 1) provide accurate and consistent data, 2) reduce opportunities for human error, 3) maintain regulatory compliance, and 4) effectively and efficiently manage data. In pursuing these objectives, Delta faces significant challenges in terms of data consistency, data volume, data complexity, data re-use, and data delivery (Figure 7). Delta is pursuing multiple solutions to address each problem. To improve document usability in the future, the industry must take action in five areas:

- Manufacturers must invest in quality and data consistency among, and within, their products.
- Manufacturers, operators, and delivery system developers must invest in the linked tools that cross all content.
- Content delivery providers must have “app like” simplicity and intuitive user interfaces.

Our Challenges and Our Response ▲ DELTA TechOps



Data Volume

- Delta manages about 3 million pages of data
- About 10% of the content is revised annually
- About 10% of the content is customized by the airline
- About 5% of the content is re-used for work cards and other maintenance documents

Our Role and Response

- Processes for document quality include check and approve
- Regularly monitor throughput, backlog and quality metrics
- Leverage automation for processing OEM revisions
- Drive custom content back to the OEM for inclusion as basic

Delta TechOps | February 2012 | 7

Figure 7. Delta's data volume statistics and corporate response.

- Airlines and operators must instill confidence in their end users that the data are correct
- Regulators must have controls for consistency and incorporation of required content by OEM.

Ultimately, we must recognize that there are a number of obstacles to providing useable documentation for aircraft maintenance. Even though we have interventions in place, we must continue to look toward future methods of improvement. The industry and regulatory agencies must collaborate to reduce and remove current and future challenges.

Brockford Tubbs – The Boeing Company

Mr. Brockford Tubbs, a manager in the Maintenance Engineering Group for the Boeing Company, is responsible for leading the Airplane Maintenance Manual Usability Team, managing the 737 model, and supervising

maintenance engineering personnel for all heritage Boeing models. Mr. Tubbs focused on the capabilities of e-enabled business solutions. The challenge today in the information age is to work through processes to implement, activate, and integrate systems for future technologies while using the source information as the foundation for making improvements.

In the past, delivering a maintenance manual revision was no simple feat (Figure 8). Before PMA (Portable Maintenance Aids), MyBoeingFleet.com (fast, real-time delivery) and Maintenance Performance Toolbox (improved linkage and user experience), revising and delivering technical support information was a time-consuming,

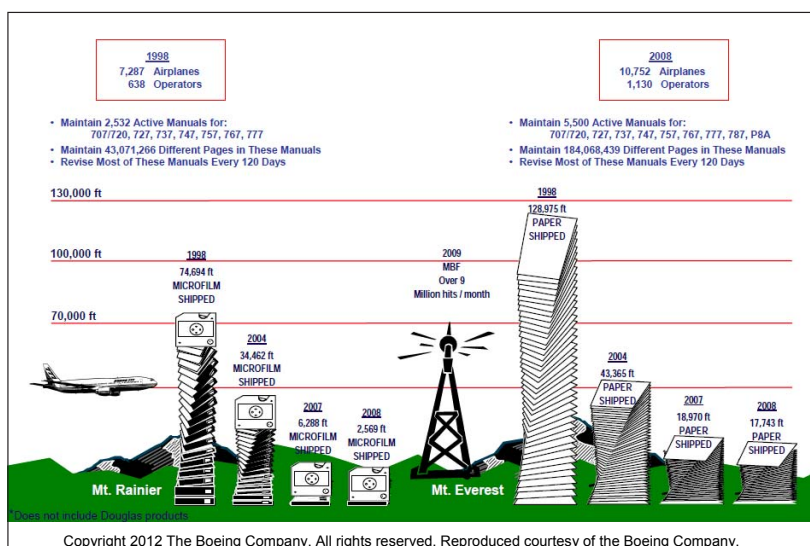
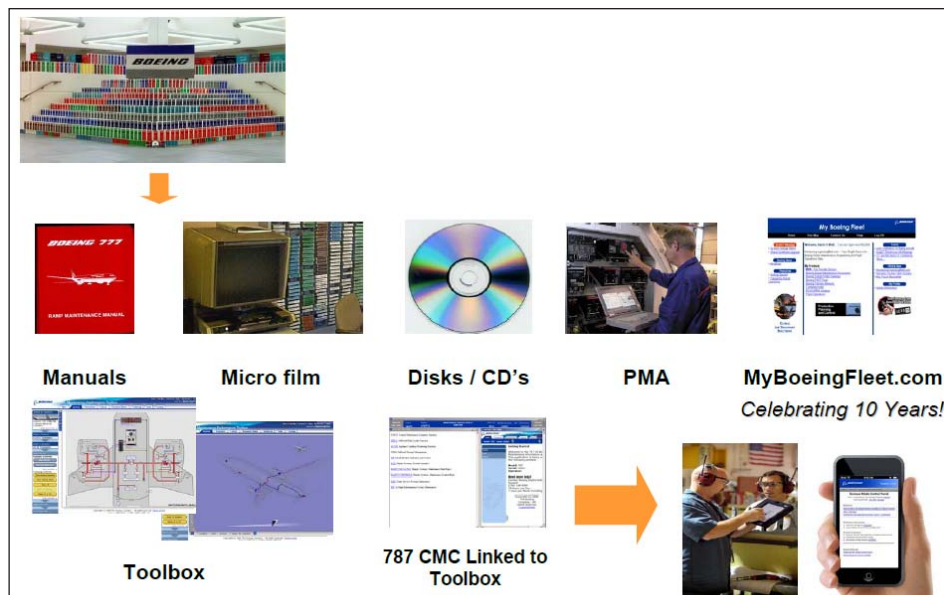


Figure 8. Boeing's technical documentation transition over 10 years.



Copyright 2012 The Boeing Company. All rights reserved. Reproduced courtesy of the Boeing Company.

Figure 9. Boeing's transition from paper technical data to PDA-accessible data.

expensive, and slow process. The resources, time, and energy involved required millions of dollars, mountains of paper, and untold amounts of microfiche. Today, Boeing is able to make and deliver changes almost in real time using improved authoring and web-based delivery tools (see Figure 9). In addition, Boeing continues to develop new tools and services to enhance the usability of their products. Maintenance Performance Toolbox service offerings, which include enhanced graphics, linking, and navigation, are examples of how industry is changing the way end users interact with OEM technical data.

As Boeing looks toward the future, visual graphic content is on the horizon. Boeing is considering how to enhance online tool usage. One improvement is real-time, easily accessible maintenance information. For example, in the new system a mechanic would get intuitive visual graphic information about where to look, what to remove, and how to process a procedure. Boeing plans to link visual tools with the actual written manual content.

Ultimately, Boeing's goal is to get the right information to the right people, at the right time, all while making decisions optimized for operational safety, security, and compliance standards. Boeing continues to keep the customer's experience in mind and keep ties to their user community by providing information in a usable format where safety and repeatability are paramount.

Discussants

The Honorable John Goglia and Dr. Bill Rankin led the group discussion at the end of the session on summarizing government and industry challenges and solutions.

1.4.4.2 Session 2: Creating and Delivering Technical Documents

Bill Colleran – Gulfstream Aerospace Corporation

Mr. Bill Colleran, Director of Technical Information Services for Gulfstream Aerospace Corporation, is responsible for developing and sustaining aircraft publications for all Gulfstream model aircraft, fleet computerized maintenance programs, and aircraft maintainability and reliability programs. Mr. Colleran noted the history of technical documentation and that its transition is evolving very rapidly. Usage of electronic page-turners and portable document formats (PDFs) with limited search capabilities are already items of the past. Gulfstream is now designing aircraft with interactive electronic technical manuals (IETM), interactive three-dimensional models, dynamic search capabilities, two-dimensional illustrations, and expanded hyper-linking (Figure 10).

These advancements are not without difficulties. The proliferation of tablet devices has made it necessary to



Figure 10. The Gulfstream 280 served as an impetus for change in technical documentation.

deploy publications to all platforms and formats. The increased partnership in aircraft production has influenced sustainability and integration of data from multiple sources.

Paul Mingler – GE Aviation

Mr. Paul Mingler, Chief Consulting Engineer of Product Safety for GE Aviation, is focused on product safety in the design of the engine, has been involved in the investigation of all accidents involving GE commercial engines, and has designed a number of proactive safety initiatives to improve propulsion system safety. Mr. Mingler discussed technical documentation issues in terms of the human user (e.g., technician, engineer, mechanic). Over the last 30 years, we have seen a reduction in the number of maintenance errors attributable to machines. Failure to follow published technical data or local instructions is still the number one cause of maintenance mishaps (Rankin, 2008).

In today's organizations, we strive to be learning organizations that conduct analytics (e.g., root-cause investigations), utilize a number of data sources, and embody a safety culture. This has led to an improved understanding of the maintenance human factors lifecycle - design for reliability and maintainability, development of manuals and procedures, manufacturing and overhauling the aircraft, and services and line maintenance throughout the aircraft's life span. The two parts of the process that seem to be most

relevant to the issues in technical documentation are "design for reliability and maintainability" and "development of manuals and procedures." In designing for reliability and maintainability, it is critical that we consider the design, the engineering process, and the data sources. We must involve technicians with shop and line maintenance experiences, evaluate design reviews, and use defensive design techniques, or "Murphy-proof," whenever possible.

The delivery and deployment of manuals and procedures must consider three areas: the technical publication process, human factors aspects, and data sources. In the technical publication process, we have to leverage new technologies, utilize color-coded warnings and cautions, call-out instructions in sequence, and capitalize on the benefits of pictures and 3D graphics, as well as compliment these guides with "kitted parts." Manuals and procedures developers must consider human factor aspects such as intuitive navigation, context sensitivities, and training aids coupled with manuals. We cannot underestimate the human factor in the technical documentation issues. It is also essential that we utilize available data sources to improve our documentation. Mr. Mingler noted they use a combination of customer feedback, revision process approach, and feedback from training schools as data sources in the development and revision of manuals and procedures (Figure 11).

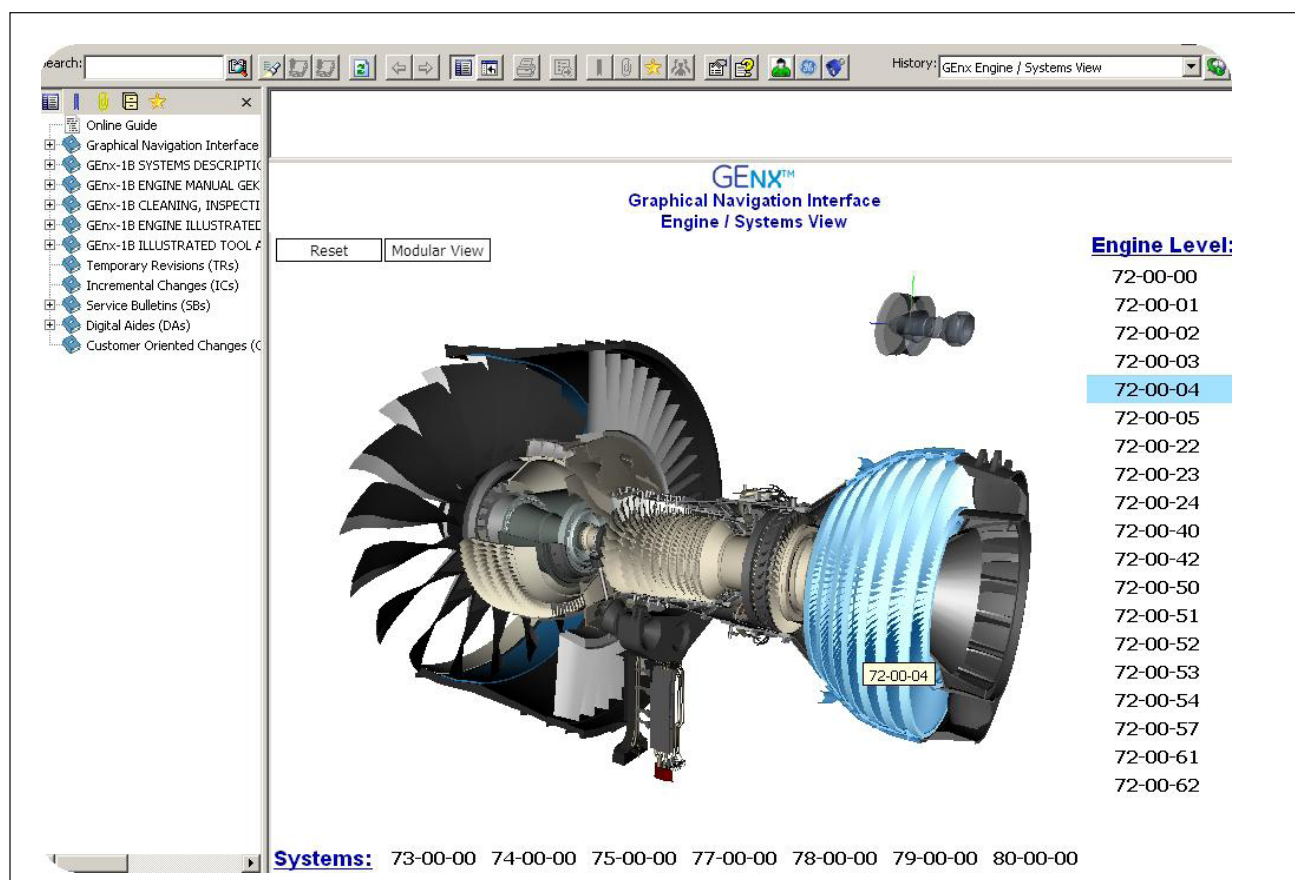


Figure 11. GE Aviation graphical navigation interface with color, 3D imaging, and part linkages.

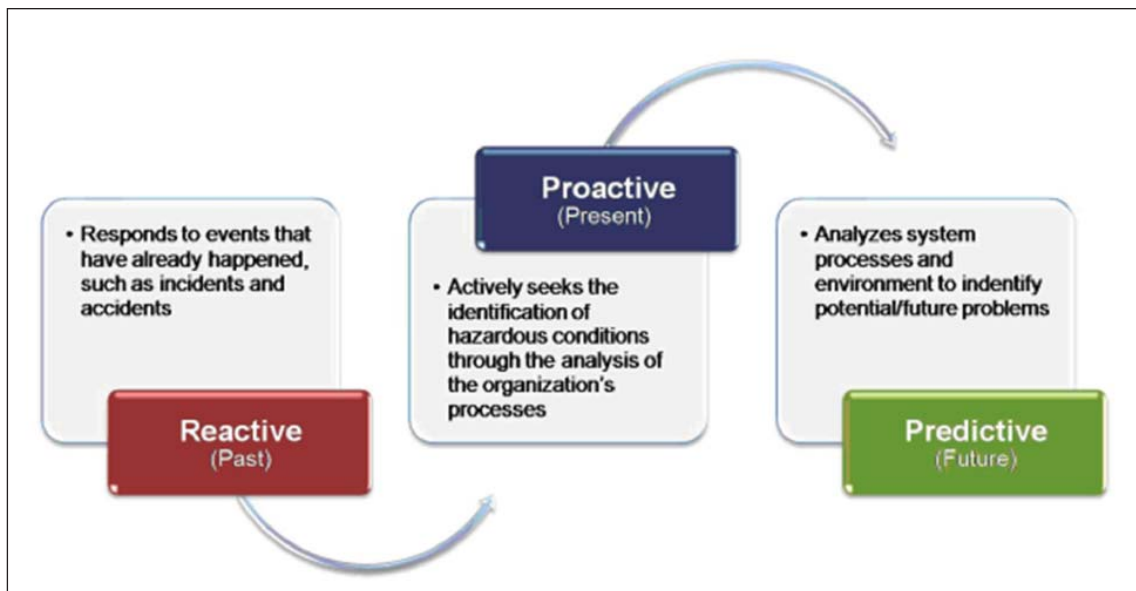


Figure 12. The Safety Management System process that should be initiated at the OEM level for technical documentation.

As the aviation maintenance industry moves forward, we must consider the advancements and characteristics of documentation and interface design experts, Google® and Apple®. Change is happening as we speak. We must make sure that our processes and equipment can accommodate new technologies and be applicable across four generations in the workforce. We can reduce maintenance error by improving our technical documentation processes, development, and deployment.

Lynn Pierce – Federal Aviation Administration

Mr. Lynn Pierce, an Aviation Safety Inspector and Maintenance Review Board chairman for the Seattle Aircraft Evaluation Group (AEG), is known for his thorough understanding of aircraft technical issues, automation, and aviation business practices. Within the FAA, Mr. Pierce is highly involved in the process review of Instructions of Continued Airworthiness (ICAs). The Seattle AEG Airworthiness Inspectors in his group reviews 1200 ICA packages, with some projects including more than 5000 pages, annually. The AEG Airworthiness Inspectors review of ICAs conservatively uses 33% of the Inspector total resources. Nearly all of the ICA packages reviewed receive a tabletop review, with little or no witnessing or validation being carried out regarding the ICA packages. Despite the limited review resource capabilities of the AEG, errors are found in almost every project reviewed. This is of great concern when considering the FAA's current policy and position regarding Organization Delegation Authority (ODA). With the implementation of ODA, the AEG has found itself in more of an audit function of ODA manual and processes without the drill down and review of technical data once accomplished by the AEG. Mr. Pierce believes we must begin with the original equipment

manufacturer to start to resolve the documentation and instructions problems we see today throughout the aviation industry. Work accomplished with inaccurate data by maintenance personnel can result in unsafe conditions and put the mechanics in jeopardy when they signed off maintenance with incorrect procedures. Mr. Pierce believes we must utilize Safety Management Systems (SMS) processes and capitalize on reactive, proactive, and predictive analysis to ensure better documentation and more accurate data (Figure 12).

Since Mr. Pierce authored IP-44 (Issue Paper) a few years ago for the International Maintenance Review Board Policy Board (IMRBPB) IP-44, which provides a path for data mining and statistic analysis when looking at aircraft data, we have seen Machine Learning emerge as an artificial intelligence. Machine Learning uses a scientific discipline concerned with the design and development of algorithms that allow computers to evolve behaviors based on empirical data, such as from sensor data or databases. A learner can take advantage of examples (data) to capture characteristics of interest of their unknown, underlying probability distribution. Data can be seen as examples that illustrate relations between observed variables. A major focus of machine learning research is to automatically learn to recognize complex patterns and make intelligent decisions based on data. This would be the next evolution of IP-44 and how we evaluate and use data in the future.

Philippe Barthas – Airbus Company

Mr. Philippe Barthas, Senior Director of Maintenance and Repair Technical Data for the Airbus Company, is responsible for delivering and supporting the maintenance and repair technical data for Airbus civil aircraft. Airbus

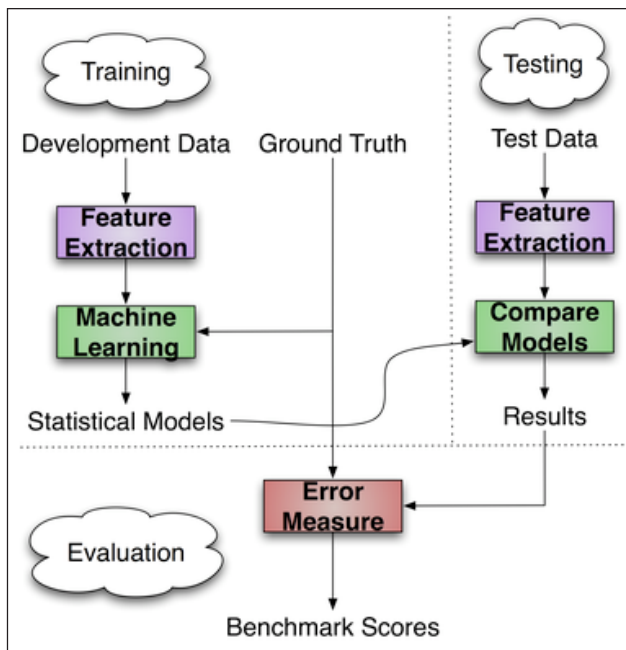


Figure 13. The evolution of IP-44 and how data will be used in the future.

constantly enhances technical data (content and technology) to contribute to safety in maintenance operations and improve the efficiency (usability) of maintenance documentation. The most common feedback he receives regarding technical data usability includes:

- task card or steps to complete the task are unclear;
- tasks involve guesswork or trial and error;
- not all of the procedures are necessary;
- following maintenance manuals slows progress making it difficult to meet deadlines;

- following procedures on routine tasks is an inefficient use of time; and
- some procedural steps could be combined, omitted, or sequenced differently without compromising safety.

To address these issues, Airbus has improved the quality of technical data through advanced consultation, enhanced data deliverables, and sustained customer support (Figure 14). To enhance consultation, Airbus has created more data interoperability, more business-oriented links between documentation modules, and quicker access to all data necessary to do the job.

In terms of data deliverables, Airbus has capitalized on technological advances to provide dynamic wiring functions for easier and faster troubleshooting, on-board integration of maintenance data and the on-board information terminals. They have utilized dynamic displays of troubleshooting steps to show “step-by-step” displays for ease of understanding and implemented interactive graphics and 3D displays and enhanced in-service configuration management. He also noted that with today’s technological capabilities, hyperlinks, interactive graphics, color in graphics, warnings, and cautions can be used much more extensively than in the past, thus contributing to improved clarity and understanding.

To also improve technical data operability, Airbus has worked to improve the process to establish and validate maintenance procedures to ensure they meet the expectations of the end-users, the mechanics, on the shop floor.

To support technical data operations, Airbus has implemented websites for consultation, downloading, reporting, and data management that are designed to

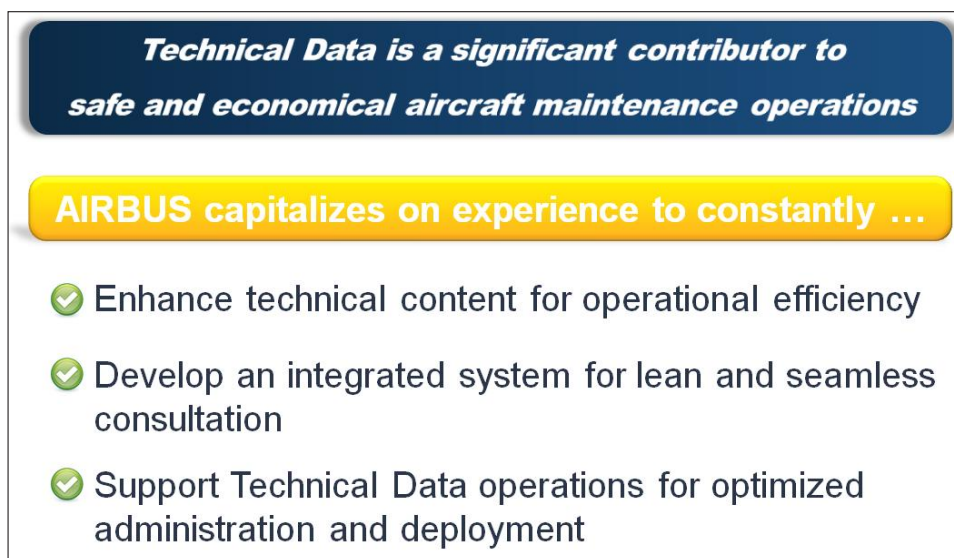


Figure 14. Airbus objectives to continuously enhance technical data usability.

improve data availability and administration of information. In addition, they have developed a Computer Assisted Documentation Education Tutorial System (C@DETS) for easy airline deployment and self-tutorial training. They have also initiated a Maintenance Event Analysis Panel (MEAP), which reviews all in-service events classified as being significant to maintenance operations, and it evaluates contributing factors and the potential consequences associated with errors. The output of the

MEAP is used to provide information about technical changes in maintenance data and training courses, and to communicate with customers.

Discussants

The Honorable John Goglia and Dr. Bill Rankin led the group discussion at the end of the session on creation and delivery of technical documents.

1.5 WORKSHOP – DAY 2



Figure 15. Workshop presentations - Day 2.

1.5.1 Day 2: Presentations

The final presentations (Figure 15) conducted during the second day of the workshop were entitled “Evidence-based Practices.”

1.5.1.1 Session 3: Evidence-Based Practices

Colin Drury – Applied Ergonomics Inc.

Dr. Colin Drury, President of Applied Ergonomics, Inc. and Distinguished Professor Emeritus at the State University of New York (SUNY) at Buffalo, made the first presentation. SUNY-Buffalo has led research on the application of human factors techniques to inspection and maintenance processes for more than 20 years. He opened his presentation with a discussion of the SHELL model and how a person (liveware) interacts with documentation (software), hardware, the environment, and other people (liveware) to accomplish a task. Most of the technical documentation issues originate in the interaction between an individual and software, so this is where improvements are needed.

As technical documentation is developed, the goal must be error-free performance. Sometimes we become sidetracked by AMT/Inspector preference, minimizing use of paper or screens, or simplicity of the documentation. While these are not bad, we have to focus on the ultimate goal of error-free performance using evidence-based design. We must understand the steps an AMT must follow to avoid errors. The technician must collect the correct documentation, read it, comprehend it, and perform the task steps correctly from the documentation. The four types of errors that can occur are:

1. Collect wrong documentation
2. Fail to read documentation
3. Fail to comprehend documentation, and
4. Fail to execute steps correctly

Dr. Drury reviewed a documentation example where he worked with an airline partner and analyzed data on actual errors than originated from using a hurriedly developed task card. The analysis showed unacceptable error rates (1.5% of responses, 20.8% of task cards). Task card errors included issues such as unexpected placement of response boxes, illogi-

cal instructions, and reference to different pages. None of the errors occurred when human factors guidelines were met. Dr. Drury challenged the industry to fix the system before fixing the liveware (the AMT).

Dr. Drury outlined what good documentation design should look like (see Figure 16). In particular, it should fit the

task to the user and be designed for the real AMT/inspector, not the engineer or the auditor. There are a number of tools currently available to help such as the Documentation Design Aid available at <https://hfskyway.faa.gov>. Research has shown that application of the design principles included in this tool increases comprehension and reduces errors.

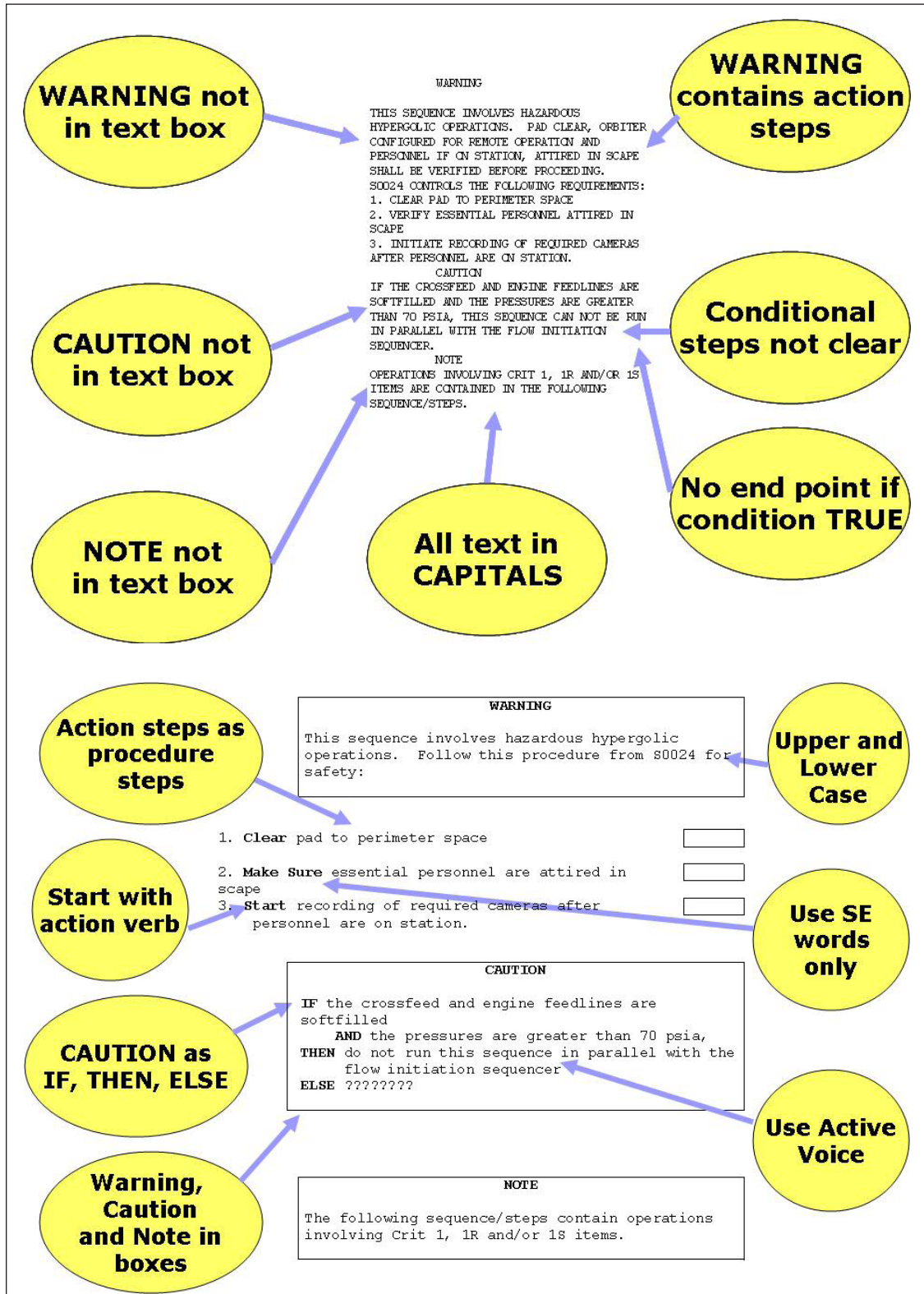


Figure 16. Old task card (top) vs. new task card (bottom) based on human factors design.

Overall, Dr. Drury urged industry to measure, measure, measure. Collected data can be used to improve individual performance and overall operations.

Maggie Ma – Boeing Company

Dr. Maggie Ma, a Systems Engineer for maintenance human factors at The Boeing Company, works closely with airlines, manufacturers, maintenance organizations, ground service providers, and international regulatory agencies to apply user-centered design methodology to design, develop, and test a variety of applications. Dr. Ma has been particularly involved in examining the issue of non-native English speakers and their use of aviation maintenance technical documentation. Currently there are two categories of documentation for instructions of continued airworthiness (ICAs): maintenance documents and engineering documents. The OEM typically produces ICAs in English, but the maintenance organization may revise the ICAs to produce bilingual ICA documents or documents in their technicians' native language. This transition of information from the OEM to the maintenance organization produces an opportunity for information to get "lost in translation." This translation issue presents an increasing challenge to the industry as outsourcing has increased from 37% to 64% (Dobbs, 2008).

Dr. Ma reviewed an FAA study she conducted examining non-native English speakers and their proneness to increased error rates (Figure 17). In this study, Dr. Ma and her colleagues measured comprehension of task cards (accuracy and time) in terms of three factors: task card complexity, type of document English, and interventions.

The results of the study revealed that accuracy was good internationally, reading level correlated with both speed and accuracy across continents, full and partial translation both improved accuracy and speed, but no other interventions helped (e.g., glossary, bilingual coach). Ultimately, the researchers concluded that language errors do occur, but they can be reduced or eliminated through training and translation. Again, measuring errors helps reveal those strategies that did work and those that did not. Maintenance organizations must be aware that time pressure compounds errors and also be alert to the symptoms of flawed communication when it occurs.

Guy Minor – Federal Aviation Administration

Mr. Guy Minor, an Aviation Safety Inspector and member of the AFS-850 FAA Safety Team Staff, is responsible for educating the maintenance industry regarding human error and just culture. Mr. Minor communicated the capabilities of the FAA Safety Team to address technical documentation problems in the industry (Figure 18). The FAA Safety Team's goal is to improve awareness regarding technical documentation issues and corresponding viable user-centered solutions. The FAA Safety Team utilizes available scientific research and communicates with industry through safety meetings, the national notice system, and the Wings and AMT Awards program.

Discussant

Mr. Rayner Hutchinson, Vice President of Quality and Safety for AAR CORP, led the group discussion at the end of the session on evidence-based practices.

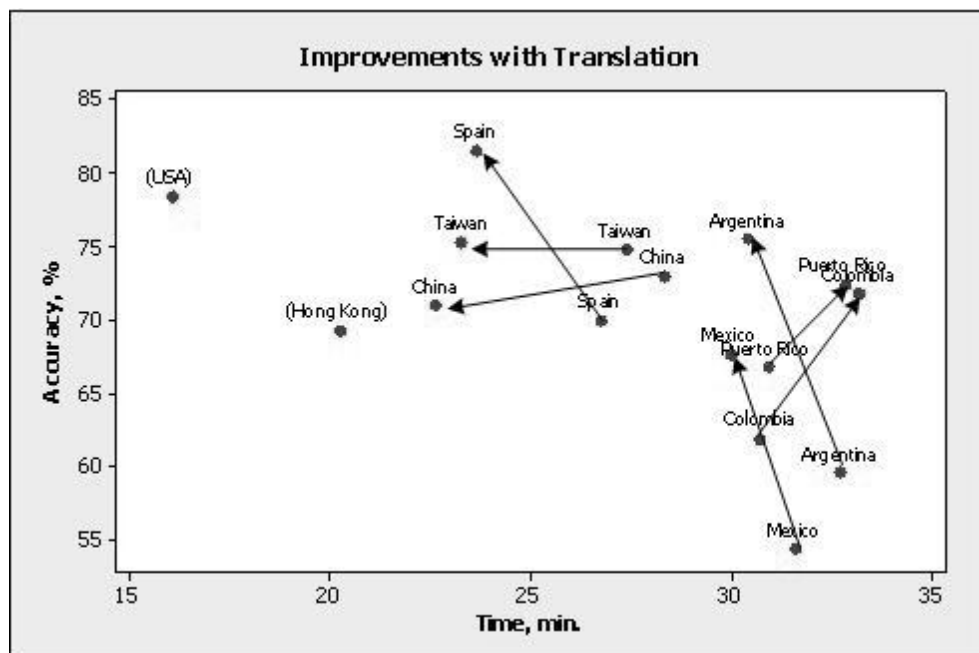


Figure 17. Changes in accuracy and time from baseline to translated conditions.

FAASafety.gov

Markets Safety Meetings
National Notice System
Wings and AMT Awards
Hosts:
Training
Safety Resources
Directory



Figure 18. Summary of the FAA Safety Team's support of improvements in technical documentation.



Figure 19. Workgroup members meet to identify challenges and short- and long-term solutions.

1.5.2 Day 2: Small group event

Following the last workshop presentation, attendees volunteered to work in one of five small workgroups to solve different technical documentation issues. Attendees were given the opportunity to serve in the workgroup where they felt their expertise would be most relevant. Each of the workgroups consisted of four to seven members. The workgroups were centered around:

- document quality,
- measurement,
- the user/mechanic,
- the government, and
- industry or management.

1.5.2.1 Workgroup task

Workgroups were tasked to identify five challenges/problems, five short-term solutions, and five long-term solutions relevant to their documentation issue and to assign a spokesperson to present the workgroup's ideas to the large group. Attendees, shown in Figure 19, spent the remainder of the morning and worked through lunch on the task.

1.5.2.2 Prioritization of workgroup challenges and solutions

Following detailed presentations of identified challenges and proposed solutions by each workgroup, attendees were asked to individually rank order the top ten challenges and top ten solutions. There were 25 challenges and 52 solutions (short- and long-term) to consider in the prioritization task.

1.5.2.3 Evaluation of the workshop

Attendees were asked to complete an evaluation form at the end of the workshop.

SECTION 2.0 WORKSHOP RESULTS

Analysis of the prioritization data involved assigning values to the rankings. The first choice was given a score of 10, the second choice was given a score of 9, and so on.

2.1 Prioritized challenges

A list of 25 challenges emerged from the five working groups. Table 1 lists the top 10 challenges, of the 25 presented by the workgroups, in the order of priority based on overall score.

The focus of the workshop was on solutions, so rather than go into an in-depth review of the challenges, brief descriptions of the top five challenges will be presented in subsections 2.1.1-2.1.5.

2.1.1 FAA consistency

There is insufficient consistency within the FAA, specifically, the interpretation of technical data, its intent, and its alignment with regulatory requirements. Regulatory expectations and requirements continue to change, and

the understanding of the linkage between the intent, the requirements, and the technical documentation can be difficult to maintain. The AEG's oversight of technical publications was identified as the number one challenge facing the operators. One issue discussed enforcement and interpretation of requirements that seemed to be regional, or even specific to an inspector, rather than general and consistent in all offices. For instance, an aircraft (or component) built in Kansas might not have the same documentation requirements and oversight as one built in Georgia.

2.1.2 Content accuracy

Accuracy of technical documentation is paramount in assuring that proper maintenance actions are performed in service. However, integration of OEMs, Supplemental Type Certificate (STC), supplier data, and operator data within the operations environment is also key in delivering on the promise of accurate data (i.e., the right data, at the right time, in a usable format for the environment at hand). The opportunity to address data quality, from the using community's perspective, is in the integration of data delivery, user feedback, and data updates that address the real-time needs of the user groups. Today, organizations have a difficult time applying the right resources, with the right knowledge, skills, and/or system solutions to address the day-to-day issues created by the lack of technical data integration.

2.1.3 Culture of noncompliance with documentation

There are many organizational norms regarding documentation use. A norm that gives tacit approval to ignore technical publications for some maintenance tasks will have negative consequences. This type of norm, perhaps

Table 1. Prioritized List of Challenges

Priority	Challenge
1	FAA consistency (DQ)
2	Content accuracy (U)
3	Culture of noncompliance with documentation (I)
4	Lack of appropriate business case for document issue improvement (M)
5	Industry standards (DQ)
6	Clarity of regulatory requirements (G)
7	Content availability (U)
8	OEM data quality and usability (DQ)
9	No quick and valid measure of document quality (M)
10	Balance production/safety, compliance, quality (I)

Workgroup designators: DQ-document quality; M-measurement; U-user/mechanic; G-government(G); I-industry or management (I).

due to the perception of timesavings, tends to spread to an increasing number of tasks until an incident occurs or additional maintenance costs are realized. Like a bad habit, organizational norms can present many challenges to changing cultures, processes, and tools.

2.1.4 Lack of appropriate business case for document issue improvement

The case can be difficult to make for investing in technical information improvements. Large and small category aircraft OEMS know that adherence to technical documentation regulations is good business. However, integration and management of all technical documentation requirements remains a shared responsibility. The business case justification for investing in improved technical data management requires improved linkage between the cost of compliance and maintaining a safe and efficient work place. Even though there are known costs associated with maintenance errors (delays, damage, personal injury), it can be difficult to correlate savings from cost avoidance items like reduced errors through improved data and data management. Effective data management (i.e., organizational culture where “zero” violations is the goal) and a robust data management investment plan holds potential for all participants to benefit – a win-win scenario for all.

2.1.5 Industry standards

Section 2.1.1 noted the inconsistent application of FAA standards regarding the use, interpretation, and compliance expectations of technical documentation. The case is the same for industry standards. Current Airlines for America (A4A; also known as Airline Transport Association, or ATA) documents capitalize on Standard Generalized Markup Language (SGML). The industry is moving forward with S1000D specifications that use Extensible Markup Language (XML) coding that is conducive to relational databases. There must be a push to move aggressively on such standards, and to let these types of standards to become the guidelines for FAA approval.

2.2 Prioritized Solutions

The five working groups (as noted in the previous section) generated a list of 52 solutions or action items. The top ten solutions, shown in Table 2, are the workshop’s action items for addressing technical documentation issues. Note that there is not a direct mapping between the two prioritized lists, since attendees ranked solutions and challenges separately.

The following subsections, 2.2.1-2.2.10, elaborate on each action item. Workshop discussions were the basis for the final recommendations, with some presented in terms of industry, government, and Individual actions.

Table 2. Top Ten Action Items to Address Documentation Issues

Priority	Action Item
1	Quantify financial loss related to documentation issues (M)
2	Develop/apply methods for evaluating the quality of technical documentation (M)
3	Leverage voluntary reporting to identify specific problems with documentation (I)
4	Improve/create guidance for FAA personnel working documentation issues, especially Instructions for Continued Airworthiness (G)
5	Expand incident investigation to identify details associated with documentation issues (M)
6	Improve integration and linkage of content across maintenance documents -- maintenance manuals, task cards, and illustrated parts catalogs (U)
7	Delegate approval from FAA to industry using established Organization Designation Authorization (DQ)
8	Improve usability of manual format, accessibility of manual, and training on manual use (U)
9	Initiate industry mandate requiring users to address known documentation issues. This applies to all levels of the organization (I)
10	Improve coordination of document professionals from industry segments and government (I)

Workgroup designators: DQ-document quality; M-measurement; U-user/mechanic; G-government(G); I-industry or management (I).

2.2.1 Quantify financial loss related to documentation issues

The highest priority action item is to quantify the costs associated with documentation issues. Airlines do not know the cost of errors associated with legacy documentation systems, and they are currently unlikely to appreciate the potential cost savings from new systems. This is quite natural: People underestimate the frequency and cost of rare events, such as errors that propagate through the system to become incidents or accidents. Workshop participants felt that if industry really understood the costs associated with poor documentation, then they would invest in improving it.

Currently there are limited regulatory reasons that require aircraft or component manufacturers to improve the usability and effectiveness of their documents. Of course, there is market incentive for these parties to invest in radically new documentation systems that make their aircraft more maintainable. However, aircraft and systems are marketed primarily on passenger comfort and acceptance, fuel efficiency, extended inspection and maintenance cycles, environmental impact, and other tangible factors to which a finance department can assign value. There is less marketing appeal in the efficiency and safety gains that improved technical documentation may provide. New generation aircraft have improved on-board maintenance documentation, portable maintenance aids, and documentation to be more compatible with portable computer systems and today's airline operational reality. Such systems are a step in the right direction but are seldom the most appealing factor that separates one new aircraft from the next.

A majority of the U.S. airline fleet average about 12.5 years old. That means there is a legacy documentation system that is not as advanced as a new Airbus, Boeing, Bombardier, or Embraer. It would take very significant investment to review and modify the legacy documentation system. It would be difficult to quantify the safety and financial benefits of a large investment in new technical documentation systems since it would require baseline data on the cost of errors associated with the old system. However, legacy aircraft will remain in the U.S. and world fleets for many years, with the latent errors of poor documentation remaining an unaccounted safety risk.

The bottom line is that, to date, there has not been a good answer regarding the financial – much less the safety impact – of technical documentation. Quantifying the cost of documentation issues may incentivize aircraft operators and suppliers to address technical documentation problems and better inform their solutions. Accomplishing Action Item 1 means that an operator, MRO, or OEM assign costs to maintenance errors attributable

to documentation issues (e.g., reworks, quality escapes, aircraft damage, personal injury). They could also assign safety impact.

The government should consider authoring an Advisory Circular or an information document describing a Cost of Quality (CoQ) program and recommending that industry use it. Participation would be voluntary; however, a standardized CoQ program, such as that recommended by the American Society for Quality (ASQ), could provide a standardized method to collect, cost, report, and analyze quality escapes within the industry. Given that the total CoQ can often be 20-30% of sales, this initiative could have huge ramifications (Westcott, 2006).

When a documentation issue arises, establish the costs associated with time, error, rework, etc. Cost data should include obvious measures associated with documentation issues (e.g., not available, not up-to-date, difficult to use) that contribute to aircraft damage, delays, and in-flight returns, as well as other performance indicators. The main cost is that of an accident, an extremely rare event, but one that can bankrupt a carrier (e.g., Value Jet, PanAm). Such events do not fit well with current accounting practice, nor does it mean that we can ignore them.

Industry Actions

- Develop a formal, standardized method to capture quality escapes.
- Encourage use of voluntary reporting systems to note documentation challenges.
- Design mechanisms to collect all documentation errors/challenges to complete the picture depicted by the voluntarily reported data.
- Assign cost values to errors, delays, etc., from documentation problems.
- Collect and evaluate the number of FAA administrative actions resulting from documentation issues.

Government Actions

- Use Aviation Safety Information Analysis and Sharing (ASIAS) system to identify documentation issues annually.
- Help industry assign safety and financial cost associated with incident reports.
- Encourage voluntary reporting and special consideration for documentation-related reports.
- Train ASAP participants in industry and in FAA to emphasize documentation issues.
- Take administrative action on airlines and manufacturers that produce and use suboptimal documentation.
- Commit to and fund applied R&D to provide guidance and training to those who produce and use documentation.

- Consider authoring an Advisory Circular or information document describing recommending use of a CoQ program within industry.

Individual Actions

- If the documentation is unavailable or incorrect, then engage the engineering and quality assurance departments to resolve the problem.
- Report ALL suboptimal work card or manufacturer's instruction to your management and to FAA.
- Use ASAP and other voluntary reporting systems to highlight the documentation issues.

2.2.2 Develop/apply methods for evaluating quality of technical documentation

What characteristics define *good* documentation? We know that good documentation aids users in performing critical tasks in maintenance and inspection because it reduces error due to misunderstanding and prevents users from ignoring paperwork and failing to perform tasks according to the instructions.

Industry has made some major changes in how technical documentation is delivered to the user. Although there has been an increase in the *diversity* of delivery media, there does not appear to be a commensurate increase in the *quality* of the documentation delivered.

The major airframe manufacturers have studied documentation quality with respect to usability (e.g., using Aerospace and Defence Industries Associations of Europe Simplified Technical English), but the engineers who write technical directions are not necessarily well-versed in the science of writing procedures—neither are the FAA AEG inspectors who write evaluation guidelines or the FAA inspectors who evaluate documents in the field. These groups of users need a valid, reliable, straightforward way to produce and evaluate quality documentation. There is a corpus of human factors literature available, some of it funded by the FAA, on designing paper and computer-based documentation (i.e., Patel, Drury, & Lofgren, 1994; Drury, 1998; Drury & Sarac, 1997; Drury, Patel, & Prabhu, 2000) and tools for auditing human-system mismatches in maintenance (Koli, Chervak, & Drury, 1999).

The methodology for evaluating documentation quality should be applied to new media and recent documentation designs discussed in the workshop that incorporate 3D animated graphics, in particular. The use of sound design principles for documentation as the basis for an audit checklist would help ensure “content validity” of the final checklist. In aviation maintenance, a current example is the checklist for each NDI (nondestructive inspection) technique developed as part of the *Handbook of System Reliability in Airframe and Engine Inspection*

(Drury, 2005). These design approaches and evaluation tools might also support maintenance training.

Furthermore, development of a document evaluation methodology/tool will require valid definitions for all aspects of *quality*, such as the design guidance embedded in existing document design tools. As part of the development process, the methodology/tool needs to be empirically tested to ensure that its output is reliable (i.e., it produces similar results when used by different evaluators or used by the same evaluator across different types of technical documentation) and valid (i.e., the results correlate well with an objective criterion such as comprehension error rates of documentation users). The tool also needs to be designed based on user requirements—easy and quick, and handles multiple forms of technical documentation.

Testing reliability, validity, and acceptability of a methodology/tool for assessing document quality requires actual users evaluating known levels of document quality. Reuse of paper and computer-based documents from prior studies where comprehension error rates have already been measured could reduce the size of the effort. However, for newer media, such as animated 3D graphics, new approaches and additional materials may need to be developed and tested.

Industry Actions

- Commit to use existing guidance documentation for review and revision of technical documentation that is identified as problematic.
- Use voluntary reporting systems to note documentation problems.
- Be willing to collect and evaluate the cost of the errors associated with poor documentation.

Government Actions

- Fund research and development to reintroduce proper documentation practices.
- Create a training course for documentation development and evaluation.
- Analyze the voluntary reporting data to identify the common characteristics for poor documentation.
- Renew Advisory Circulars and other relevant guidance material for industry and for inspectors.

Individual Actions

- If the documentation is unavailable or incorrect, then engage the engineering and quality assurance departments to resolve the problem.
- Report ALL suboptimal work card or manufacturer's instruction to your management and to FAA.
- Use ASAP and other voluntary reporting systems to highlight the documentation concerns.

2.2.3 Leverage voluntary reporting to identify specific problems with documentation

To facilitate company responsiveness in resolving documentation issues, the number 3 solution was use of a FAA/company supported, non-punitive reporting process, with the company taking responsibility for informing the workforce of corrective actions to incentivize its use.

Recommendations regarding Action Item 3 are somewhat related to Action Item 5, as they both deal with improved reporting and collecting of technical documentation deficiencies. Voluntary disclosure programs are increasingly popular as SMS evolve. This is true for the air carrier, general aviation, and MRO environments. Example programs in the U.S. include the FAA ASAP, the new FAA Maintenance and Ramp Line Operations Safety Assessment (LOSA), and the long-standing NASA ASRS. These programs permit personnel to report errors anonymously, usually avoiding any FAA civil action. For instance, a mechanic could use existing government-sponsored programs to report instances of deviations from the 14 CFR Part 43 or Part 121 rule applied to technical publications.

The FAA should create materials to help identify the type of information and level of detail needed in a report to communicate (clear, correct, complete, and concise) a documentation issue. The information should allow categorization of the reported error – to determine if it was attributable to performance, task conditions, accepted practices within the organization, and/or quality of the documentation (e.g., design, currency, and availability).

There are certain tasks that industry does well and other tasks that are more appropriate for government. When the task is generic and all in the industry share the benefits, then it should be a government task. Of course, it is best when there are industry participants on the government development team.

Industry Actions

- Change use of voluntary reporting systems to emphasize documentation issues (FAA R&D can support this effort).
- Encourage voluntary reports about documentation even in advance of an event.
- Pay employees for high value voluntary reports on documentation problems.

Government Actions

- Use ASIAs system to identify documentation issues annually. Transition from data collection to information reporting.
- Encourage voluntary reporting and special consideration for documentation-related reports.
- Train ASAP participants in industry and in FAA to emphasize documentation issues.

- Create checklists for documentation evaluation (Applied R&D effort).

Individual Actions

- Report ALL suboptimal work card or manufacturer's instruction to your management and to FAA.
- Use ASAP and other voluntary reporting systems to highlight the documentation challenges.
- If ASAP does not offer a means to report documentation issues, then report the situation to ASAP manager.

2.2.4 Improve/create guidance for FAA personnel working documentation issues, especially Instructions for Continued Airworthiness (ICA)

Action item 4 is inherently associated with Action Item 2. The issue focuses on FAA personnel who review the ICA documents, which include maintenance manuals, illustrated parts catalogs, and fault isolation/troubleshooting manuals. These are critical documents in a manufacturer's approved documentation package

Tools and training should be developed and applied to empower government and industry personnel who create and validate the technical instructions, presumably based on the evaluation methodology developed in Action Item 2. Industry and government workshops on topics like A4A S1000D would be an excellent start. Accomplishing this involves making it a requirement and funding it accordingly.

Industry Actions

- Commit to use existing guidance for review and revision of technical documentation
- Use voluntary reporting systems to note documentation challenges.
- Strive for standardization among all documents.

Government Actions

- Renew Advisory Circulars and other relevant guidance material for industry and for inspectors.
- Simplify oversight guidelines.
- Assign responsible parties to work the issue.
- Fund research and development to reintroduce proper documentation practices.
- Create training course for documentation development and evaluation.
- Analyze the voluntary reporting data to determine the common characteristics for poor documentation.
- Create special training course for Aviation Safety Inspectors who will work in AEG.

Individual Actions

- Report ALL suboptimal work card or manufacturer's instruction to your management and to FAA.

- When something is wrong, file a report in the Aviation Safety Reporting System and cite a violation of 14 CFR Part 43 13(a).

2.2.5 Expand incident investigation to identify details associated with documentation issues

Current requirements for incident/accident investigations must require a complete root cause analysis (RCA) when it appears “a procedure was not followed.” The cause may be a maintenance error, where a well-documented procedure was not properly executed. Or the cause may be a document-related issue where the instructor was not clear, complete, or correct. Although sufficient for an investigation, the categories are too broad from the standpoint of actionable change to mitigate future risk. As well, existing reporting systems (mentioned in section 2.3) may contain information relevant to an investigation, but it often does not explicitly state what the precursor was to a maintenance error.

The FAA should commit to a research and development effort focused on improving outcomes of formal and informal investigations of maintenance errors and document-related issues by improving the data quality and developing analysis tools, e.g., based on the tools developed in Action Item 2. FAA researchers could assist in determining what the “right” questions are for a reporting system during a formal investigation. They could also create, test, and implement an analysis tool, similar to that created for fatigue risk assessment, to support analyzing documentation-related information output from existing reporting systems. This line of research would apply to the recommendation in section 2.3 for FAA/company-supported internal, voluntary reporting programs.

Industry Actions

- Change current event and accident investigation forms to have a section dedicated to the use of technical documentation. If technical documentation is suspect, then ensure sufficient root cause analyses.
- Create internal procedures for immediate correction of technical documentation any time it may be a small (or large) contributing factor to a safety event.

Government Actions

- Create procedures and training to help event investigators recognize the manner in which technical documentation may have been an contributing factors to an event.
- Ensure that all FAA accident investigations that identify procedures or documentation as contributing factors also ensure that a proper root cause analysis is conducted.

Individual Actions

- Report all detailed information about documentation issues that contributed to an error/event/accident.

2.2.6 Improve integration and linkage of content across maintenance documents -- maintenance manuals, task cards, and illustrated parts catalogs

Today, line and heavy maintenance are accomplished more rapidly and in faster-paced environments. The maintenance data and the manuals that contain the relevant information needed to perform the required tasks include an ever-increasing amount of information. Accessing this data efficiently and accurately has become paramount for the mechanic, engineering, manufacturing, quality, and management staffs to perform their work. Access to the right data, in real-time, on-demand, and in the work environment is more important today than ever.

2.2.6.1 Providing the right access

To provide the right access, accurate links between the required technical information (i.e., maintenance documents, engineering data, quality control data, and maintenance records) is critical in supporting repeatable maintenance actions. OEMs, third party providers, and maintenance data solution providers (along with industry) should look to provide the links between datasets that allow for quicker, more accurate, and repeatable processes for accomplishing the required maintenance actions in the line and heavy maintenance environments.

2.2.6.2 Providing the right tools

Delivery tools should be developed to allow for the single point of use of all relevant maintenance, engineering, and quality data in the accomplishment of required in-service maintenance. This includes access to the required information at line and heavy stations. To go further, today’s datasets (i.e., OEM, Supplier, and Airlines) should address the emerging requirements for real-time, mobile, and point-of-use access to data that the business environment demands in all industries.

2.2.6.3 Providing the right solutions

Finally, integration of data management tools is needed to allow for the inter-linking of required datasets (i.e., OEM, Airline, Third Party, and supplier). Integration of the data through database management offers the opportunity to improve access, understanding, and oversight of maintenance operations for all involved (e.g., OEM, airlines, and regulatory agencies). Integrated solutions for managing maintenance activity will enhance maintenance execution, management, and oversight not achievable by other means.

Industry Actions

- Manufacturers should take the lead and work with FAA AEG to standardize integration/connectivity of documents.
- Evaluate the utility of new technology.

- Seek employee and customer guidance on this topic.
- Obtain corporate commitment to this effort.
- Consider developing a single portal where contents are similarly formatted and easily accessible.

Government Actions

- Coordinate with industry.

Individual Actions

- Give ideas for improved access to data.

2.2.7 Delegate approval from FAA to industry using established Organization Designation Authorization (ODA)

The ODA program empowers private companies to take the formal responsibility for approving their own documentation without extensive oversight from the FAA. With ODA the FAA oversees the process of approval but does not review the details of a company's product technical documentation. The process relieves some of the detailed FAA workload and delay in obtaining an approval. The workshop attendees recommend that the FAA more broadly apply ODA for this purpose.

Industry Actions

- Propose to FAA better ways to delegate authority.

Government Actions

- Capitalize on ODA to a greater extent.
- Create the guidance materials to empower industry for self-approval and to help FAA inspectors to better oversee the Designated Approval process.
- Take actions to improve documentation guidance material. Assign a responsible person and organization. Set timetables for production and adhere to them.

2.2.8 Improve usability of manual format, accessibility of manual, and training on manual use

Accomplishing Action Item 8 requires additional published guidance for all document creators and reviewers. Workshop attendees noted that some instructions are simply "unusable," and procedures have not been sufficiently validated by the manufacturer engineers who prepare the instructions. If so, a review of the validation process and usability assessment is needed at the manufacturer or the operator level, when specific maintenance procedures are written and job cards are created. Regardless, there is an opportunity for improvement.

Industry Actions

- Change voluntary reporting systems to emphasize documentation challenges (FAA R&D can support this effort).

- Take an active lead in building documents that easily plug into more useful systems of delivery.
- Pay employees for high-value voluntary reports on problematic documentation (this is an investment for change).
- Set specific goals for revisions of the problematic documents.

Government Actions

- Train ASAP participants in industry and in FAA to emphasize documentation issues.
- Create checklists for documentation development and evaluation (applied R&D effort).
- Update guidance material and applied R&D results.

Individual Actions

- Report ALL suboptimal work card or manufacturer's instruction to your management and to FAA.
- Push for change as individual maintenance personnel by reporting the problem/issue to the engineering and quality assurance departments.
- Complete an ASRS report to document problem.
- OEM and operator authors need to have basic knowledge of usability and how it applies to technical documentation design and authoring.

2.2.9 Initiate industry mandate requiring users to address known documentation issues

Requests from users for manual revisions are often lumped with other company requests and not addressed in a timely manner. When users do not see timely results from manual revision requests, they frequently give up and create "workarounds" to complete tasks, ignoring deficiencies in the manuals until a problem occurs. The operators and manufacturers must make a renewed commitment to expedite the process to address issues with documentation and consider a minimum time limit that any documentation issue remains open.

Industry Actions

- Revisit (airlines, in particular) the process for timeliness of document revision.

Government Actions

- Hold manufacturers, airlines, maintenance organizations, and individuals responsible for inferior documents that they knowingly create or use.

Individual Actions

- Report bad documentation when you see it. Demand that it be addressed. Actively change the culture!

2.2.10 Improve coordination of document professionals from industry segments and government

The workshop participants were concerned that each manufacturer, operator, MRO, and FAA office seems to be individual entities with limited coordination. There is very little coordination or shared information among the various entities that create, verify, validate, or approve documentation. The group suggests that something like an annual conference would be valuable to all parties. This is integrally tied to setting appropriate standards for technical documentation.

Industry Actions

- Promote an annual gathering of documentation professionals from within company, industry-wide, and government. Invite expert panelists and speakers/trainers to help standardize values and approach.

Government Actions

- Commit to increasing professional training and conference attendance for FAA inspectors from AEG and other documentation roles.
- Create/revise documents and guidance to promote education and standardization.

Individual Actions

- Individual document creators/engineers/regulators should push for the recommendations made in this report.

2.2.11 Challenges and Action Item Summary

Technical documentation is one of the most common problems in aviation, and the solutions are extremely difficult in today's typical culture. Addressing the problem will require significant commitment and investment by all parties. Fixing it means changing a culture. The question remains: Is the aviation industry ready to tackle these challenges?

The ten prioritized action items presented here to address technical documentation issues are not dependent on new or modified regulations.

The manufacturers are willing to alter procedures to improve effectiveness, but such alteration requires an effective reporting system that informs them of problematic procedures, graphics, etc.

The recommendations can proceed as quickly as industry and government are willing to invest resources in the issue. The recommendations can and should proceed in parallel.

The FAA has initiated activity by submitting technical documentation as an important research activity for 2012-2015 funding. FAA divisions representing both GA and scheduled air carriers/MRO submitted requests for support in this area.

REFERENCES

- Avers, K.E., Johnson, W.B., Banks, J.O., & Nei, D. (2011). Prioritizing Maintenance Human Factors Challenges and Solutions: Workshop Proceedings. (Report No. DOT/FAA/AM-11/11). Washington, DC: Office of Aerospace Medicine, Federal Aviation Administration.
- Chervak, S.C. & Drury, C.G. (2003). Effects of job instruction on maintenance task performance. *Occupational Ergonomics*, 3(2), 121-132.
- Chervak, S., Drury, C.G., & Ouellette, J. L. (1996). Simplified English for aircraft task cards. *Proceedings of the Human Factors and Ergonomic Society 39th Annual Meeting*, 303-307.
- Dobbs, D. A. (2008). Air Carriers' Outsourcing of Aircraft Maintenance. US Department of Transportation, Office of the Inspector General, Memorandum to the Acting FAA Administrator, Sept. 30, 2008.
- Drury, C.G. (1998). Case study: error rates and paper-work design. *Applied Ergonomics*, 29(3), 213-216.
- Drury, C.G. (2003). Effective documentation techniques. *Proceedings of the 17th Annual FAA/CAA/Transport Canada Safety Management in Aviation Maintenance Symposium*, Toronto, CA, September 2003.
- Drury, C.G. (2005). Handbook of System Reliability in Airframe and Engine Inspection. Retrieved from <http://www.tc.faa.gov/LOGISTICS/grants/pdf/2004/04-G-037.pdf/Table%20of%20Contents.doc>.
- Drury, C.G., Patel, S. C., & Prabhu, P. V. (2000). Relative advantage of portable computer-based workcards for aircraft inspection. *International Journal of Industrial Ergonomics*. 26(2), 163-176.
- Drury, C.G. & Sarac, A. (1997). A design aid for improved documentation in aircraft maintenance. *Proceedings of the 41st Annual Human Factors and Ergonomics Society Meeting*, Albuquerque, NM, 1158-1162.
- Gawande, A. (2010). *The checklist manifesto – how to get things right*, New York, New York: Metropolitan Books – Henry Holt and Company.
- Giustozzi, D. (2009). *Aircraft Maintenance Manuals Designed for Today*, an unpublished white paper presented to members of the Air Transport Association (now A4A). Mr. Giustozzi compiled a similar list to discuss challenges of maintenance documentation.

- Johnson, W.B. (2010). Maintenance Human Factors Leaders' Workshop Proceedings, *Proceeding of the First Federal Aviation Administration AVS Maintenance Human Factors Leader's Workshop*, Oklahoma City, OK, August 2010.
- Johnson, W.B. & Watson, J. (2001). *Installation error in airline maintenance*. Washington, DC: Federal Aviation Administration Office of Aviation Medicine. <http://hfskyway.faa.gov>.
- Kanki, B.G., & Walter, D. (1997). Reduction of maintenance error through focused interventions, *Meeting Proceedings of the 11th Federal Aviation Administration Meeting on Human Factors Issues in Aircraft Maintenance and Inspection: Human Error in Aviation Maintenance*, 117-121.
- Koli, S., Chervak, S., & Drury, C.G. (1999). Human factors audit programs for nonrepetitive tasks. *Human Factors and Ergonomics in Manufacturing*, 8(3), 215-231.
- NTSB (2003). NTSB/AAR-04-01 Airmidwest dba USAir Express, Flight 5481, Charlotte, NC, Recommendation A-04-13.
- Patel, S.C., Drury, C.G., & Lofgren, J. (1994). Design of task cards for aircraft inspection. *Applied Ergonomics*, 1994, 25(5), 283-293.
- Rankin, W. (2008). Safety management systems and Boeing-related safety activities, presented November 6-7 at the Safety Management System Workshop for Air Transport Industry.
- Sutton, I.S. (2010). *Process risk and reliability management: operational integrity management*. Amsterdam: Elsevier.
- Walker, I.R. (2011). *Reliability in scientific research: improving the dependability of measurements, calculations, equipment, and software*. Cambridge: Cambridge University Press.
- Westcott, R.T. (2006). *The certified manager of quality/organizational excellence handbook, Third Edition*. Milwaukee, WI: Quality Press.

