Maintenance Human Factors at Northwest Airlines

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INTRODUCTION

First, I would like to express my appreciation to our hosts, the FAA and Galaxy Scientific for providing us, as professionals concerned with the maintenance of aircraft, a forum in which to share our ideas and approaches to the complex and challenging endeavor of researching and applying human factors to aircraft maintenance. I welcome this opportunity to update all of you on the progress we at Northwest Airlines are making in using human factors to increase the safety and reliability of our aircraft. As the Director of Technical Operations Training and the Acting Director of Quality Assurance, I am directly responsible for managing and supporting all of our initiatives in human factors.

Before I begin this presentation, however, I want to say a few words about our approach to human factors: we believe that the introduction of a human factors focus in the workplace needs to be an evolutionary--not revolutionary--one. We are starting small, limiting our scope of impact, trying systems and processes out in only one hangar first and with just one group of employees. As we proceed, we will evaluate and re-evaluate our systems and continually modify them to work for us.

OVERVIEW

I would like to begin by telling you about our human factors goal at Northwest and explaining our organizational structure. Then we can look back at what we have already accomplished, where we are now, and where we are headed.

Human Factors Goal at NWA

Our number one goal at Northwest has always been and will always be safety. This isn't going to change. What has changed is that we now view the attainment of our goal through a wider lens, a lens that encompasses the human element. We will now use human factors as a means of achieving our goal and supporting our mission: "to consistently provide safe, clean, technically sound aircraft to support the on-time operation of Northwest Airlines."

All other departments within Northwest view human factors as a means of achieving "zero accidents" as well. Our pilots in Flight Operations use Crew Resource Management in Line Oriented Flight Training and Debriefing (LOFT). In-Flight, which is the flight attendant division, provides general training on Crew Resource Management, and for the past two years has teamed up with pilot Annual Recurrent Training to conduct joint pilot-flight attendant training focused on a specific subject within crew resource management.

Last year all dispatchers and maintenance control staff completed a culture survey, received Awareness Training as part of their annual refresher training, and developed a behavioral model.

Ground Services has taken a different tack: they are conducting Aircraft Damage Investigations (ADIT) to help determine contributing factors to ground aircraft damage and develop corrective actions.

In Technical Operations, we have accomplished a culture survey, developed a behavioral model and implemented an automated maintenance mishap management system. The focus of my talk will be on Technical Operations, but if you have questions about other areas, I will try to answer them.

Human Factors Organizational Structure

The Tech Ops Human Factors Steering Committee (Figure 5-1, appendix) is headed by our Senior Vice President and includes representation from all departments within Technical Operations. Also on the committee are the president of IAM District 143, Marv Sandrin; Boeing's VP and General Manager of Customer Services Division, Fred Mitchell; and the Vice President of Flight Operations and a pioneer in the field of human factors, Dr. Clayton Foushee. The Planning Group (Figure 5-1, appendix), in effect, carries out the directives from the Steering Committee and includes representatives from Flight Operations and the IAM as well.

Maintenance Error Decision Aid (MEDA)

Looking back on what we accomplished last year in maintenance human factors, I am pleased with the quality of our work and the issues we elected to focus on. But intuitively, I believe we could have made greater strides. One drawback of a more cautious, evolutionary approach is that progress is slower and harder to measure.

Northwest was one of the airlines that participated in the MEDA field test effort. Our personnel completed MEDA training in early January, 1995, and investigated 44 incidents between January and August of last year.

Our approach was to start small and restrict the investigations to the Boeing 747 hangar in Minneapolis. This seemed an appropriate place to start because, as you may recall, in March of 1993 a 747 engine disengaged from the wing as the aircraft landed at Narita, Tokyo's airport, causing the airport to shut down for several hours. One of the NTSB's findings pointed to a lack of human factors engineering principles in the mechanic's job instruction cards. Although not all incidents investigated were as severe as that one (and thank goodness, we haven't had any more serious than that!), the tendency was to use MEDA for major errors.

MEDA Results

The MEDA investigations revealed that the kinds of errors we at Northwest were experiencing were similar to those of other airlines and to the industry as a whole (Figure 5-2, appendix). The three major contributors to maintenance errors were information, communication and job instructions.

HUMAN FACTORS QUESTIONNAIRE - TECH OPS

Concurrent with our MEDA efforts last year, we surveyed our culture. With the help of the experts from NASA/UT and Dr. Bob Helmreich, the Flight Management Attitudes Questionnaire was modified and adapted for maintenance technicians. The questionnaire was issued to the 496 maintenance technicians in the 747 hangar in Minneapolis. We had a return rate of almost 85% with over 700 written suggestions and 66% of the respondents providing at least one written comment. The primary areas of concern were ranked in this order: communication, safety, accountability, and technology.

TECH OPS RESOURCE MANAGEMENT

These areas of concern were kept in mind as we worked on developing a model for Technical Operations Human Factors. We wanted our model to complement those already built for Flight Operations, In-flight and the SOC. They were, after all, based on the work of the experts at NASA/UT. Using the pilot model of CRM, we recruited several maintenance technicians to review the model and suggest how it might be tailored to work in the hangars, on the line and in the shops. The result was a set of human factors skills which we want to see used in all areas of Tech Ops and practiced when interacting with other Northwest departments as well as agencies external to Northwest, including the FAA, security, and our alliance partners.

Each human factors skill, which we call "performance indicator", is a clearly defined behavior which can be observed in training and practiced on the job. The performance indicators are divided into four general categories, or "clusters": Communication, Crew Development, Workload Management, and Technical Proficiency.

Communication

The Communication Cluster describes the model behaviors for crews to use in their communications and involves both the clarity of communication and appropriate techniques.

1. **Actively participates in shift turnover briefing.**

The shift turnover briefing includes all information pertinent to completing aircraft repair or maintenance. It addresses status of work done, problems encountered and potential problems. The current shift crew may also recommend solutions or procedures.

Both the current and relief shift crews are responsible for ensuring that all necessary information is obtained for an orderly transfer of responsibilities.

2. Seeks information and direction from others when necessary.

Crew members ask questions and seek information from each other, supervisors, or other Technical Operations personnel about maintenance issues and decisions made. The flight crew, other NWA departments or agencies outside NWA are consulted when appropriate.

Crewmembers recognize personal limitations, such as limited experience on a particular aircraft or aircraft system and actively seek direction or advice on maintenance issues when necessary.

3. Clearly communicates decisions about maintenance or repair done on the aircraft.

Crewmembers clearly communicate information regarding tasks accomplished or in-progress or troubleshooting done. Communication may be done orally or in writing using appropriate documentation. If communication is accomplished orally, crewmembers must also document accomplishment of tasks in the logbook, on the job instruction cards (CITEXT) or in the computer system (SCEPTRE). Communication should include other NWA departments as well as agencies outside NWA when appropriate.

This communication level should be complete enough and provide sufficient detail to allow co-workers and other departments to be proactive in solving problems as opposed to continually playing "catch up" and to eliminate redundancy.

4. Asserts with the appropriate level of persistence to maintain safety and aircraft airworthiness.

Crewmembers state their own ideas, opinions and recommendations. They assert themselves and defend their point of view. Crewmembers use appropriate levels of assertiveness, as required, to maintain safety and aircraft airworthiness. This may extend to other NWA departments or agencies outside NWA.

5. Critiques self and co-workers when appropriate.

Crew members continually assess their own and others' performance to improve operation efficiency and safety. Feedback may be of a positive or negative nature and should be focused on improving the action without attacking the actor. It is specific, based on observation and provided for the purpose of maximizing crew effectiveness.

Crew Development

This cluster describes behavior relating to group interaction and how well the crew works together to ensure operational safety and aircraft airworthiness.

1. **Involves crewmembers in decision making process.**

   Decisions are made in a timely manner taking into consideration all facts available and are conveyed to other crewmembers when appropriate.

   Crewmembers participate in the decision-making process, when necessary, to increase the likelihood of making the most appropriate decision.

2. **Exercises confident authority.**

   The supervisor uses authority in a confident and competent manner, without being autocratic, and acts decisively when the situation dictates.

   Other crewmembers exercise the authority vested in their respective positions, as required to perform their duties.

3. **Copes effectively with operational stress.**

   Crewmembers cope effectively with operational stress and remain calm in critical and high workload situations. Crewmembers recognize the signs of stress in themselves and co-workers and communicate observations to others when safety or operational efficiency is compromised.

   When resources are available, crewmembers seek help in coping with or alleviating stress. They cope with or remove themselves from situations in which stress from a non-operational origin may negatively affect job performance.

4. **Uses appropriate techniques to manage interpersonal and operational conflict.**

   Crewmembers assess underlying problems, identify operational goals, and suggest solutions to lessen interpersonal or operational conflict.

   Crewmembers respect another's viewpoint and use a method of conflict resolution appropriate for the nature and criticality of the problem. They look for jointly determined solutions whenever possible.

5. **Adapts to co-worker interpersonal differences.**

   Crewmembers demonstrate an ability to adapt to different personalities and characteristics.

Crewmembers are respectful of different backgrounds and belief systems. Crew members identify and establish common characteristics as a basis for building an effective work group.

Workload Management

This cluster describes factors in managing workload in order to accomplish needed tasks without compromising safety.

1. Prioritizes tasks to accomplish in timely and effective manner.

Crewmembers clearly prioritize operational tasks. Primary tasks such as an expiring MEL status on an aircraft are allocated sufficient resources before duties such as routine maintenance are addressed. Low priority or non-essential activities such as social interaction do not interfere with more important tasks.

2. Utilizes tools and resources to maximize efficiency and minimize errors.

Crewmembers procure and organize tools and consult appropriate technical manuals or computer systems to perform necessary tasks with the maximum efficiency and safety.

3. Monitors all relevant operational factors to maintain safety.

Crewmembers are constantly monitoring proper use of tools and materials, movement and position of equipment and other operational factors that may compromise safety. The crew uses the information to determine changes in operations and to report them to other co-workers.

4. Manages time to accomplish tasks.

Crewmembers plan sufficient time to accomplish duties. They recognize that time requirements vary by task and allocate accordingly. Flexibility is maintained to allow for handling possible abnormal or irregular operations.

5. Distributes tasks to maximize efficiency.

The crew distributes the workload so that everyone is utilized, while no one is overworked. Each crewmember recognizes and reports work overload in self and other crewmembers.

Technical Proficiency

This cluster describes the technical performance of crewmembers with regard to policies, regulations and the use of tools and resources available.

1. Demonstrates technical skills.

Crewmembers demonstrate proficiency in use of tools, equipment, troubleshooting skills and other processes.

2. Demonstrates knowledge of aircraft systems.

Crewmembers demonstrate working knowledge of applicable aircraft systems and consult technical manuals or co-workers when needed. Crewmembers recognize any personal limitations in performing assigned tasks and procure assistance when necessary.

Whenever sufficient time and resources have been allocated, crewmembers will update and improve skills as needed to perform their job effectively.

3. Adheres to company policies and government regulations.

Crewmembers comply with all company policies and applicable government regulations in regard to both technical and safety issues. Crewmembers demonstrate watchfulness in maintaining compliance among co-workers.

4. Demonstrates knowledge of computer system and manuals.

Crewmembers know how to enter and access data in the computer system (SCEPTRE) and other computer systems. They consult relevant technical manuals and the General Engineering and Maintenance Manual (GEMM) as necessary.

Human Factors Awareness Training

The focus of the Awareness Training module will be on understanding and applying the performance indicators I just described. The four areas of concern identified in our culture survey (Communication, Safety, Accountability and Technology), will receive special emphasis when we introduce the model. We plan to tap the "Liveware" data from the Mishap Management System (more about that in a moment) and our MEDA investigations to cull real-life examples of errors caused by a lack of specific human factors behaviors and use them in our training.

We are working with Flight Operations to complete the Awareness Training module by the end of the first quarter of this year and look forward to implementing the prototype in the 747 hangar in the second quarter.

Task Analytic Training System (TATS)

TATS has been a real success story in our shops. We began using TATS last year and expect the TATS process to continue into the future. Diane Walter from Boeing has been a key driver and supporter of TATS at Northwest and I see from the agenda that Diane follows this presentation. The work force to which TATS has been introduced has received it well. As of today, over 100 TATS modules have been completed in our APU shop, the JT9D shop, the hydraulic shop, the machine shop and the plating shop. As one process which encourages open communication, crew development, workload management and technical proficiency, TATS has proven to be a successful human factors initiative.

Aurora Mishap Management System (AMMS)

In late September of last year, we were provided with a demonstration of the Aurora Mishap Management System (AMMS). The functionality displayed by the system closely coincided with our needs for an automated data collection system. We were favorably impressed with the AMMS for a number of reasons. Primary among those reasons was the fact that AMMS basically incorporates much of the "goodness" designed into MEDA, and expands that basic concept into a very user-friendly tool. Among its uses are the ability to collect data on-line and analyze it automatically; the capability to identify systemic problems; and a feature which assists in developing intervention strategies.

AMMS at Northwest Airlines

AMMS was implemented here at Northwest on 2 October 1995. The Steering Committee directed that its use be restricted to the Boeing 747 hangars in Minneapolis until our processes, policies and infrastructure are fully developed and fine-tuned.

Eighteen investigators, which included representatives from management and IAM labor, were trained on the use of the AMMS laptop PC-based system. The intent was to use AMMS to investigate all mishaps in the Boeing 747 hangars. Some of the mishaps investigated included shift turn-over problems, On-the-job injuries, reworks, late delivery of parts, critical path task scheduling, and job instruction cards. In approximately two months, 116 mishaps were investigated. This fell short of the projected number, but was a marked increase over the number of MEDA investigations.

The collection of error data from these investigations has definitely helped to identify the economic impact of mishaps in our maintenance operation, and has also helped to create a higher level of safety awareness.

Mishap Management System Functionality

One feature of AMMS is the Maintenance Investigator. The Investigator provides a means to conduct new investigations as well as update or view completed investigations. The Investigator also houses the prevention strategy analysis module.

Another feature of AMMS, which we heavily rely on and value, is the INFO base. The INFO base enables us to search on narrative data in the error investigation database and turn this narrative data into statistical graphs. In this way, we can identify systemic problems and begin zeroing in on effective intervention strategies.

The INFO base also contains excellent reference material, such as ICAO Human Factors. We foresee our company policies (such as GEMM) and aircraft/engine maintenance manuals being added to the INFO base for easy reference.

Quick Look Reports

The next several slides reflect the types of AMMS output available and provide a good idea of the system's capabilities for reporting. One caveat before we proceed: the data reflected in these reports is not conclusive; it is used only to indicate areas that should undergo additional analysis. In order, we will view 1) the costs of mishaps; 2) mishaps sorted by functional area responsible; 3) mishaps sorted by the types of task being accomplished at the time of error; and 4) mishaps sorted by contributing software, hardware, environment and liveware (people) factors. The acronym for these factors is "SHEL".

Cost of Maintenance Mishaps

Of the total 116 mishaps investigated, approximately 75% of them have some economic value assigned to them. Several investigations did not have dollar values assigned because the mishaps occurred outside of the target area of investigation. If values *were* assigned to those mishaps, the total would be in excess of $1,000,000. (Figure 5-3, appendix)

As this report indicates, mishaps involving parts is our biggest driver for data collected thus far, with impact on operations running a close second. Mishaps involving parts included parts not arriving on time, wrong parts being delivered, and parts which were out of stock. Dollar values associated with operations are usually calculated on the impact of delayed or canceled flights because the aircraft was late coming out of its check. Although it is not shown here, another module in the AMMS provides a Return on Investment (ROI) for the proposed intervention.

Mishaps by Functional Area

Another way to view the collected data is reflected in this report. Depicted here are the areas or specialties involved in the investigated mishap. From this graph (Figure 5-4, appendix), it may appear that the hydraulic and cabin groups create the most mishaps. We are not, however, jumping to that conclusion. The high numbers from these two groups might be because they have more tasks to accomplish, or it might be because they are more prone to come forward and admit that an error occurred. We intend to follow-up on this type of data and determine the causes.

Mishaps by Task Classification

This report breaks down investigations by the type of task that was being performed when the mishap occurred. Although caution must still be exercised when attempting to draw conclusions from this graph (Figure 5-5, appendix), it does tend to support other data indicators from the perspective of reliability. For example, we have a higher probability of inducing errors in hardware when we are accomplishing removals and replacement of parts and when we are performing check outs of a system.

Mishaps Identifying SHEL Factors

The SHEL factors are part of the Investigator feature of the system. You will recall that SHEL is the acronym for software, hardware, environment, and liveware. In general terms, software is defined as the availability, adequacy, and appropriateness of information. Hardware refers to availability, adequacy and function of aircraft, parts, tools and equipment. Environment refers to availability, adequacy and appropriateness of the maintenance facility or the structure's inside working conditions. Liveware refers to physical, mental, or emotional factors and includes relationships with other persons or organizations.

From this report (Figure 5-6, appendix), hardware and software appear to be areas which merit further investigation. It should be noted, however, that only 40% of the investigations conducted had some type of SHEL response that could be considered a contributing factor. We expect this number to rise as we educate our employees on identifying human factors skills and recognizing them (or the lack of them!) in the workplace.

TECH OPS HUMAN FACTORS - FUTURE

I want to close by talking a little about the future of human factors in maintenance.

I will begin by saying: The future begins today.

- We have a human factors specialist hired who will start work this week. She will begin by observing and absorbing our operations in the 747 hangars.
- We will be expanding the use of AMMS in to other areas of Tech Ops. As needs dictate, the tool will be modified. The Steering Committee has already requested, for example, that a feedback mechanism be built in to the system, so that as data is collected, the responsible parties are automatically pulled in to the loop.
- The use of TATS will also continue to expand. Some of our other shops have requested assistance in building TATS modules.
- Awareness Training will eventually be delivered to all maintenance technicians, support staff, managers and executive management.
- As we revise and create new training programs, human factors issues will be included in them. In the future, human factors will not stand out as a separate focus; we hope to see it become integrated throughout Tech Operations; it will become a seamless part of our culture.

We have begun, BUT we still have a long way to go---

I would like to conclude by saying that while we are proud of how far we have come in such a short time, we still have a long way to go. Some of the issues we will struggle with this next year include:

- Moving our culture from a 'blame and train' one to one which embraces open communication and disclosure of problems and errors.
- Educating our Tech Ops managers and crew chiefs to adopt a more consensual, consultive leadership style and abandon autocratic ones.
- Improving the quality and scope of our investigations to determine "root cause."
- And in today's fiscally constrained environment, articulating the need to our controllers for continued financial support. They, like us, need to keep in mind, that as long as the human element is involved, mistakes are going to be made. Our job has to be to manage those mistakes, learning from them to prevent their reoccurrence and improving our operation to remain competitive.

APPENDIX

Figure 5-1 Steering Committee and Planning Group

Figure 5-2 MEDA Results

Figure 5-3 Cost of Maintenance Mishaps

Figure 5-4 Mishaps by Functional Area

Figure 5-5 Mishaps by Task Classification

Figure 5-6 Mishaps Identifying SHEL Factor