

ATA Specification 113

Maintenance Human Factors Program Guidelines

Revision 2002.1



AIR TRANSPORT ASSOCIATION

Air Transport Association of America, Inc.
1301 Pennsylvania Avenue, NW - Suite 1100
Washington, DC 20004-1707
USA

Copyright © 2002-2003 Air Transport Association of America, Inc. All rights reserved. No part of this document may be reproduced or transmitted by any means, electronic or mechanical, including photocopying and recording, or by any information storage or retrieval system, except as may be expressly permitted in writing by the publisher.

Important Information About This Document

Read Before Using This Document

This document contains recommended specifications that have been developed for the covered topics. ATA does not mandate their use. You must decide whether or not to use the recommendations in this document. You may choose to use them in whole, in part, or not at all.

There may be practices, standards and/or regulatory requirements applicable to your operations that exceed the recommendations in this document. You are solely responsible for determining if such practices, standards or requirements exist and whether they apply to your activities, and for complying with those that are applicable. Such practices, standards and requirements can change significantly over time.

ATA does not guarantee, promise or warrant that the specifications in this document will meet the needs of your operations. This is a determination that you must make and for which ATA is not responsible.

For Additional Information

For more information or to order additional publications, refer to the ATA Publications Catalog, the Web site at www.airlines.org, e-mail pubs@airlines.org, or call the ATA Distribution Center at:

800-497-3326 (U.S. and Canada)
301-490-7951

For Technical Information and Change Submissions

Errata information for ATA Publications is available at the ATA Publications Web page.

For technical information or to recommend an alteration or amendment to this specification, please submit the recommendation and any supporting documentation to ATA:

E-mail: pubs@airlines.org
Phone: 202-626-4062
Fax: 202-626-4181

Highlights

Release History

Revision 2002.1 (March 2002)

Revision 2000.1 (January 2000)

Original Issue (January 29, 1999)

Revision 2002.1 (March 2002)

Location	Description of Change
Chapter 2	Enhanced definition of "Maintenance Resource Management (MRM)"
Chapter 3 and 3-3	Editorial Expansion
Chapter 4-1 and 4-2	Editorial Expansion
Chapter 5-1	Editorial Expansion
Chapter 8	NEW Chapter on ROI
Annex 1	Editorial Expansion

Chapter 1. Introduction

It is well known that Human Factors issues, which can be causal factors, are involved in aviation accidents. The purpose of these guidelines is to set forth voluntary standards suitable for adoption by companies engaged in aircraft and aircraft component maintenance for developing and maintaining a maintenance human factors program to enhance safety and aid maintenance personnel in preventing aviation accidents and incidents.

This guidance material was developed by the ATA Maintenance Human Factors Subcommittee made up of, among others, Human Factors representatives from Airbus, Goodrich Aviation Technical Services, The Boeing Company, Continental Airlines, Delta Air Lines, FedEx, Flight Safety International, Galaxy Scientific Corporation, The International Association of Machinists and Aerospace Workers (IAM), The Federal Aviation Administration (FAA), National Aeronautics and Space Administration (NASA), Northwest Airlines, United Airlines, US Airways, and ATA.

This ATA Guideline does not, in itself, impose any performance obligations on any airline, or any other entity. For this reason, any entity, which contractually performs maintenance for an airline must determine from that airline which provisions of these guidelines, if any, are applicable to the specific situation.

Chapter 2. Definitions

Anthropometry	The science that deals with the measurement of the size, weight, and proportions of the human body.
Audit	A methodical, planned review used to determine and evaluate how standards or requirements are being complied with.
Contributing Factor	A factor or cause affecting human performance, that, if altered, would have prevented or reduced the likelihood of an accident or incident.
Error	Any action by a person or people that results in an unintended aircraft discrepancy. An error may include, but is not limited to, noncompliance with a maintenance program, a civil aviation authority regulation, or a company procedure.
Error chain	A sequence of contributing factors resulting in an error.
Error management system	A system or process to collect, analyze, track, trend, and organize information regarding human errors or mishaps.
Environment	The conditions in which the human, machine, and software "system" must function. It can also mean all of the conditions and elements, which make up the surroundings of an individual.
Ergonomics	The applied science having the objective of adapting work or working conditions to enhance performance of the worker.
Ergonomic Audit	A methodical audit/investigation of the workplace, organization and task that is likely to improve human performance and reduce errors.
Feedback System	The means whereby job performers receive information regarding the quality, effectiveness and timeliness of their work
Human Factors	A field of science and application that studies man's performance in an operational system; incorporating methods and principles of behavioral and social sciences, engineering, ergonomics, and physiology; including the identification and study of variables that influence individual and team performance.
Maintenance Resource Management (MRM)	An interactive process focused upon improving the opportunity for the maintenance technician to perform work more safely and effectively. It refers to an organizational culture that values trust, teamwork, and open communication. The term "MRM" is often applied to, but not limited to formal training, which supports these objectives.
Metrics	A standard of measurement.
Operational Audit	Maintenance procedure checks designed to evaluate the performance of small or large maintenance tasks or processes.
Needs Analysis	Determination of what is required to perform the job and identification of the skills, knowledge, and attitudes are necessary for successful job completion.

Norms	The way work is normally performed in a maintenance organization, irrespective of formal procedures, and generally accepted by the majority.
Performance Analysis	The process that defines the differences between what is expected in a task and what is actually being done.
Prevention Strategy	A measure designed to reduce, eliminate, or control occurrence of accident or incident event.
Self Disclosure	The process by which a certificate holder and/or individual may reveal possible violation of the Federal Aviation Regulations to the FAA with intent to prevent further occurrence of the violation, and with limited amnesty from enforcement action.

Chapter 3. Scope and Placement of Aviation Maintenance Human Factors Programs

Aviation Maintenance Human Factors Programs are developed to effect changes within a system. Whether the program is undertaken to reduce human error, decrease cumulative trauma, increase awareness, or improve efficiency, it should be broad in focus. Systems are dynamic by nature. When a change, even a small change, is made, it has an effect on the entire system. For example, one way to lessen the likelihood of human error in a given task is to train the people involved in a certain way. Other ways to lessen the likelihood or error might be to change the following:

- Aspects of the task . . .
 - o The task elements
 - o The motivation to do the task
 - o The number of people used to do the task
 - o The postures people take while doing the task
 - o The amount of time to do the task
 - o Where the task is accomplished
- Training . . .
 - o That focuses on safety awareness
 - o That improves practice and skills for strengthening MRM culture
- Opportunity to discuss errors in a non-punitive environment . . .
 - o Leads to ability to recognize, trap, and correct errors before they occur

If a program were to focus on just training, workstation design, industrial engineering, or biomechanics, it would miss out on the opportunity for improving the entire maintenance system. An effective program should take into account the various subspecialties within the discipline of human factors. A good reference document is the FAA Human Factors Guide for Aviation Maintenance [FAA98a]. This document breaks down many elements of a program and provides information and guidance on each subject.

3-1. Corporate Commitment and Support

3-1-1. Description and Purposes of an Aviation Maintenance Human Factors Program

The concept and purpose of an Aviation Maintenance Human Factors program is to identify, educate, and apply modern accident prevention fundamentals through systematic processes in an effort to protect people, equipment, property and the environment. A thorough Aviation Maintenance Human Factors program provides an active, on-going prevention education program that continually reviews the interfaces of man, machine, mission, and management. The continual

learning process include the recognition and study of multiple causal relationships surrounding potential and past workplace accidents, incidents, injuries and deaths for the purpose of providing a prevention strategy rather than an after the fact review program.

3-1-2. Benefits of an Aviation Maintenance Human Factors Program

A forward-looking Aviation Maintenance Human Factors Program will provide an organization the framework to preclude or reduce the possibility of loss associated with workplace accidents, incidents, injuries and deaths. It will also provide management the feedback necessary to position the workforce for future growth and improved performance. By identifying the elements affecting human performance and the obstacles to improvement, management will be better armed for strategic planning. Also, when the workforce recognizes the organization's effort to remove hazards, educate and value safety, a natural increase in professionalism, performance and morale should occur. In addition, the general public will value the contribution to the industry and the recognition of safety initiatives.

3-1-3. Support Required

Management support is key to an effective Aviation Maintenance Human Factors Program. Human factors principles need to be identified, understood, educated, applied and written into management policies. In short, it must become part of the company culture starting with senior management commitment. Management must have a thorough indoctrination into Aviation Maintenance Human Factors and an understanding that management is a key to the success of the program.

3-2. Workforce Commitment and Support

3-2-1. Description and Purpose

A vital element of any Aviation Maintenance Human Factors Program is management/workforce cooperation. If the quality of maintenance performed on an airplane enhances flight safety, and quality results from positive cooperative efforts, then it behooves all parties to exert this effort. Positive attitudes produce positive results.

A collaborative approach toward the design and development of an Aviation Maintenance Human Factors Program will result in numerous benefits.

3-2-2. Employee Benefits of an Aviation Maintenance Human Factors Program

Commitment of the workforce toward the success of an effective Aviation Maintenance Human Factors Program will produce numerous benefits, including but not limited to:

- Increased safety
- Error reduction
- Teamwork enhancements
- Development of positive and assertive communication between all parties.

- Maintenance effectiveness

3-2-3. Employee Support Required

Just as all levels of management should provide total commitment and support toward the program, the workforce must also provide their complete support. Numerous cooperative programs currently in place within the aviation industry have demonstrated that there is an un-tapped wealth of information and knowledge within the workforce. The support of this group is a key and vital factor toward the program's success.

Joint management/workforce task groups should be formed to develop and maintain an Aviation Maintenance Human Factors Program to address methods for reducing human error in the workplace.

3-2-4. Education of Program Elements

A common mistake encountered during the design, development, and implementation of change programs is the failure to communicate these changes to the workforce.

The communication process must commence during the early design and development of the program. All information releases must clearly indicate that representatives of both management and the workforce at all levels are fully supportive of this effort. The communications should solicit input from the workforce to their task force representatives.

3-3. Placement of Aviation Maintenance Human Factors Programs

Human Factors practitioners carry out their work by interfacing between the many departments within the organization. For example, they work with the safety department regarding occupational injuries, with the training department on course development projects, and with quality assurance or with line and base maintenance and their support operations to work on programs to reduce human error. The very nature of Aviation Maintenance Human Factors Programs makes fitting them into one department difficult.

The purpose of this chapter is to give examples of locations where Aviation Maintenance Human Factors Programs are placed in different aviation maintenance organizations; it is not to dictate the one best way.

A recent Boeing survey of customer data relating to human factors found that the Human Factors function resided within a maintenance organization as follows:

Quality Assurance/Quality Control	58%
Maintenance Control	30%
Other Departments	12%

Both Maintenance Control and Quality Assurance/Quality Control are typically support organizations. The benefit of a human factors program that resides in a support organization is that it can serve as an internal consultant to many departments within the company without being influenced by the specific organizational culture of those departments.

Placement of Aviation Maintenance Human Factors Program initiatives within any maintenance organization should be

considered, even debated, at length by the organization. Before a program is initiated, a clear goal for the program should be defined and designed to meet that goal. It is much easier to understand the goal of the program if it is specifically stated, e.g., to reduce maintenance error, to improve line maintenance communication processes, etc. To focus only on "awareness" is to under-specify any program from the outset.

A suggested general model for Aviation Maintenance Human Factors program implementation should address the following:

- Program goal statement
- Scope of the effort i.e., what departments will be affected by the program, and for how-long
- What the "tools" of the program will be e.g., error reduction processes, awareness training courses, ergonomics audits, etc.
- What department, function, or focal-point person will have administrative oversight of the program
- Timelines for implementation
- Methods of program evaluation, e.g., surveys, operational audits, division performance metrics, etc.
- Systematic feedback to the affected workgroups to illustrate positive effects
- A recurrent exposure or training function

Chapter 4. Maintenance Human Factors Program Elements

This chapter provides a general description of the different elements of a human factors program and explains options for how they may interact. Additional information related to element implementation are contained within [Chapter 5], [Chapter 6], and [Chapter 7].

Once management and workforce commitment is established, there are several elements to consider when establishing a human factors program. The basic elements are training, error management, and ergonomics. Each of these can be linked with the other two, and to get the most benefit from a human factors program, each should eventually be incorporated.

4-1. Maintenance Human Factors Training

Maintenance Human Factors Training can encompass awareness training, skills training in communication and teamwork (including, for example, assertiveness, decision making, and conflict management) as well as specific human factors training focusing on areas that need improvement.

An organization may want to begin its human factors program with a human factors awareness course for all of its maintenance and engineering personnel. This awareness course should familiarize participants with basic human factors principles and how they can influence their job performance. There are several commercially available awareness training seminars, and many organizations have built their own awareness programs with the help of human factors professionals in the industry. The Federal Aviation Administration has also developed guidance materials for awareness training. These include the Human Factors Guide for Aviation Maintenance [FAA98a], the Maintenance Resource Management Handbook [FAA98b], and the Advisory Circular 120-72, MRM Training [FAA2000], which includes an awareness training curriculum.

Maintenance Resource Management skills training is similar to Crew Resource Management (CRM) training for flight operations personnel. MRM training includes topics such as communication skills, team building, developing assertiveness, workload management, decision making and situational awareness. This training should be more hands-on than the awareness training, with more participation in exercises and examples including external case studies, e.g., the Dryden incident [Mohansky92] and personal or in-house studies.

Once maintenance error investigation data identifies specific human factors-related areas that need improvement, more focused training should be conducted in those areas. An example of this might be training on how to perform shift turnover procedures. Once this specific training is accomplished, audits may be used to determine its effectiveness.

4-2. Maintenance Error Management

Central to the maintenance human factors program is an error management process that includes both proactive and reactive elements. The reactive element includes error reporting, and structured mishap investigation. It should seek to identify causal factors connected with the mishap and recommend systemic solutions. The proactive element includes decision making and conflict management processes to detect errors and prevent them in real time. The error detection and prevention process should be such that it is simple to implement, and consistently applied. It should use communication and decision making techniques consistent with Maintenance Resource Management (MRM). Both proactive and reactive processes should be such that each is used as an opportunity to solve systemic problems and not to

punish a particular individual.

To succeed with either the proactive or reactive element, trust is needed from all parties.

The maintenance error reporting and investigation process, when applied in the above sense, will yield data regarding the type of mistakes made by the maintenance personnel as well as the type of errors prevalent in the system. Initially, this may be done using a manual process, but eventually as more data is collected, it may become necessary to incorporate a computerized data analysis tool. There are a few commercially available maintenance error data analysis tools, and some organizations have developed their own with good results [Marx98]. See [Chapter 6] for additional information.

Once an organization has started to analyze data for contributing factors, it is very important to implement prevention and/or intervention strategies to keep the errors and events from recurring. Interventions can be based on the analysis of data for just one event and error, or more global interventions can be developed based on the analysis of data across several events and errors. An example of an intervention based on one event would be a revision to a task card. An example of a more global intervention based on an analysis of several events would be additional technical training on a specific airplane system for an entire department.

A proactive error management process consistent with MRM concepts, and one that has been used to prevent mishaps, is the "CAP" or "Concept Alignment Process [Patankar99]. This is a simple process that can be used to resolve inconsistencies in knowledge held among individuals, departments, and even organizations. Six steps illustrate a simple-to-follow process to resolve differences in knowledge, and to minimize the reoccurrence of similar differences. A *concept* is defined as knowledge or information expressed by one person or party, which is either affirmed or challenged by another. If a difference between the points-of-view is stated, it is the person or team's responsibility to seek validation for the *concepts* from an independent third source. If one *concept* can be validated and one cannot, the validated *concept* shall become the working *concept*. If both can be validated, the choice of which becomes the working *concept* is up to the most senior technician, who is typically expected to choose the safest or most conservative course of action. Often in using the CAP, the mechanics, management, and flight crew will investigate the cause of the difference in the *concepts* and recommend appropriate changes. Changes have been made in operating policies and procedures, maintenance manuals, and other documentation as a direct result of this process.

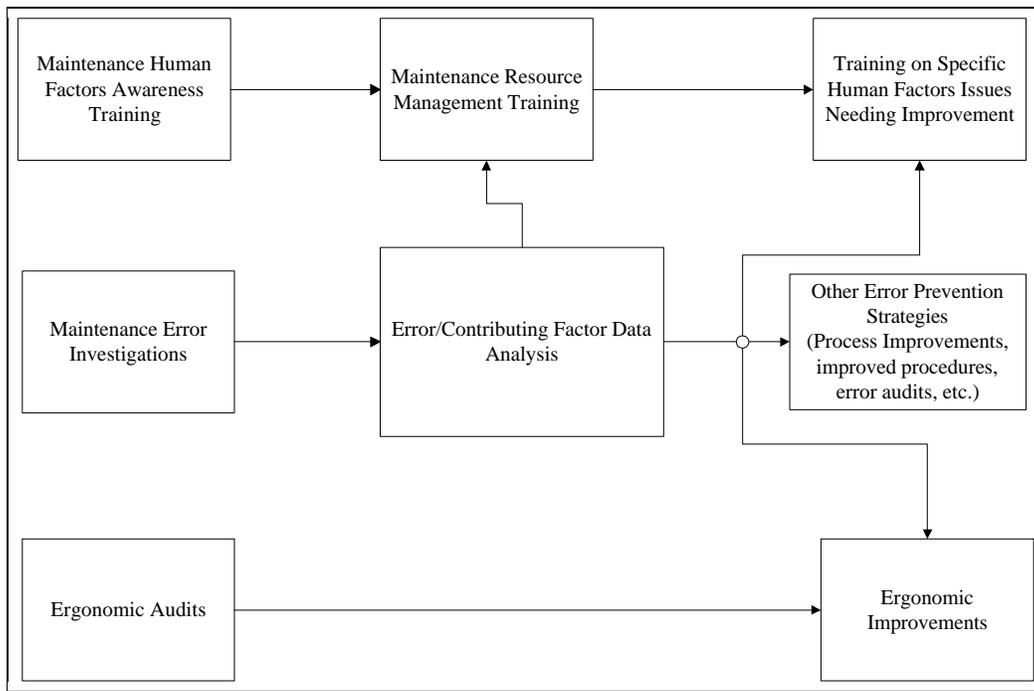
4-3. Ergonomics

For a complete maintenance human factors program, ergonomic principles should be utilized and incorporated into the maintenance work environment. First, ergonomic audits should be conducted to determine what opportunities there are for making improvements to this working environment. Next, improvements need to be made and their impact needs to be monitored.

4-4. Program Element Interaction

The following block diagram shows how the basic elements discussed above might typically interact with each other within a maintenance organization. This diagram is not intended to be the only example of how the programs can interact. For example, some organizations have used their own maintenance error investigation results as a part of their awareness training. Also, having maintenance human factors awareness training first may help assigned maintenance staff to become more proficient error investigators.

Figure 4-4.1. Model of Typical Human Factors Program and How the Basic Elements Interact



Chapter 5. Program Development - Training

Training is a vital communication vehicle for the implementation of a Human Factors program within the Maintenance organization. For this reason, the program should be developed and implemented utilizing a sound instructional development process. A preferred method is the Instructional Systems Design (ISD) model as it places a strong emphasis on developing a program that fully meets the end user's needs as well as incorporating extensive user testing during the design and development phases [Taber97]

This document will address program development using the ISD model, although other instructional development processes may be used if they better fit your organization's culture or available resources.

As identified in [Chapter 3], a crucial element of an Aviation Maintenance Human Factors Program is management/workforce cooperation. A collaborative approach towards the design, validation, adoption, and implementation of the program will result in a well-rounded, mutually accepted tool for human factors training.

Once initiated, the training, in whatever format, must be an evolving and on-going process. Historical data strongly suggests that positive cultural change takes place only when an organization supports and reinforces the values espoused in the training program.

5-1. Needs Assessment/Analysis

The aim of this step in the process is to determine the goals and objectives of Human Factors training as well as the needs and constraints of the customer base (organization and trainees).

The goals and objectives of MRM training should be consistent with the overall Maintenance Human Factors program in which it is an element. In some cases, Human Factors initiatives may be effectively linked. For example, data from one's error management system may help prioritize safety issues to be incorporated into the MRM curriculum. Similarly, incorporation of human factors principles into briefing policies may be accompanied by MRM training for effective communication. Training is only one type of error prevention strategy, but it is an important front-line defense against human error. As with other elements of the Human Factors program, it requires both corporate and workforce commitment and support.

Identifying the needs and constraints of the user group helps to focus MRM training on known problem areas within the organization. It helps to tailor training content to specific workforce attributes, e.g., experience level, training requirements, skill mix and to specific issues related to the workplace, e.g., norms, new policies, procedures, technologies, change in resources.

There are at least three broad categories that can be applied to human factors training;

- Initial training that provides an introduction to MRM concepts
- Continuous training that focuses on the practice and refinement of MRM skills
- The integration of MRM skills and principles into technical training.

5-2. Design Phase

This step further refines the training goals and objectives in order to select content as well as instructional and evaluation strategies for each major topic identified in the needs analysis. Consistent with the ISD process, training developers should clearly define pre-requisite knowledge and skills, as well as standards for the desired training, post-training knowledge and skills. On this basis, both individuals and training programs can be evaluated with respect to the learning objectives stated.

At this point the selection of media and media mix should be considered so that the media that best suit the learning process can be utilized. In addition, decisions regarding the feasibility of using off-the-shelf products and/or developing one's own training materials.

Interaction is an important part of the training program. Although lecture is necessary to insure the trainees are at an equal knowledge level in basic human factors terminology and concepts, it is equally important that the trainees become directly involved in the learning process.

Exercises should be developed which are consistent with the basic curriculum of the program and which promote trainee involvement. Some exercises may appear "light" in application, but can directly support the goals and objectives of the basic curricula. Visual media also support the program's curriculum. "Shock" videos have a profound effect on the trainee; however, they must be incorporated into the program consistent with the topic of discussion and have the ability to tie in directly to the job performance of the attendees.

5-3. Basic Curriculum

The basic curriculum may be organized into subject matter areas that can be applied in both human factors awareness and skills training. The subject matter areas can be further organized into individual modules. Typical candidate modules may include maintenance human error, error chains and contributing factors, verbal and written communication skills, teamwork, leadership, norms, decision-making, situation awareness, and stress management. Modules are then prioritized and scheduled for development. Media selection may be further defined at this step in the process. Sample curricula may be found in the FAA MRM Handbook [FAA98b] .

Delivery of the training program may involve the use of professional instructors, facilitators selected from management and the workforce, or other personnel as appropriate to each individual organization. Regardless of the position of the delivery people, they must be credible and accepted by the trainees.

The use of accident/incident case studies to illustrate particular human factors modules has been found to be a useful teaching tool. These are particularly effective if the case study is from the trainee's own organization, with due consideration for anonymity.

5-4. Prototype

The prototyping of the program includes:

- Delivery of all training materials in whatever media were selected during the design phase

- Training of facilitators
- walk-throughs of all sections of the program to insure that the flow of material is correct and all learning objectives are supported.

Meetings should be held and feedback solicited from facilitators, potential students, management, and subject matter experts.

5-5. Validation

Validation of the program occurs after the prototype modifications and testing have been accomplished. This includes delivery of the entire program in a typical training environment. All of the training materials should be used and trainees should perform all of the course exercises. Meetings should be held to discuss the evaluation of the prototype in an effort to fine-tune the program. A continuing evaluation process should be established to insure the program objectives are being met.

5-6. Adoption

Adoption is the scheduling and formal announcement of the human factors program. It is important that senior members of the company management team show strong support of the program. There should be consensus on all aspects of the training by all participants of the development team (designers, validation team, facilitators, etc.).

Prior to implementation, the nature and scope of the program should be communicated to the workforce. The purpose and goals of the program should be clearly stated so that misunderstandings about the focus and implementation of the training program can be avoided.

5-7. Implementation

The implementation phase is the actual roll out of the training program and is usually done in stages or steps with groups based on need, work assignment, or geographic location. This allows the continuing evaluation of the program and promotes the program by demonstrating positive results.

The entire maintenance organization should attend these sessions, with emphasis on cross-functional training groups.

5-8. Trainee Evaluation

It is important to evaluate the trainees' comprehension of the course material. This may be done by any means deemed appropriate and should be done at the conclusion of the training program as well as at later dates in order to determine effectiveness and application of their training. Examples of trainee evaluation measures include:

- Trainee attitudes and human factors knowledge
- Trainee reaction to the class
- Trainee performance on the job after training.

5-9. Program Measurement

It is important to identify or develop valid and reliable processes for measuring training program effectiveness. Pre-training baselines are needed for making post training comparisons. Because there are multiple ways to assess program effectiveness, it is advantageous to collect a variety of measures when possible.

Measurement data may be acquired through various means: surveys, observations, and existing organization metrics, e.g., on-the-job injuries, ground damage incidents. [Chapter 6], Error Management, provides a source of information to measure the program's effectiveness. In addition, it is often useful to collect data at specified intervals in order to assess whether effects are short vs. long term, immediate vs. slow to appear, etc.

Facilitator evaluations should be conducted as part of the overall feedback loop. See [Section 5-10] for additional information.

5-10. Feedback

Feedback is a valuable part of the MRM training program that allows the end product to influence the training program in a constant cycle of evaluation and improvement. This feedback may be in the form of class and facilitator evaluations, on the job evaluations of trainee's performance, or the achievement of organizational goals. The important thing is that it be honest and that it be heard and allowed to impact course content and implementation where needed.

Feedback that is related to topics covered in the course or brought up by the trainees in the course of the training should be addressed by the appropriate personnel at the first opportunity and the information relayed to the trainee as soon as possible. This direct feedback channel will do much to enhance the credibility of the training program. Examples of good feedback channels include company newsletters, bulletins, e-mail, case studies, success stories, etc.

Chapter 6. Program Development - Error Management

6-1. Needs Assessment/Analysis

The growing international focus on maintenance error reduction strategies has made many new investigation, analysis, and prevention/intervention strategies available to the maintenance organization. The challenge, therefore, is to build an error management program that is properly tailored for the environment in which it is to function.

Appropriate attention must be given to establishing an error threshold in order to define an error management program and to determine what resources and tools are required to support it. A low threshold error management program focusing on frequently occurring or common errors such as misdrilled holes would obviously require additional resources to conduct investigations and a large capacity analytical tool to track error data. On the other hand, a program with the high error threshold of investigating only major events reported to the FAA may require few resources, but would not collect sufficient information to identify trends before they lead to a significant error. A typical approach of successful maintenance organizations is to initially set a high error threshold and, as resources are developed and the process of investigating and analyzing errors becomes more efficient, the error threshold is able to be set at a lower level. Each maintenance organization must therefore establish its program in consideration that initial results may be inconsistent or minimal, but continued development of the program will further the ultimate goal of reducing errors and maximizing safety benefits.

6-2. Program Design

The design phase of an error management program should consider the following:

- Who should oversee or administer the program? [Section 6-3]
- How should errors be investigated? [Section 6-4]
- How should investigation results be validated? [Section 6-5]
- How should error data be tracked and analyzed? [Section 6-6]
- How can prevention/intervention strategies be implemented to prevent errors from recurring? [Section 6-7]
- How should results of the program be measured? [Section 6-8]

6-3. Program Administration

Although the error management program is best facilitated through a single support group, the success of the program will depend on active support of and participation in error reduction activities by all members of the maintenance organization. Individual responsibilities of positions or departments should be determined in the design phase. It is recommended that a formal program description be generated to include assignment of responsibilities that ensure the expectations are understood and implemented. Responsibilities inherent with an error management program that may be considered for assignment include:

- Senior management support of the program to include participation in periodic formal review to ensure

involvement of responsible parties.

- Workforce representatives to support the program including participation in periodic formal review to ensure involvement of responsible parties.
- Quality Assurance/Flight Safety Department co-ordinate and schedule special audits, inspections and investigations.
- Maintenance Department resources participate in audits, inspection and investigations.
- Maintenance, Inspection, or Engineering, as appropriate, initiate, develop and implement prevention/intervention strategies.
- Quality Assurance/Flight Safety Department collect and analyze collected error data .
- Quality Assurance and Maintenance provide program results to Training Department for curriculum additions or revisions.
- Management/Human Resources implement disciplinary practices that are conducive to open and honest error disclosures by maintenance personnel.

6-4. Error Investigation Process

The error investigation process selected is of significant importance to the overall success of the error management program simply because it reveals the problem area. The means to collect the information surrounding an error may be based on a standardized form, on a computer database, or a combination of the two. The investigation may be conducted by self-reporting, by a single investigator, or by a committee. A great deal of research has been undertaken by airlines, regulatory agencies, and academia to evaluate existing investigative approaches and develop new ones.

Two examples of investigation approaches that focus on contributing factors to human error caused events are:

- Round Table - The Round Table essentially uses a group investigative approach. The employee involved in the error discusses the factors of the event with the Round Table committee. The round table process may not record data onto any type of permanent investigation record. Rather, the round table committee, upon hearing the testimony, will assign action items and take corrective action based upon its internal committee discussions. A typical make-up of the round table committee includes a labor representative, management representative, and local FAA representative.
- MEDA (Boeing) - Maintenance Error Decision Aid (MEDA) is a form based investigative tool. An investigator who is trained based on a program developed by Boeing, is assigned to investigate an identified mishap. The MEDA form provides a standardized format for the investigator to consider contributing factors and to assess their relationship to the error. In addition, the standardized format facilitates the collection and tracking of data regarding what may otherwise appear to be a wide array of unrelated errors. This information can be used to facilitate the necessary changes in support of the maintenance technician.

Establishing an awareness of other developments in human factors investigation techniques can be accomplished by participating in industry working groups and symposia focused on maintenance safety. The Air Transportation Association, Federal Aviation Administration, National Transportation Safety Board, and The Boeing Company have all sponsored efforts in this area and are willing to provide information by mail or through Internet sites.

Regardless of what process is used to investigate human errors, it is essential to the success of the program that all affected

members of the organization are aware of how and under what conditions investigations will be conducted. Clarification or revisions to existing company disciplinary policies may be necessary to facilitate self-reporting and willing cooperation by personnel who participate in the error reporting and investigation process. This policy clarification/revision should serve to generate a non-threatening environment and encourage open reporting. A successful maintenance safety culture should recognize that errors are normal, and that the investigation process should always focus on factors that contribute to maintenance errors, not the person or the discrepancy. Therefore, a structured disciplinary policy is advisable that recognizes the importance of obtaining information over punishment, but does not tolerate deliberate or reckless unsafe actions.

6-5. Validation of Investigation Results

If the investigation is successful in identifying human factors oriented contributing factors, a validation process should then be conducted to confirm the findings and reveal how widespread the problem is. If an error is truly isolated to a maintenance crew or individual, appropriate prevention/intervention strategies would be far different than that for problems which are determined to be systemic. Isolation of a recurring maintenance error to a specific part of a maintenance program, or verification that it exists company-wide, is critical to the success of the design of the intervention strategies. Validating investigation findings, however, must be focused on the contributing factors—not the error itself—and routine information collection techniques including written statements and incident orientated investigations will quite often prove to be inadequate.

Special audits, inspections, and evaluations may be used to form the basis of the validation process. Validation techniques fall into the following categories:

- Unscheduled “FAA type” audits and spot checks, using FAA guidance and checklists, conducted by a small team of individuals comprised of both Quality Assurance and maintenance personnel.
- Maintenance procedural checks, called “operational audits” designed to evaluate the performance of specific maintenance tasks.
- Focused scheduled system audits patterned after C.A.S.E. procedures and checklists that are not only scheduled on a normal recurring basis, but are tailored around issues identified during error investigations.
- Ergonomic audit. See [Chapter 7] for further information.

6-6. Data Analysis

After an error is investigated and the event data is collected, there must be some process for analyzing the data to determine the extent of the problem as well as to determine a prevention strategy. Analysis can occur at two basic levels. First, single events can be analyzed to determine if preventative strategies can be developed stemming from one particular mishap. Analysis occurs because the organization does not want this particular mishap to occur again or it wishes to prevent another entire class of events through investigation of this single event. The second type of analysis involves the review of multiple mishap records in order to spot trends and to develop corrective actions that may apply to systemic contributors to error [Marx97]. As the amount of data collected grows it becomes immensely important to track, analyze, and trend numerous error related facts and resultant contributing factors, including: time and place of incident, training of personnel involved, documentation used, task turnover, etc. If the error threshold is set high and relatively few investigations are conducted, computerization may not be necessary to manage the data. Data basing, however, can be beneficial in large organizations where many users require access to the investigation data for corrective action purposes and where the number of investigations conducted exceeds the reliance on the support staff’s memory. Computerizing the investigation process has also been shown to assist greatly in the investigation documentation process by using advanced

programming and search concepts to simplify the entry of standardized descriptive data. This assures more accurate categorization and, therefore, retrieval of contributing factors trend data.

Some examples of data systems that have been developed and are in use are as follows:

- BASIS - British Airways Safety Information System; Developed by British Airways to store and manage discrepancies relating to flight and maintenance events.
- TEAM - Tools for Error Analysis in Maintenance; Developed by Galaxy Scientific. Follows MEDA format.
- AMMS - Aurora Mishap Management System: Developed by Aurora Safety and Information Systems, Inc. PC based investigation and analysis system
- BFG - BFGoodrich Error Reduction Program: Developed by the Maintenance, Repair, and Overhaul group of BFGoodrich Aerospace. MEDA formatted database that provides error analysis/trending and corrective action follow-up.

6-7. Prevention/Intervention Strategies

The commonly understood objective of every error management program is that once an error is investigated and the contributing factors are identified, prevention/intervention strategies should be developed. Use of investigation data can provide the validation for new or revised practices, procedures, tooling, MRM and technical training or any other factors that have an effect on maintenance errors. Again, an essential element is full endorsement of the prevention/intervention strategy process by management. Without this management's visibility, the error management philosophy may not be taken seriously by the work force. Periodic formal review by management to evaluate the completion status of prevention/intervention strategies is necessary to maintain participation.

Participation in and accountability for the development of the prevention/intervention strategies should reside with the technical departments cited in the finding or concern. The plan should then receive management scrutiny as well as a follow up review after implementation. Each prevention/intervention strategy should include the following elements:

- Identification or description of the error
- Analysis of objective evidence obtained during the investigation and validation phases to determine the contributing factors to the error.
- Identification of planned corrective steps to address the factors contributing to the error.
- Implementation schedule, including a time frame for putting corrective steps in place.
- Identification of individuals or departments responsible for implementing the corrective steps
- Follow up status reporting requirements.

6-8. Program Metrics

In a busy maintenance organization, there is no greater waste of resources than prevention/intervention strategies that do not solve problems or will not be used. To ensure that the error management program is providing positive results, the organization should publish and distribute information describing program performance.

Preparing metrics information does not require complex data analysis procedures, nor should it be confused with an airline reliability program. It can be as simple as a bar chart plotting the number of like errors against time. The primary objective is to ensure that improvement, or lack thereof, is visually evident.

Examples of sources of metrics data include the following:

- Internally identified pre-delivery discrepancies
- Post delivery operational performance
- Crew reported maintenance discrepancies (logbook items)
- Records accuracy tracking through audits
- Regulatory audits with predetermined criteria

Chapter 7. Ergonomics

The purpose of this chapter is to provide an overview of the relationship of ergonomics to the other elements of a typical human factors program. The objective will be to provide the user with the resources to identify ergonomics-based interventions to human performance problems encountered.

In the United States, the terms “Human Factors” and “Ergonomics” are often thought of as being synonymous. However, there are many who distinguish between the two by saying that “human factors” deals with the psychological and social aspects of a given work situation, e.g., sensation, perception, motivation, reaction time, and “ergonomics” deals with the more physical aspects of the situation, e.g. lifting, repetitive motion, awkward postures.

Ergonomics as defined in [Chapter 2] of this specification is:

"The applied science having the objective of adapting work or working conditions to enhance performance of the worker."

The primary focus of ergonomics is on the recognition that humans have physical and psychological characteristics that must be considered if the human is to be effective in the performance of his/her job. There are a number of benefits to applying ergonomics toward solving workplace problems:

Most, if not all work situations involve some interplay between physical and psychological issues. Humans may work in groups that have to deal with deadline pressures, awkward postures, external stressors, poorly written procedures, and the inadequate tools.

Working to increase the “fit” between the workers and the work using just physical ergonomics, or just psycho/social human factors, will not address all of the contributing factors to the problems within a given situation.

Every work situation has constraints attached to it. There may be no way to change a procedure, or it may be cost prohibitive to change the type certificate of an aircraft to make maintaining it more “user friendly.” Using a more “holistic” approach allows the freedom to deal with constraints by looking at the physical, psychological, and social parts of the problem.

As an illustration, a problem that may manifest itself in an “ergonomic way,” (workers who must get in to awkward postures to lift heavy items), may be caused by a “human factors” issue (an organizational culture that does not allocate resources to maintain equipment to aid in accomplishing the task with less physical effort).

7-1. Needs Assessment/Analysis

Ergonomic analysis often includes discussions of models of system performance such as the Software-Hardware-Environment-Liveware (SHEL) (International Civil Aviation Organization - ICAO Circular Human Factors Digest No. 1 "Fundamental Human Factors Concepts", Circular 216-AN/131) [DeGreen70], or People-Environment-Actions-Resources model.[Johnson98]. These models help to explain the many factors that can have an impact on how and why we do what we do. These types of models can be very useful in analyzing and working to resolve current problems. Often, the term "**ergonomic audit**" is used to describe the process of evaluating the human factor/ergonomic influence in a situation. Ergonomic audit can also be taken to mean that some form of problem or undesirable condition has been identified and an audit has been undertaken to find possible intervention or prevention

strategies.

Human Factors/Ergonomics professionals look at a problem from two viewpoints in order to determine whether to *fit the job to the person and or fit the person to the job*.

Whether using a “model” for the basis of an analysis, or just looking for some kind of structure to help get started, there are several relevant categories that should be understood when trying to apply ergonomic interventions:

- The People Involved: How do people interact and behave in groups in relation to the work process and task?
- The Tools and Technology: How are tools and technology used? How do they affect the users’ ability to do their job?
- The Organization: How does the organization affect the workers’ ability to do their job?
- The Work Processes: How do the written procedures and norms affect people and the quality of the work products?
- The Task: How does the task affect the workers' ability to do their jobs?
- The Environment: What affect does the physical environment have on the workers and the job?

7-2. Ergonomic Goals

The goals of ergonomic interventions should be understood and identified. The goals of the ergonomic audit should be to determine the benefits of an intervention. It should be noted that the goals of an ergonomic intervention are not one-dimensional; i.e., several objectives may be achieved through an intervention. A few possible objectives for the intervention could be:

- Reduced error
- Fewer injuries or illness
- Fewer health problems
- Increased productivity
- Higher quality

7-3. Ergonomic Interventions

Ergonomic interventions can be categorized in a number of different ways, but should include consideration of the following elements:

- Reduction of work-related injuries and hazards
- Reduction of musculoskeletal risk factors including, but not limited to repetition, forceful exertion, awkward posture, vibration, mechanical stress, or static stress
- Enhancing safety in design of job aids and tasks

-
- Employing user-centered design principles
 - Considering anthropometric factors in workstation design
 - Considering primary senses (vision, hearing, taste, smell, tactile)
-

7-4. Ergonomic Intervention Example

The best way to illustrate how a set of ergonomic interventions can be applied is to provide an example:

*Inspector John Doe missed a crack on an inspection. This crack was later found and corrected. Traditional investigation into a mistake like this would stop at assigning blame to the inspector. An **ergonomic audit** would take this inquiry further to analyze why the inspector failed to detect the crack. Investigative findings might include:*

- *There have been seven past cases of missed cracks at this work area*
- *The inspector involved was newly assigned to this particular fleet*
- *There were no safety rails around the aircraft in the area to be inspected*
- *The area to be inspected was on a part of the aircraft that was not easy to get to (the inspector got into an awkward posture to get as close as possible to the area)*
- *There was a lack of detailed procedures for this inspection*
- *The inspection was done under a tight deadline (overnight check, aircraft needed for revenue service the next morning).*
- *A single inspector performed the inspection with one 35-minute break for rest during an eight-hour shift*
- *Two of the seven inspectors on the crew had family problems that were not resolved-resulting in high absenteeism and increased workload for the remaining inspectors*
- *The aircraft was outside and it was quite rainy for the shift*

The application of human performance principles in this situation, using such models as SHELL or PEAR for instance, suggest ways of dealing with some of the problems that present themselves as well as the constraints of the situation:

7-4-1. People

Are a large percentage new to the work group?

What training are they given to help them become familiar with their new assignment?

Are procedures written to help newly hired or newly transferred workers do their job?

Is the pressure to get the aircraft out actual or perceived?

What, if any, Personal Protective Equipment (PPE) are the inspectors wearing?

What is the impact of the awkward postures on the inspector?

What are people limitations?

7-4-2. Tools and Technology

Is there a better way for inspectors to get up close to the area?

Are there tools to help inspect the area?

Is there a technology that could help make the crack more visible to the inspector?

What tools are available to help inspect the area?

What is the condition and calibration of tooling?

7-4-3. Organization

Is there pressure to get the aircraft out?

Is that pressure the result of unrealistic scheduling of the check or task?

Is there a requirement for safety rails?

What PPE is required?

Who purchases the PPE (the organization or the workers)?

Are there qualification requirements to complete the task?

7-4-4. Work Processes

Are inspection processes or procedures accurately documented and known by the workforce?

Does the inspection require use of written criteria to determine pass/fail?

Is it standard for the inspectors to perform the inspection outside?

Should workflow allow for more repetitive breaks or rotating personnel?

7-4-5. Task

Does this inspection need to be performed at this point in the check?

Is there a better place in the maintenance program for the inspection? (perhaps when the area is more completely disassembled)

Are there norms for doing this task that have not been explained to the new inspector?

Is the procedure an adequate depiction of the way the job is done?

7-4-6. Environment

Are there extremes in the weather during certain times of year or year round?

Can this work be done in another area where weather would not be as much of a factor?

Can this area of the aircraft be shielded from the elements while this work is being performed?

In the answers to these and more questions, people responsible for the implementation of human factors/ergonomics interventions would be able to suggest several ways to reduce error and the risk of missing a crack. In doing so, they will also work to reduce the risk of injury.

Examples of ergonomic interventions in this case could include:

- Redesign the procedures using a group of inspectors both new and experienced with the fleet.
- A familiarization training module for people new to the inspection force or aircraft
- Design a new technology to enable inspectors to see the area and do close inspection from a safe and less awkward position
- Design a harness to provide the inspector with a safe support close to the work
- Inspect the area when it is more accessible
- Do the inspection in a hangar during a more in-depth check
- Design a canopy for the workers to be under if the work is performed outside; provide appropriate lighting for the task

An excellent starting point for ergonomic audit information is the FAA Human Factors Guide for Aviation Maintenance 3.0.[FAA98a] It provides an ergonomic audit checklist that can be a starting point for anyone desiring to begin a structured evaluation of the workplace.

7-5. Validation

After ergonomic interventions are identified and user-centered principles applied, then the applicability and effectiveness needs to be validated with a representative sample group. The most common ways to perform this validation are:

- User testing

- Organizational metrics

In user testing, a number of parameters must be considered to ensure that the testing is representative of the user population. Factors such as history with the system/task, training and qualifications, linguistic ability, knowledge level, age, gender, physical limitations and capabilities, and attitudes or motivation must all be considered when performing user testing. Failure to adequately identify one or more significant constraints may undermine the long-term effectiveness of the ergonomic interventions.

The ergonomic interventions may be tracked against reliable organizational metrics that can be directly tied to their implementation. Workplace injury, lost workdays, reduced re-work, reduced ground damage, etc., are all measurable with regards to the effects of ergonomic interventions.

7-6. Adoption

Often, the adoption of ergonomic interventions will be dependent on resource availability. Justification for resource expenditures may depend on a cost benefit analysis that can be made for adoption of the solution. If the intervention or prevention proposed has had the benefit of good user testing, then the business case is much easier to make. Benefits such as increased inspection accuracy, decreased task span-time, and reduced personnel injury exposure can make adoption of ergonomic interventions more easily justifiable.

7-7. Implementation

Implementation of ergonomic interventions should be coordinated through the various maintenance staff functions that they impact. If the ergonomic intervention is a “system” solution having broad-scale effect, then a structured system-wide approach will have to be employed to ensure consistent implementation and measurable results. If the intervention or prevention is more local in nature, affecting a shop or hanger, then the implementation can typically be coordinated through local management.

7-8. Evaluation and Measurement

Evaluation of the effectiveness of the ergonomic interventions or preventions again must be tied to reliable organizational metrics to monitor success and progress. If the chosen metrics do not reflect the desired results after a satisfactory time period has passed, then either the intervention or prevention strategies must be re-evaluated as to whether or not it was implemented correctly, or another strategy should be tried. The risk of this approach is that a continuous “de-stabilization loop” is established that may have negative system effects. The desire to “tweak” or fine-tune interventions must be resisted, or done only after it has been verified that a truly different intervention or prevention strategy is required.

See [Section 7-5], Validation, of this chapter for examples of organizational metrics that can be employed as measurement tools to gauge the effectiveness of ergonomic interventions or preventions. If existing metrics are judged to be deficient then another alternative is to perform site visits to directly observe the effects of the implemented strategy, or to utilize surveys to measure the workforce opinion of strategy effectiveness.

7-9. Feedback

As with all other elements of a human factors program, feedback is an essential element in the constant cycle of evaluation and improvement. Other sections of this specification have highlighted that feedback must be honest, timely, and acted upon in order for any program to be credible. The same holds true for feedback provided as part of the ergonomic intervention or prevention implementation process. Where the benefit is increased safety of people, or identified reduction in injury potential, then the feedback may be generated from the local area to the rest of the organization. Where the benefit is more system-wide in nature (as reflected in some organizational metric) then the feedback may be generated from a centralized management level out to the local workgroups. Either way, it is important to recognize that feedback is part of a continuous loop.

Chapter 8. Return On Investment (ROI): Design, Measurement, and Use of ROI Tools in Maintenance Human Factors Programs

The preceding chapters have shown that Maintenance Human Factors Programs include, on one hand, certain products or outcomes, such as the design of maintenance tools and workplace, the design of training programs, and the design of the maintenance organization and its culture. On the other hand, Maintenance Human Factors Programs are also shown to require a target or focus of those products. The different targets include the individual mechanic, mechanics working together in groups or teams, and the larger maintenance system with its technical and administrative processes, its hierarchy, its social system, and its environment(s).

		Human Factors PRODUCTS		
		Tools & Workplace	Training	Organization & Culture
Human Factors FOCUS	Individual	x	x	x
	Team	x	x	x
	System	x	x	x

This table illustrates how these 2 dimensions complement each other to achieve the mission of the human factors program . . . where "x" signifies the successful achievement of mishap management or safety improvement. It is clear that human factors programs are varied in their purpose and process, and that the complexity of their results increases from the table's upper left to its lower right corner. This complexity can be difficult to communicate or understand. A standardized method of understanding and assessing human factors programs across this range of complexity is required in order to sustain program support. Calculating Return On Investment (ROI) is such a method.

Earlier chapters have shown the need of human factors programs for corporate commitment and support, for program measurement and evaluation, and to assess and validate the multidimensional goals and objectives that each cell in the above table represents. One of these objectives must be the economic return, or the dollar cost to dollar earned. Such a monetary objective, as dollars saved by a maintenance human factors program, is essential to any business enterprise, just as a strong safety record and strong employee morale have been shown to be.

Evaluating the benefits of human factors training, and other organizational interventions, has been long admired, but little practiced [Kirkpatrick75]. Evaluating the economic benefits of such programs is even rarer [Phillips97]. Training and other human factors interventions, especially for safety improvement, are rarely treated as investments and are usually just considered necessary costs of doing business. Little wonder then that converting human factors benefits into a standardized and comparable format, such as "return on investment," is so little in evidence, and has only lately been

discussed and understood within the training and organizational effectiveness community.

8.1. Corporate Commitment and Support

Although human factors programs can, and do, have immediate "successes," their long term success and survival depends on continuous support from top management and trade union leadership. For company management (and increasingly for union leaders) to provide needed support, they require measures which establish that these human factors programs are financially sound investments -- and that "safety pays."

8.2. Return on Investment (ROI)

Profits are derived from earnings. The rate at which earnings grow is a function of the company's return on investment: net income as a percentage of investment costs. Although ROI competes with other financial indicators (e.g., return on equity, return on assets) for an executive's attention, it is the longest lived and most robust of the evaluation tools for management decisions.

ROI is a standardized way of expressing the economic value that is known and understood by business executives. In conventional terms, a company's "earnings" are its "income" minus its "expenses" for some fixed period of time. Given that definition of "earnings," ROI is traditionally reported as "earnings divided by "investment." To further standardize the ROI expression, the resulting quotient is multiplied by 100 to convert it to a percentage expression.

$$\text{ROI} = ((\text{Earnings}) / (\text{Investments})) \times 100$$

For example, if this formula yielded a result of "25," it would mean that the investment costs are recovered, and an additional 25% of the cost amount is received as earnings. That same result can be said to mean that "\$1.25 is returned for every dollar invested."

Assessment of costs and benefit mark an important step in measuring ROI. It is essential that true and accurate costs, as well as cash savings or benefits, of any human factors intervention (whether training, or structure/process, or a combination) be specified and calculated.

But cost or benefit data should not be presented alone -- "it came in below budget" or "it saved a substantial amount of cash" -- because such expressions are too often disregarded by top management. Most managers and executives familiar with financial analysis would consider such direct statements to be without reference and, therefore, without much meaningful information for decision making.

This is also true when both cost and benefit data are available and they are presented by placing them in direct comparison with one another -- in the familiar "cost-benefit differences" or "cost-benefit ratios." These combinations cannot correspond with other efforts to justify the economic success of an intervention, nor are they a standardized measure to be understood in implied comparison with other results. The benefit minus cost "differences," or benefit divided by cost "ratios," cannot be considered effective outcome measures by themselves because the actual, practical effect may be magnified or otherwise skewed by the absolute size of the effort and its budget.

The formula for ROI, above, is, thus, not the same as a direct cost-benefit ratio; since cash "earnings" are not a direct equivalent to cash savings or "benefits." The concept "benefits" is more similar to the "income" in traditional ROI calculations. Given this, the human factors (HF) equivalent to earnings would be benefits minus costs, or "net program

benefits"[Phillips97]. Thus for the calculation of human factors ROI, the numerator of the equation is the net program benefits, or "Net Human Factors Benefits." The denominator, "Human Factors Program Costs," likewise compares to "investment" in traditional ROI.

$$\text{HF ROI} = ((\text{Net HF Benefits}) / (\text{HF Costs})) \times 100$$

Both the standardized ROI formula and its HF ROI derivative uses costs and raw cash benefits in their calculations, and they overcome the limitations of directly reporting those raw numbers

8.3. Time Value of Money

"A dollar is not a dollar," (or so the saying goes)!

It is too simplistic to merely compute an HF ROI based upon program benefits and costs. HF Programs will span several years. Net benefits and costs can be different every year. Therefore, it is important to identify the net benefits and costs for each year of the program. See the example below:

YEAR	Net HF Benefits	HF Costs
0	\$0.00	\$100,000
1	\$25,000	\$100,000
2	\$30,000	\$100,000
3	\$35,000	\$100,000
4	\$40,000	\$0.00

As one can see, the Net HF Benefits and the Net HF Costs are different for each year. The example shows the case where there are some initial "start-up" costs in the first year, with no benefits and increasing benefits throughout the life of the program.

In situations like this, executives will ask for the "Present Value" of the program. The merit in computing the present value lies in the realization that a dollar today is worth more than a dollar in the future. This exists for three (3) reasons:

1. Inflation reduces purchasing power in the future.
2. Benefits become more uncertain as the date of benefits moves further into the future.
3. Opportunity costs. A dollar today is worth more than a dollar in the future because it can be invested today and grow into more than a dollar in the future.

One must therefore think of an HF project as extending over time, and compute the net HF benefits and HF costs for each year of the project. Once these figures are determined, one can compute the present value of each element. The computation can be done using financial tables, financial calculators or spreadsheet programs. In computing the present value, one is required to use an appropriate interest rate that reflects the opportunity cost to the company. This interest rate (sometimes referred to as hurdle rate) can be different for every organization. One must use the appropriate rate for their organization in any calculation.

Using the example above, the present value of each figure (at a 12% interest rate) would be:

YEAR	Net HF	PRESENT VALUE	HF Costs	PRESENT VALUE
	Benefits	Net HF Benefits		HF Costs
0	\$0.00	\$0.00	\$100,000	\$0.00
1	\$25,000	\$22,325	\$100,000	\$89,300
2	\$30,000	\$23,910	\$100,000	\$79,700
3	\$35,000	\$24,920	\$100,000	\$71,200
4	\$40,000	\$25,440	\$0.00	\$0.00
TOTAL	\$130,000	\$96,595	\$400,000	\$240,000

Stated in other terms . . . (to the Financial Department) the example above has a net benefit of \$96,595 and a cost of \$240,000 as expressed in today's dollars.

With these new numbers, the components of the Net Present Value (i.e., the present value of Net HF Benefits and present value of HF Costs) can then be used to compute an HF ROI in "present value" terms.

$$\text{HF ROI} = ((\text{Net HF Benefits}) / (\text{HF Costs})) \times 100$$

$$\text{HF ROI} = ((\$96,595) / (\$240,000)) \times 100$$

$$\text{HF ROI} = 40.2\%$$

In this example, since 40.2% is greater than 12% (the interest rate the company defined as the "hurdle rate"), the project would be approved.

8.4. Minimum Return Limits

Sometimes referred to as "hurdle rate," this is the limit at which financial executives and top management will expect a program's profit, or return, to exceed, or it will not receive further support.

8.5. Accounting for Human Factors Program Contribution

Once senior executives have recognized the utility and validity of calculating ROI for human factors programs, and have lent their support to the effort, a minor addition to the formula will aid in their clearly comparing the results of various human factors programs on even terms with one another, and with other safety improvement programs.

In a complex organization, it follows that many different initiatives will simultaneously be in play to improve those safety behaviors and outcomes. Human factors programs, like many other organizational improvement interventions, are in

competition for recognition and support. No intervention, regardless how good, can cause a perfect and total effect on intended outcomes. But in pursuit of safety improvement, many programs in many departments are undertaken to achieve that goal. This motivation to pursue an ideal is especially true when dealing with certain core organizational outcomes, such as safety to an airline, which have central value to all members. Passions can run high and the pursuit of absolute causation can bias change agents toward attributing more effect to their own program than might be realistic. Post-hoc allocation of resulting improvements in those outcomes can therefore become the subject of debate among the organization's "change agents."

A simple solution for this potential conflict is available. Concurrent programs attempting safety improvement efforts can be compared using statistical correlation. In fact, the outcomes of HF training have been used to estimate cause-effect associations. In one case, reasonable estimates of the causal relationships between human factors training and subsequent safety results were obtained between longitudinal measures of safety and attitude data in several maintenance samples. The new knowledge and attitudes from HF training correlated with 30 months of subsequent lost-time injuries data and a reduction in maintenance related ground damage incidents [Taylor97]. A form of these correlation coefficients expresses the degree of influence a human factors program has on subsequent safety outcomes. The formula below shows the addition of the coefficient to the numerator of the standard ROI formula as a "causal operator" to account for the degree of effect the targeted HF intervention has had on net program benefits.

$$\text{Causal HF ROI} = \left(\frac{((\text{Net HF Benefits}) \times (\text{Causal Operator}))}{(\text{HF Costs})} \right) \times 100$$

[Taylor2000] has shown that the effect of this modification to the traditional ROI equation is to reduce the size of net program benefit by a positive factor between zero (0) and one (1), and thus change the benefit outcome downward to a level that acknowledges the residual as potential effects on that benefit belonging to other interventions. Thus the competing claims for causal effect of various programs on safety can be quantified and compared with one another.

Return on investment (ROI) is a simple, but powerful idea. It can and should be applied to evaluation of human factors initiatives including awareness and communication training.

8.6. ROI Summary

The method for measuring ROI requires quantification of several variables, but appropriate measurements are usually available, or can be readily developed from past work done by others.

- The program's developers and champions can easily calculate costs for the organization effectiveness intervention with some help from the financial department.
- The data for raw program benefits, or outcome results, are usually available, and the dollar cost per benefit incident can be obtained with help from the company's finance group.
- Time value of the money spent on human factors interventions should be assessed in context of competing programs, to help determine the length of time allowed to sustain the effort.
- The minimum return top management is willing to tolerate is usually available and should be sought.
- The resources needed to fulfill the data collection and analysis requirements for HF ROI are available to the typical internal HF Developer or champion.
 - a. Metrics for changes in human knowledge, attitudes, and behaviors following human factors interventions should be created. Well documented and tested illustrations for such measures are available in the references

and additional readings section of this specification.

- b. Correlation statistics used to estimate the degree of relationship between human change following human factors interventions, and subsequent safety results, are available in current personal computer spreadsheet programs.
- The ROI formulae presented in this chapter provide methods of calculating the financial returns of HF programs, depending on the data collected.

Annex 1

References

- [DeGreen70] DeGreen, K. (1970). *Systems Psychology*, New York, NY, McGraw-Hill.
- [FAA98a] Federal Aviation Administration (1995, 1998). *The Human Factors Guide for Aviation Maintenance and Inspection*, Washington, DC (Available online at www.hfskyway.faa.gov)
- [FAA98b] Federal Aviation Administration (1998). *Maintenance Resource Management Handbook*, Washington, DC
- [FAA2000] Federal Aviation Administration (2000). *Advisory Circular 120-72, MRM Training*, Washington, DC
- [Johnson98] Johnson, William B. (1998). *Human Factors in Airline Maintenance: Past, Present, and Future*, Proceedings of the 12th Symposium on Human Factors in Aviation Maintenance, Washington, DC, FAA
- [Kirkpatrick75] Kirkpatrick, D.L. (1975). *Techniques for evaluating training programs*, *Evaluating Training Programs*, Alexandria, VA; American Society for Training and Development, pp. 1-17.
- [Mohansky92] Mohansky, V.P. (1992). *Commission of Inquiry into the Air Ontario Accident at Dryden Ontario (Final Report, Vol. 1-4)*, Ottawa, Ontario, Canada
- [Marx97] Marx, D. M. (1997). *A Review of Maintenance Error Investigation & Analysis Systems for FAA*, Aug 2, 1997
- [Marx98] Marx, D. M. (1998). *Learning From Our Mistakes: A Review of Maintenance Error Investigation and Analysis Systems in Human Factors in Aviation Maintenance: Phase 8 - Progress Report*, Galaxy Scientific Corporation, Tucker, GA
- [Patankar99] Patankar, M. and Taylor, J. (1999). *Corporate Aviation on the Leading Edge: Systemic Implementation of Micro-Human Factors in Aviation Maintenance* [Technical Number 1999-01-1596]. *SAE Transactions: Journal of Aerospace* 1(108), 305-310

-
- [Phillips97] Phillips, J.L. (1997). *Return on Investment*. Houston: Gulf Publishing.
- [Taber97] Taber, R. (1997). *Instructional Systems Development Guidelines*, Galaxy Scientific Corporation, Tucker, GA
- [Taylor2000] Taylor, J.C. (2000). *A New Model for Measuring Return On Investment (ROI) for Safety Programs in Aviation: An Example from Airline Maintenance Resource Management (MRM)*. SAE Technical Paper 2000-01-2090. SAE Advances in Aviation Safety Conference & Exposition, Daytona Beach, FL.
- [Taylor97] Taylor, J.C.; Robertson, M.M. & Choi, S. (1997). *Empirical Results of Maintenance Resource Management Training for Aviation Maintenance Technicians*. In *Proceedings of the Ninth International Symposium on Aviation Psychology*. Columbus, OH: The Ohio State University, pp. 1020-1025.

Additional Readings

- [Chafin91] Chafin, D. and Andersson, G. (1991). *Occupational Biomechanics*, 2nd Edition, John Wiley.
- [Cortlett95] Cortlett, E. N. and Clark, T. S. (1995). *The Ergonomics of Workspaces and Machines*, 2nd Edition, Taylor and Francis.
- [Cushman87] Cushman, W. and Crist, B. (1987). Illumination in Salvendy G., ed. *Handbook of Human Factors*, Wiley Interscience.
- [Dorner89] Dorner, D. (1989). *The Logic of Failure*, New York; Metropolitan Books, Henry Holt and Company.
- [ErgoWeb] ErgoWeb: A website for ergonomic information. www.ergoweb.com
- [ERNAP98] Ergonomic Audit Program (ERNAP). In *Human Factors Issues in Aircraft Maintenance and Inspection '98 (CD-ROM)*, Federal Aviation Administration. 1998.
- [Grandjean88] Grandjean, Eteinne (1988). *Fitting the Task to the Man*, 4th Edition., Taylor and Francis.
- [Higgins98] Higgins, Robert C. (1998). *Analysis for Financial Management*, Irwin/McGraw-Hill.
- [Kodak83] Eastman Kodak Company. (1983). *Human factors section/Health, Safety, and Human Factors Laboratory, Ergonomic Design for People at Work, Vols. 1&2*, Van Nostrand Reinhold Books.
- [Pearce97] Pearce, J.A. II and Robinson, R.B. Jr. (1997). *Formulation, Implementation, and Control of Competitive Strategy*. Boston; Irwin, McGraw-Hill.
- [Pocket86] *The Vest Pocket MBA* (1986). New York; Prentice-Hall, Inc.

- [Pritchard77] Pritchard, R.E., Clark, J.J., and Hindelang, T.J. (1977). *The Economic Analysis of Capital Expenditure*. New York: Prentice-Hall, Inc.
- [Rankin96] Rankin, W.L. and Allen, J.P. (1996). Boeing Introduces MEDA Maintenance Error Decision Aid. *The Airliner*, April-June, Seattle: Boeing Commercial Airplane Company.
- [Rouse91] Rouse, W. B. (1991). *Design for Success*, Wiley Interscience.
- [Sanders93] Sanders, M. S. (1993). *Human Factors in Engineering and Design*, 7th Edition., McGraw-Hill.
- [Taylor98] Taylor, J.C. and Christensen, T.D. (1998). *Airline Maintenance Resource Management; Improving Communication*, Warrendale, PA: SAE International.
- [Wick93] Wick, J. and Wick, J. (1993). *Ergonomics Advanced Trainers Guide*, Boeing.