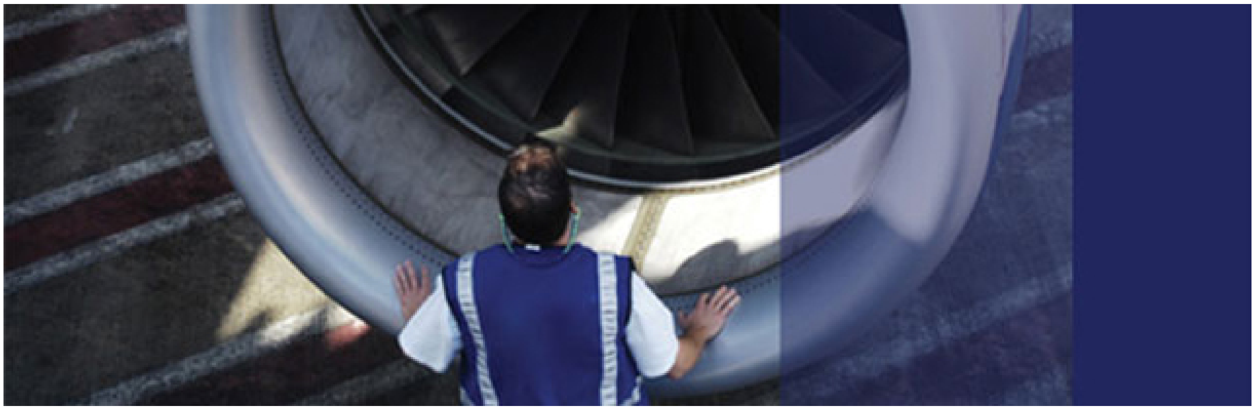

Human Factors Guide for Aviation Maintenance and Inspection

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FAA HUMAN FACTORS GUIDE
FOR AVIATION MAINTENANCE AND INSPECTION

CHAPTER 1: HUMAN FACTORS

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INTRODUCTION

This chapter describes some of the fundamental concepts in the field of Human Factors and how they apply to aviation maintenance. Used properly, human factors principles and methods can help aviation maintenance supervisors, engineers, technicians, and inspectors perform their jobs with more efficiently, more safely, and with less stress. In this Guide, the terms “human factors” and “ergonomics” are used interchangeably. Any meaningful distinction between the two terms has disappeared, at least for the purposes of the discussion related to aviation maintenance.

Aviation maintenance has changed over the years. Newer aircraft contain materials, power plants, and electronic subsystems that did not exist in earlier models, and the number of older aircraft has increased. Technicians use more, and more sophisticated, equipment and procedures.

While the aircraft on which they work have evolved dramatically over the last 50 years, maintenance workers still exhibit all of the capabilities, limitations, and idiosyncrasies that are part of being human. The nature of aviation maintenance is such that AMTs and inspectors often work under conditions that stress their physical, cognitive, and perceptual limits. Maintenance technicians, engineers, and inspectors sometimes work in cramped, awkward, or space-limited locations (Photo 1), they also work under intense time pressure, they work on complex systems (Photo 2), they work both indoors and outdoors (Photo 3), and much of their work is done at night (Photo 4).

Photo 1. Working in an awkward position (note special rolling seat).

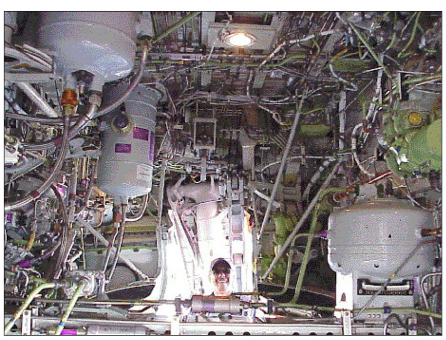


Photo 2. Example of a complex system.

Photo 3. Line maintenance outdoors on a ramp

Photo 4. Line maintenance at night.

The roots of Human Factors are firmly planted in aviation. The first identifiable work in the area of equipment design and human performance was done during World War II. Prior to the war-related research, most people held a fairly simplistic view of how people interacted with their environment. The idea of humans as infinitely "flexible" seemed to guide most design. It soon became apparent, however, that human users' interaction with their jobs and equipment is much more complex than we thought.

Over the last 20-30 years, aircraft have become more and more reliable. These improvements are especially notable for engines. During that same period, aircraft operation has become safer due to the increase in automated flight support systems and the diffusion of crew resource management (CRM) techniques throughout the industry. Because of these improvements, the locus of aviation accidents has slowly shifted to improper ground operation and to maintenance, Some estimates now place maintenance errors as the root cause of 20-30% of serious aviation incidents.

Beginning with the Aloha Airlines mishap in 1988, the Federal Aviation Administration (FAA), along with international regulators and industry organizations, have focused on the design of maintenance tasks, equipment, and training.

Photo 5. Aloha Airlines B-737 after skin de-lamination.

To be sure, most human factors research in the aviation domain has focused on flight crews, operational procedures, and flight deck design. However, over at least the last 15 years, EASA, the FAA, the Air Transport Association (ATA), and it's international counterpart, the International Air Transport Association (IATA), have maintained active programs to perform human factors research, develop applications, and perform training related to human factors in aviation maintenance.

Commercial aviation maintenance and training organizations have also developed training programs to support the EASA requirements regarding maintenance human factors. This Guide is part of the continuing emphasis being placed on human factors in aviation maintenance.

REGULATORY REQUIREMENTS

In most respects, the international aviation regulatory authorities have taken the global lead in imposing human factors requirements on aviation maintenance organizations. The European Aviation Safety Authority (EASA), formerly the Joint Aviation Authority (JAA), is the European counterpart to the FAA. For a number of years, the predecessor to EASA required human factors training for all certified Aviation Maintenance Engineers (AMEs) and inspectors. AMEs are the equivalent of Aviation Maintenance Technicians (AMTs) in the United States.

When the JAA was re-named EASA, human factors training requirements were made obligatory as part of the certification of aviation maintenance organizations. These requirements can be found in Part 145 Section ANNEX II, Section 30 (e) of the EASA regulations.

> (e) The organisation shall establish and control the competence of personnel involved in any maintenance, management and/or quality audits in accordance with a procedure and to a standard agreed by the competent authority. In addition to the necessary expertise related to the job function, competence must include an understanding of the application of human factors and human performance issues appropriate to that person's function in the organisation. "Human factors" means principles which apply to aeronautical design, certification, training, operations and maintenance and which seek safe interface between the human and other system components by proper consideration of human performance. "Human performance" means human capabilities and limitations which have an impact on the safety and efficiency of aeronautical operations.

Until July, 2005, the Federal Aviation Regulations (FAR's), which comprise Title 14 of the Code of Federal Regulations (CFR), did not contain explicit human factors requirements. Certain regulations related to maintenance "performance", such as Parts 43.13 and 43.15, Part 121-Subpart L, and Part 135-Subpart J, are obviously based on human factors types of considerations. However, they do not invoke specific human factors guidelines or standards.

In July, 2005, the FAA issued a Flight Standards Handbook Bulletin for Airworthiness (HBAW), Order 8300.10 – Appendix 3, that introduced a new human factors curriculum requirement in the approval process for Part 145 repair station training programs. The curriculum content mirrored that of the EASA human factors training curriculum requirements. In addition to the new handbook chapter, the FAA also issued Advisory Circular (AC) 145-10, which spelled out the position of the FAA regarding human factors as an integral component of Part 145 training programs. AC145-10 also explicitly concurred with the EASA position on the importance of human factors training for aviation maintenance.

There are presently two other sources of regulatory requirements directly related to human factors in aviation maintenance. The first is the set of regulations that compose the Occupational Safety and Health Administration (OSHA) requirements. OSHA regulations are contained in the Code of Federal Regulations (CFR), Title 29, Parts 1900 to 1910. Only a small fraction of these regulations are directly related to human factors issues. Applicable sections of the OSHA regulations are cited in appropriate chapters of this Guide.

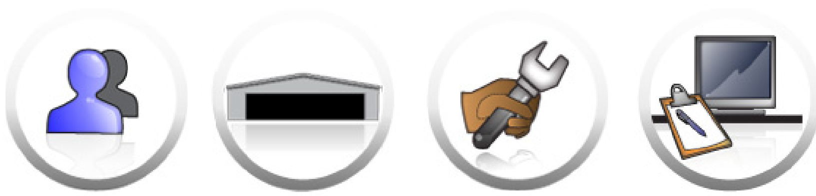
The second source of human factors-related regulatory requirements is the Americans with Disabilities Act (ADA). This legislation mandates, among other things, that all employers must make "reasonable accommodations" for disabled workers. There are other implications of the ADA. For example, ADA provisions directly affect the processes of personnel selection and job assignment. Again, the relevant parts of the ADA are cited as appropriate in this Guide.

CONCEPTS

There are many concepts related to the science and practice of Human Factors. However, from a practical standpoint, it is most helpful to have a unified view of the things we should be concerned about when considering aviation maintenance from a human factors perspective. In other words, we need a good idea of what's important. A good way to gain this understanding is by using a "model".

The PEAR Model

The PEAR model is a simple framework for thinking about human factors in aviation maintenance. Actually, the PEAR model works for practically any domain, not just aviation maintenance, but it is particularly helpful for maintainers.



PEAR is an acronym for People, Environment, Actions, and Resources. These four components comprise the essence of what we are typically concerned about in the human factors world. While the "people" component is only one of four in the PEAR model, people are at the heart of the entire model. The science of Human Factors concerns itself primarily with people and how they interact with each other and the world around them.

Table 1-1. Components of the PEAR model.

People—Who are we?	**ENVIRONMENT—Where do we work?**
Physical Factors	Physical
Physical Size	Weather
Sex	Location inside/outside
Age	Workspace
Physical characteristics	Lighting
Strength	Noise
Sensory limitations	Safety
Physiological Factors	Organizational
Nutritional factors	Personnel
Health	Supervision
Lifestyle	Shift
Fatigue	Union-management relations
Drugs	Pressures
Physical limitations	Crew structure
Psychological Factors	Size of company
Workload	Profitability
Experience	Morale
Knowledge	Culture
Training	**RESOURCES—What and whom do we use to do our job?**
Attitude	
Mental or emotional state	Procedures/Work Cards
Psychosocial Factors	Manuals/Bulletins/FARs
Interpersonal conflicts	Test Equipment
Personal loss	Hand/Power Tools
Financial hardships	Machine Tools
ACTIONS—What do we do?	Computers
Steps	Paperwork/Signoffs
Performance criteria	Ground Handling Equipment
Number of people involved	Forklifts/Tow Motors
Communication	Ladders/Steps/Work Platforms
Oral	Cranes Hoist/Jacks
Visual	Fixtures
Written	Materials
Information and Control Requirements	Task Lighting
	Manpower
	Training

METHODS

There are several general methods used to identify human factors problems and to embed user capabilities and limitations into systems and products. These methods are always used to accomplish one or more of the following tasks:

- Identify user characteristics
- Identify task requirements
- Evaluate jobs, tasks, or products.

"Know thy users" is a fundamental tenet of human factors. The general idea is that if we can describe the users in enough detail and also can identify the requirements of the tasks they are going to perform, we have most of the information we need to design a usable product or system.

The methods described below are mostly not cookbook-type procedures. They can be used to examine people and tasks at a certain level of detail. However, to be fully effective, these methods require specialized knowledge and techniques within the expertise of trained human factors practitioners.

Checklist Evaluation

For a wide range of tasks and procedures, checklists exist or can be developed that allow non-experts to identify potential human factors problems. Such checklists are usually based on general human factors principles or on published data related to the area of concern.

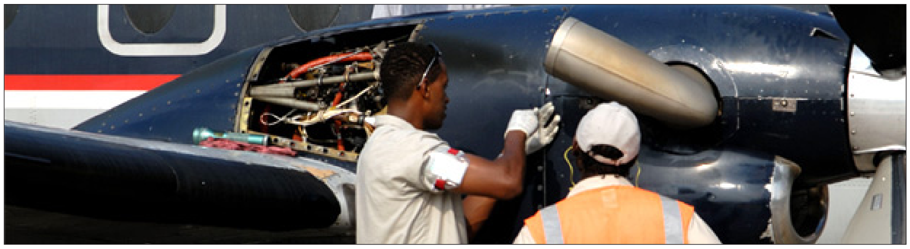
Checklists used for evaluation are fundamentally different from operational checklists, which are procedural job performance aids. is an example of an evaluation checklist.

Properly constructed checklists allow people with little or no human factors experience to compare the attributes of existing or planned systems with acceptable ranges of values for those attributes.

Where it's possible to use them, checklists allow for relatively quick evaluation of a large range of variables. Since checklists are already so widespread in the aviation industry, this method probably has a lot of intrinsic appeal and will be more quickly accepted than other, less familiar methods.

Field Observation

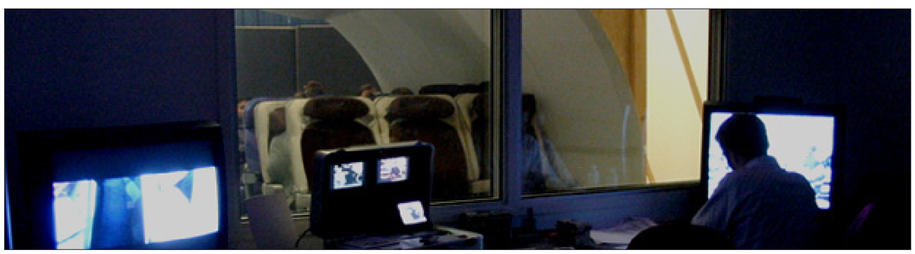
Some of the simplest and most useful information gathering techniques are lumped into the category of "field observation". One of the most popular field observation methods is called "ethnography", which was borrowed from the field of anthropology. In its original form, ethnography required a researcher to live with the people being studied. However, the label has been applied to nearly any technique in which analysts observe people doing various tasks.



The big issue with field observation is that an analyst who is not well-versed in the tasks they are observing can easily miss important clues regarding what workers are doing. More importantly, analysts don't necessarily know why workers are doing specific tasks or steps. To overcome this weakness, field observation must embed interviews with the people who are being observed. That is, we ask people what they're doing and why they're doing it.

Formal Usability Testing

Usability testing is quite broad. Activities that are considered tests in industrial settings are often little more than demonstrations or quick test-drives by end users. While such activities are somewhat valuable, they tend to be unstructured, poorly controlled, and undocumented. Human factors practitioners distinguish between these unstructured "tests" and more formal testing procedures.



Formal usability testing is one of the fastest growing specialty areas in the human factors domain. Several books have been written to help non-specialists plan and conduct various types of usability tests. While these books can provide valuable insight into the usability testing process, there are so many subtle effects related to testing and interpreting results of tests that usability testing requires specialized knowledge.

Incident Investigation

Errors in aviation maintenance settings are typically identified when they are linked with property damage, injuries, or both. Such incidents are formally examined with an incident investigation technique. These techniques are collectively known as "root cause" methods because they attempt to identify and classify all of the proximate causes for a maintenance incident.

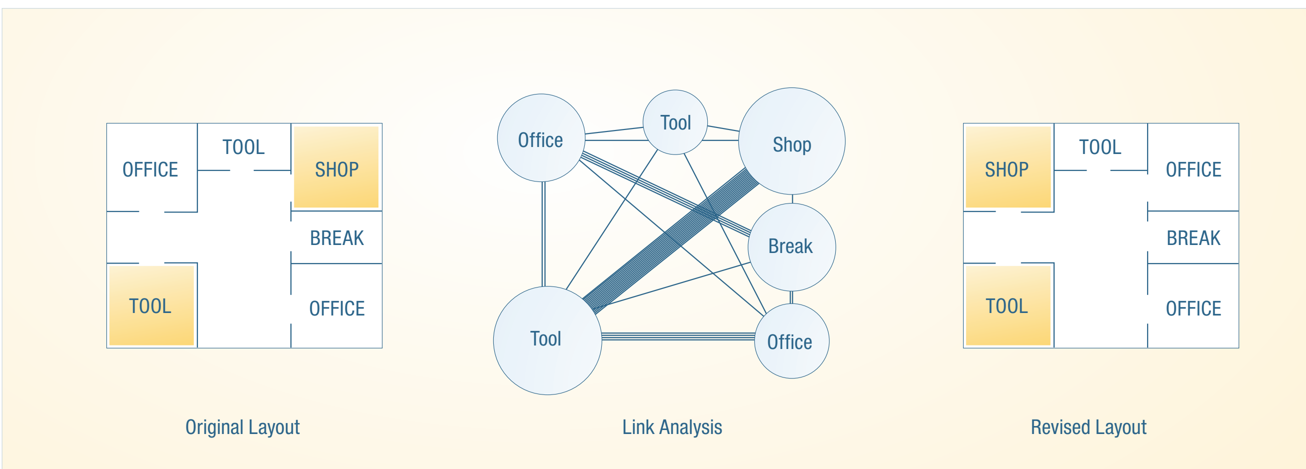
A number of formal root cause incident investigation techniques have been developed within the aviation community. Probably the most well-known technique is the Maintenance Error Decision Aid (MEDA) developed and taught by Boeing.

All of the existing aviation maintenance error investigation techniques are a combination of checklists and questionnaires, usually combined with interviews and some type of evaluation process. All of these techniques include an embedded database where incident classification information is retained for analysis.

Link Analysis

Most jobs, and even most tasks, aren't static actions occurring in isolation. Real jobs and tasks consist of many individual actions extending over time and space. Link analysis methodology allows us to determine important associations among various task-related elements such as displays, controls, tools, locations, etc.

The technique is easily applied to situations in which we need to layout a computer screen, a workshop, a hangar, or other job components. While users per-



form job tasks or follow job-related procedures, the analyst(s) notes where they go and how often they move between any two locations. When this is done, a statistical picture of important associations emerges and we can arrange task elements to minimize the distance users have to move to complete a task.

A common example of the product of link analysis is the "task triangle" used by kitchen designers. Through link analysis, we know that people move most frequently among the refrigerator, stove, and sink. Since the links among these three elements are strong, kitchen designers try to place them at the corners of a fairly small triangle.

Questionnaires and Opinionnaires

A good method for gathering human factors information is simply to ask users to give it to us. Written questionnaires and opinionnaires are good options for soliciting information from end users. A questionnaire asks people to fill in factual information or to select from a given set of response choices. They are a particularly efficient way of gathering demographic information such as age, gender, educational background, years of experience, skills, etc.

An opinionnaire, on the other hand, asks people to render an opinion about various items. Items in an opinionnaire can be open-ended or they can be constructed so that responses can be numerically analyzed. Open-ended items allow respondents to provide information using their own words. An example of an open-ended opinionnaire item is “Describe how easy or difficult it is for you to use the new computerized maintenance manual.”

Numerical opinion ratings are usually obtained using “anchored” scales. On an anchored scale, a description defines each scale point. We might ask users to rate how easy it is for them to use the computerized maintenance manual on a scale of 1 to 7 with the following scale points:

1 = impossible to use
2 = very difficult to use
3 = difficult to use
4 = neither difficult nor easy
5 = easy to use
6 = very easy to use
7 = requires absolutely no skill or effort to use.

Questionnaires and opinionnaires are inexpensive methods of gathering information. Two of the biggest problems with them are a low response rate and the difficulty of developing unbiased questions.

Task Analysis

Task analysis can be considered the mother of all human factors techniques. Entire books have been written on the topic. Task analysis is the name given to a range of methods used to determine important task elements. The intent of each is to describe just what AMTs and inspectors have to do and know to complete their job tasks.

Task analysis should be used to evaluate people performing their job in the actual job setting. The most common source of errors in gathering task information arises from a failure to interact with real end users. It’s not good enough to talk with supervisors of end users, with people who know a lot about end users, or with people who used to be end users. For task analysis, we need to gather task information from the people who perform the tasks.

By observing users in their actual job settings, the analyst(s) can gather environmental, organizational, and other job-related information that might have a significant effects on the overall evaluation. For example, if we see that two people have to view a piece of test equipment simultaneously, then our analysis (and the design of the test equipment) must reflect that requirement. **Table 1-2** is an example of the output of one type of task analysis.

Table 1-2. Task: Tensioning elevator trim tab control cables

Step	Who Does it?	Knowledge/Skill	Tools	Other Resources
Place elevators in neutral and install rig pin in aft elevator bellcrank	AMT in cockpit AMT at aft bellcrank	Operation of elevators; Identity and location of rig pin and rig pin hole in aft elevator bellcrank	Rig pin; Screwdriver to remove bellcrank access plate	Communication with AMT at elevators and at bellcrank
Rig cables to the proper tension as shown in Figure X.	AMT working on tensioning turnbuckles	Ability to interpret Figure X; Ability to measure tension; Ability to adjust turnbuckles	Tension gauge; wrenches to adjust turnbuckles	Figure X in the procedures; task light to illuminate turnbuckles
Set cockpit trim tab control wheel so it indicates "0" trim units	AMT in pilot's seat in cockpit	Operation of trim control wheel; Ability to interpret trim scale on control wheel	None	Communication with AMT at elevators
Adjust turnbuckles to maintain linear measurement shown in Figure Y.	AMT at turnbuckles	Ability to interpret Figure Y; Ability to adjust turnbuckles	Wrenches to adjust turnbuckles; Ruler or tape measure	Figure Y in procedures; Communication with AMT in cockpit
...	...	...	...	...

Walkthrough Evaluation

Checklists are useful for evaluating static system or product elements. However, most aviation maintenance tasks are not static. They require AMTs to perform a series of steps, often in a particular sequence. For such tasks, the walkthrough method can identify human factors problems.

A walkthrough consists of having people walk through a certain set of tasks or steps. A trained observer watches the actions and notes those steps or task elements for which a human factors problem exists. Walkthroughs are often recorded on videotape for later examination. An example of a walkthrough checklist is Table 1-3, which is geared toward facility evaluation.

Walkthroughs incorporate some of the timing elements of real tasks, as well as the AMTs interactions with other people. The method is particularly well-suited for highly proceduralized tasks. It can also be used for activities that require more than one person. On the minus side, walkthroughs can be time-consuming, require trained observers, and can require recording equipment. Since walkthroughs must be done with some version of the actual product or system, they are often done on simulators.

GUIDELINES

We have included a number of detailed guidelines in the topical chapters of this Guide. For the overall topic of Human Factors, however, it is difficult to provide detailed instructions regarding precisely how (and which) human capabilities are relevant to every aviation maintenance task. In the most general sense, our goal is to ensure that the environment, tools, procedures, and physical and psychological job requirements match the capabilities and limitations of AMTs.

In keeping with the PEAR model, we provide a series of checklists that deal with its individual components. The questions contained in these checklists illustrate the types of information that are typically important in determining the "match" between human workers and other elements of the aviation maintenance environment.

People

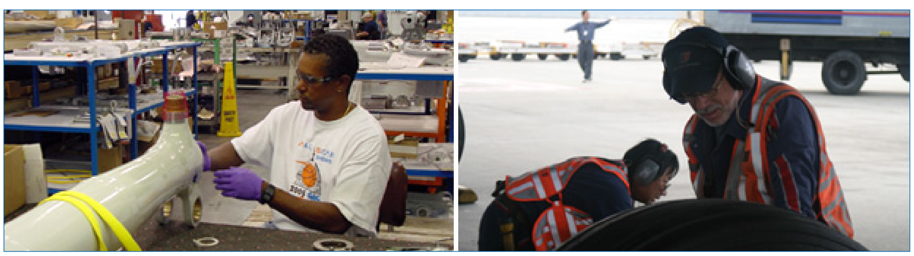
Before we can match the capabilities and limitations of AMTs to their tasks, tools, etc., we need to understand those characteristics. Table 1-2 is a representative list of questions that are aimed at gathering such information. The term "demographics" refers to descriptive data about a particular group of people. The technical term for a group of people who perform a certain type of work is "population".

Table 1-3. Human factors elements related to demographics
1. What is the proportion of males and females in the worker population?
2. What is the age distribution of the worker population?
3. Is English the first language of all workers? If not, what are the predominant first languages of workers? Are there any workers who cannot read English (or any language)?
4. What is the distribution of cultural backgrounds of workers? Will we have to accommodate workers from other countries?
5. What educational background do we require of workers? If no particular background is required, what is the distribution of educational backgrounds in the worker population? What percentage of workers have graduated from high school?
6. Do we require any skills, such as the ability to type, of workers?
7. Are there any requirements related to the job background of workers?
8. What is the distribution of computer experience in the worker population?
9. Do we test workers for visual capabilities, such as acuity, stereopsis, color vision, etc.?
10. About what proportion of workers wear corrective lenses?
11. Do we test workers for auditory capabilities?
12. Do we screen workers according to any disability criteria?
13. Do we screen workers for any minimum or maximum physical variables, such as height, weight, strength, etc.?
14. Do we presently have any workers with known disabilities? If so, what are they?

One thing is worth noting here. If our population of interest consists entirely of AMTs, then we already know certain things about it. For example, every member of the population has been trained as an AMT and holds an AMT license (or the equivalent for AMEs). However, one should not automatically conclude that everyone who will be involved in a particular repair task is an AMT.

Environment

Aircraft maintenance is performed in various physical settings. Line maintenance is typically done while an aircraft is parked at a boarding gate. Depot maintenance, on the other hand, is normally performed while the aircraft is parked in a hangar or parked on the ramp near a hangar. Certain specialized maintenance, such as for engines, avionics, painting, etc., is done in purpose-built workshops or work areas.



The term “environment”, when used in the context of human factors, refers to both the physical workplace and the overall organizational framework within which the aviation maintenance department exists. Table 1-3 contains questions related to the overall physical work environment. Table 1-4 addresses the environmental elements of specific workspaces. Table 1-5 is aimed more at the organizational and job environment.

Actions

The term “actions” refers to the tasks that are necessary to perform one’s job. Many aviation maintenance jobs are highly proceduralized. Each step in a job might be spelled out on a job card or a computerized maintenance manual. In such cases, specifying job tasks is a as easy as copying each step in the procedure. However, the level of detail in maintenance procedures varies considerably from job to job. Also, certain steps in maintenance tasks are considered to be part of the general skill and knowledge set of an AMT, so the details of these steps are not listed in the procedure. An example of such a general task is blocking cables during a rigging procedure.

Guidelines, tasks, and the resources to perform tasks are highly interwoven, so it is often difficult to distinguish between them. For example, suppose an operational check requires an AMT to measure the free play of pitch trim tabs. This task might be described on a job card as follows:

"The free play in the elevator trim tabs should not exceed 0.5 inch of total deflection at the trailing edge. Pin the elevator controls at neutral and use the appropriate elevator trim tab deflection template (P/N xyz-001234) to measure the free play."

This hypothetical example includes a guideline (deflection cannot exceed 0.5 inch), an action and a method (pin the elevator controls and use a specific tool to measure the free play), and a resource (the tab deflection template). Tables 1-6 and 1-7 contain questions that relate to both actions and the resources to perform those actions.

Resources

In the aviation maintenance world, it would be quite unusual for an AMT to be able to perform a job task without using computers, procedures, tools, test equipment, fixtures, or talking with other AMTs, factory technical support people, etc. All of these "other things" that AMTs use to do their jobs are the focus of the "resources" element of the PEAR human factors model.

It is important to identify and understand the resources required for a particular procedure or task. Often, human factors problems arise either because of a poor match between AMTs (and inspectors) and the resources required to perform their job or because required resources are not available in a timely fashion.

Various items in Tables 1-6 and 1-7 refer to resources necessary for certain jobs and tasks.

Table 1-4. Human factors elements related to the general physical environment
1. Does the worker perform tasks indoors, outdoors, or both?
2. If the worker performs any tasks outdoors, does he or she work in all seasons in any kind of weather?
3. Is work done at night, as well as during the day?
4. Does the worker have to wear any kind of protective clothing or safety devices?
5. If the worker works indoors, what type of lighting is used?
6. Are there windows in the workplace? If so, are they small or large? Are they adjacent or in individual workspaces? Which way do they face?
7. What type(s) of lighting is used in the work area?
8. What are some of the representative illumination levels in the work area?
9. What are some representative air temperatures?
10. How is the air temperature controlled?
11. What is the relative humidity in the work area?
12. How is the relative humidity controlled?
13. Are workers generally comfortable in the ambient temperature and humidity, or do they think it's normally too hot, cold, humid, dry, etc.?
14. What is the ambient noise level in the work area?
15. Is any kind of noise "masking" used in the work area? What type?
16. What is the volumetric air flow in the work area? Is it adjustable?
17. What type of floor covering is used in the work area?
18. How many individual workspaces are contained in the work area?
19. How are individual workspaces set off and arranged?
20. Are there any common or break areas in or adjacent to the work areas? If so, where are they in relation to the individual workspaces?
21. Is there any kind of vending and/or cooking equipment in the break area? If not, is there vending and cooking equipment anywhere near the work area?
22. Where are the bathroom facilities and drinking fountains?
23. Are there dressing/locker areas? Where are they located?
24. Is there any type of security lock that must be passed to enter (or leave) the work area? What kind of people get past security, and how do they do so?
25. Where are the supervisory offices or areas located with respect to overall work area and the individual workspaces?
26. Does the arrangement of individual workspaces relate to rank, seniority, or job function or title?
27. Is the work area accessible to individuals with physical handicaps?

Table 1-5. Human factors elements related to individual workspaces
1. How many people occupy each workspace?
2. How is each workspace set off from other workspaces?
3. Are individual workspaces identified as belonging to a particular person?
4. Does more than one person use each workspace, for example on different shifts?
5. Does each workspace have a door that can be closed? Do any workspaces have a door?
6. How much overall floor space is included in each workspace?
7. Do workers feel they have enough room to perform their jobs?
8. What types of furniture and fixtures are included in each workspace?
9. What are the dimensions of the workspace furniture?
10. Do workers have any complaints about the furniture?
11. Do workers sit or stand (or both) to perform their jobs?
12. If workers sit, what type of chair do they use? How many legs does it have? Is it adjustable? If so, how? Does it have rollers? Does it have arms? What is the floor covering in the workspace? Does the chair rest on a hard mat?
13. Does the workspace include a computer display? If so, where is it located? What is the height of the computer's display surface? What is the screen size? Is it color? How many pixels are on the display? How much worksurface area is taken by the display? Can workers adjust its position? Can workers ad just display parameters such as brightness?
14. Does each workspace include one or more input devices? If one device is a keyboard, what type is it? Does it have its own shelf or stand? What other input devices are used?
15. Does each workspace have some type of adjustable task lighting? What kind?
16. What is the typical illumination level at the worker's work surface?
17. Can workers see their co-workers while seated (or standing) at their work area?
18. Can workers converse with their co-workers while seated (or standing) at their work area?
19. Do workers wear headphones or earpieces while in their workspace? If so, can they move out of their workspace while still wearing these devices?
20. Do workers wear a microphone while in their workspace? If so, can they move out of their workspace while still wearing it?
21. Do any workspaces contain special furniture or other devices to accommodate physical, visual, or auditory handicaps?
22. Do workspaces contain storage areas? If so, what type(s) and how much capacity do they have?

Table 1-6. Human factors elements related to jobs
1. How many people work in the entire work area?
2. What job titles do these people have? What is the distribution?
3. Are workers split into groups according to any particular scheme? If so, what is the scheme?
4. Are the workers unionized?
5. Does job seniority mean anything relative to the tasks being performed? That is, must a person have a certain tenure before being allowed to perform certain tasks?
6. What is the average tenure of workers in this group?
7. Are workers grouped into specialists in particular types of tasks? If so, how are the tasks defined?
8. Are workers free to "bid" on other jobs within the group or company?
9. How are workers compensated for their work, e.g., hourly vs. salaried, overtime pay, etc.?
10. Are workers given any incentives, financial or otherwise, to increase their job performance? If so, what are those incentives?
11. What measures are used to evaluate worker performance?
12. Is there a "promotion from within (or without)" policy?
13. Do workers have to meet particular job performance measures each day? If so, what are they?
14. How are workers scheduled to work?
15. Are workers monitored while they are working?
16. How much training are workers given before they begin working?
17. How much experience must workers have before they are considered fully proficient on the system?
18. Are workers given any recurrent training?
19. What is the most difficult aspect of the present system to learn?
20. What is the turnover rate among workers?
21. How many errors do typical workers commit per unit time (hour, day, etc.)?
22. How much does it cost to process each "transaction"?
23. How long does it take to process each "transaction"?
24. How much does it cost to correct an error?
25. What is the most frequent worker complaint regarding the work?
26. What is the most frequent worker complaint regarding the system?

Table 1-7. Human factors elements that pertain to task-related elements of a job
1. What are the main categories of tasks these workers perform?
2. About what proportion of workers' time each day is devoted to each type of task?
3. Are similar tasks done in groups, or can different types of tasks be done in any order?
4. Do similar tasks tend to be done at certain times of day or on certain days of the week?
5. Can the worker select the type of task to perform, or is selection externally driven, e.g., by customers?
6. Are workers sensitive to the time it takes to perform certain tasks? If so, which tasks are most time-sensitive and what are their appropriate time targets?
7. Can workers perform their job tasks while they remain in their workspace, or must they move to other work areas?
8. For each major task activity, what are the steps necessary to complete the task?
9. For the task steps mentioned above, what information is essential for completing each step? How should it be depicted?
10. What input and output devices must workers use to interact as they complete tasks in each category?
11. Do workers have to transcribe information from computer to paper, or vice versa? If so, which information?
12. Do workers have to interact with others to perform tasks? If so, for which tasks, with which other people, and how do they interact?
13. Do tasks have to be completed once they are begun, or can they be suspended and then restarted at some later time?
14. Do workers have to use documents or other written information to complete tasks? If so, which documents and what type of other information is necessary?
15. Is any task-related information routinely difficult to obtain or, once obtained, to use?
16. Do workers need access to equipment other than that the company provides? An example might be a worker's need for a calculator.
17. Are there any particular strength requirements for any task? If so, what are they?
18. Do workers have to interact with people who speak different languages? If so, how is this done?
19. Can workers refer certain tasks to supervisors? If so, how is this done?
20. Is the worker's day structured in any particular manner? Can the worker count on doing a particular type of task at a certain time each day?

Table 1-8. Human factors elements related to a specific task
1. How many workers are required to perform this task?
2. What are these workers' job titles?
3. If more than one worker is required to perform the task, do they work simultaneously or one at a time?
4. Do workers performing this task have to communicate with other people at various points?
5. How much time does the overall task require?
6. Are the people who perform the task evaluated or judged on the amount of time required to complete it?
7. What individual steps are required for the task?
8. Who performs each step?
9. What tools are required for each step?
10. Where must workers go to obtain tools? How do they obtain tools?
11. Is there a written procedure that must be followed for each step?
12. If procedures are used, are they sign-off procedures? Single or double sign-off?
13. For each step, how does the worker know that the step has been completed?
14. For each step, what documents must the worker have access to?
15. Are written materials other than procedures required for a particular step or for the overall task? Which ones? Where are they stored?
16. How long does it take to perform each step?
17. Are there any hazards inherent in this task?
18. What measures are used to evaluate worker performance?
19. Once the task is completed, is the work inspected? By whom?
20. What time of day is this task usually performed?
21. Are workers monitored while they are working? By whom?
22. Is this task scheduled or on-demand?
23. If the task is on-demand, what is its nominal priority?
24. At what time of day is this task usually performed?
25. Do workers consider this task particularly difficult or bothersome?
26. Is any prestige associated with performing this task? If so, describe it.

WHERE TO GET HELP

FAA

There are a number of human factors resources within the Federal Aviation Administration. The most direct link for aviation maintenance is the Senior Scientific and Technical Advisor for Human Factors in Aviation Maintenance.

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Human Factors and Ergonomics Society (HFES)

The HFES is the only organization in the United Stated dedicated specifically to the Human Factors profession. The HFES was formed in 1957 and typically maintains about 5,000 members. The organization headquarters is in California.

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International Ergonomics Association (IEA)

The International Ergonomics Association is a federation of over 40 ergonomics and human factors societies located all over the world.. All members of the HFES are automatically also members of the IEA. The main contact point within the IEA is through the office of their Secretary General.

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EXAMPLE SCENARIO

You've received a number of complaints from the Operations Department regarding a recurring hydraulic leak in a particular type of aircraft. You've asked your technicians and inspectors about this problem. They've told you that these leaks occur in a fitting that is "hidden," making it particularly difficult to tighten and inspect.

Issues

1. How will you determine whether this fitting is actually the problem causing the recurring leaks?

2. How will you go about evaluating the accessibility of the fitting?

3. How will you determine just what technicians and inspectors have to do to tighten and inspect the fitting?

4. How can you determine whether factors other than the fitting contribute to this problem?

Responses

1. According to the scenario description, you've already taken the first step to resolve this issue. By talking to the technicians and inspectors who perform the task of tightening the fitting, you have taken advantage of their knowledge and experience. While addressing the remaining issues in this scenario, you will gather enough information to say, with a high degree of certainty, whether the fitting itself is the cause of the recurring leak.

2. The most appropriate method for evaluating the accessibility of the fitting is task analysis, which is described in the METHODS section. The GUIDELINES section contains a series of checklists from which you can extract enough items to examine the accessibility issue. Essentially, you're going to watch one or more technician tighten the fitting in question.

3. This is simply a continuation of the previous issue. You should conduct a task analysis addressing the procedures related to the fitting in question. Specifically, Table 1-6 and Table 1-7 contain items that should help you identify each of the steps leading up to and including tightening this fitting.

4. It's often the case that a troublesome component is only one aspect of a maintenance problem. For example, procedures might be inadequate; certain tasks might require more, or fewer, people than are allocated to them; inappropriate tools might be used, etc. As part of the task analysis, you should look at various job-, task-, and workspace-related elements. These topics are covered in Tables 1-6, 1-5, and 1-4, respectively.

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CHAPTER 2:
ESTABLISHING A HUMAN FACTORS PROGRAM

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LANDING PAGE

The gap between seeing the value in applying human factors in an aviation maintenance organization and actually establishing a program can seem quite wide. There are several common errors associated with defining and implementing a human factors program. Probably the most pervasive error is one of perspective, that is, viewing the HF program as separate and distinct from the organization's overall safety management system (SMS). In reality, the best chance of success for an HF program is to make it an integral part of a pervasive SMS and the supporting "safety culture".

The goal of this chapter of the HF Guide is to provide both philosophical and practical guidance to help you establish an HF program in your organization. We encourage you to start this process at the top of the organization by gaining upper management support for the HF program. Without such support, it is very difficult, if not impossible, to establish a meaningful HF program.

Considering the HF program to be a part of the much broader SMS should help it gain acceptance within the ranks of top management. This is important because establishing an HF program requires certain resources, which are usually controlled by upper management.

We also encourage a good deal of up-front work prior to putting an HF program in place. This work includes extensive interaction with the AMTs who will have to live with the program. The people who actually turn wrenches need to understand the breadth and goals of the HF program. They are an HF program's best and most valuable resource.

In this chapter, we suggest that an HF program be introduced slowly and in a way that demonstrates its value. Start small, start in a way that can immediately show positive results, and then expand at a pace that can be sustained over the life of the program, which is to say, over the lifespan of the organization.

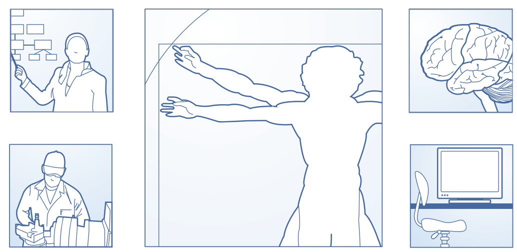
INTRODUCTION

This chapter discusses how an aviation maintenance organization can establish a human factors (HF) program and why it should do so. As to the "why", there are a number of compelling reasons for establishing such a program. The goals of an internal HF program are really no different than the overall goals of any aviation maintenance department, namely:

- Ensure a safe and pleasant working environment.
- Minimize errors that can affect personal safety and airworthiness.
- Make maintenance tasks as efficient as possible.
- Comply with regulatory training requirements.

...with the addition of one more goal—

- Provide an organizational locus for all human factors-related activities.



Typically, HF programs are justified on the basis of cost savings related to reducing human errors. However, as the above list shows, there are a number of other positive effects that flow from having a functional HF program. Some are intangible, such as the positive feelings among AMTs due to the willingness of management to invest in a program that aims to improve their welfare and working conditions.

A good motivational and practical framework for establishing a human factors program is that of a Safety Management System (SMS). The International Civil Aviation Organization (ICAO) has developed an SMS framework that serves as the basis for harmonizing each country's SMS program. That framework is shown in Table 2-1.

Table 2-1. ICAO Safety Management System Framework
1 Safety policy and objectives
1.1 Management commitment and responsibility
1.2 Safety accountabilities of managers
1.3 Appointment of key safety personnel
1.4 SMS implementation plan
1.5 Documentation
2 Safety hazard identification and risk management
2.1 Hazard identification processes
2.2 Risk assessment and mitigation processes
2.3 Internal safety investigations
3 Safety assurance
3.1 Safety performance monitoring and measurement
3.2 Audits and surveys
3.3 The management of change
3.4 Continuous improvement of the safety system
4 Safety promotion
4.1 Training and education
4.2 Safety communication
5 Emergency response planning
5.1 Development of the emergency response plan

So, how does one go about establishing an internal HF program and what should be within its scope?

REGULATORY REQUIREMENTS

As we noted in the Human Factors chapter, there are various international and domestic regulatory requirements regarding human factors training for AMTs and AMEs. However, there are no specific U.S. requirements for establishing a human factors "program". All current regulations address the need for maintainers to know and understand certain human factors concepts, principles, and methods. These regulations stop short of mandating an organized and ongoing internal program devoted to the human factors elements of aviation maintenance.

An indirect source of requirements for establishing a human factors program is the proliferation of new regulations and guidelines related to "safety management systems", or SMS. Member states of the International Civil Aviation Organization (ICAO) are now required to implement a safety management system as part of their overall safety program. Transport Canada has taken the lead in defining the content of an acceptable SMS, which includes both proactive and reactive elements.

http://www.tc.gc.ca/CivilAviation/SMS/Breeze/SMSE/index.htm

CONCEPTS

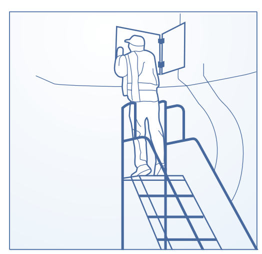
In this chapter, we consider the elements of actually establishing a human factors program within an aviation maintenance organization. The concepts that apply to this endeavor are somewhat different than those that apply to specific topical areas, such as documentation, training, etc. In this section and throughout this chapter, we will be looking at things from a programmatic perspective, rather than with the idea of applying methods and guidelines to solve a particular problem.

Accountable Executive

The ICAO SMS framework includes the requirement for direct accountability for safety on the part of senior management. The person ultimately responsible for safety in an aviation organization is called the "accountable executive". This individual is typically a senior executive who has both the organizational clout and financial control to ensure that the SMS has the resources it needs to function properly. This person might or might not have personal oversight of the SMS or human factors programs.

Error Tolerance

Many aviation maintenance managers likely hold the idea that, if they just work hard enough and motivate people properly, they can eliminate human errors in their shop. This is a worthy, but unattainable goal. Many years of research and even more years of practical experience have demonstrated that human beings are incapable of error-free performance over any significant length of time.



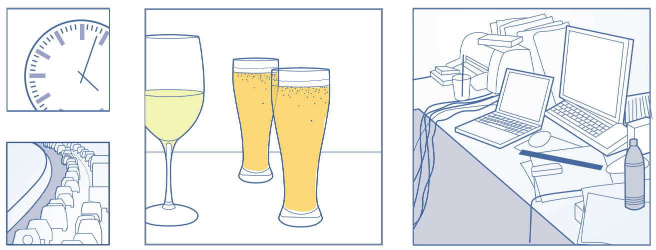
A realistic goal for aviation maintenance organizations is to reduce errors as much as feasible and to structure itself and its processes in such a way that it is error tolerant. Error tolerance is the ability of an organization to continue to function safely in the presence of human errors. This does not imply that the systems are strong enough to survive errors that are allowed to propagate through them. Rather, it implies that processes are in place to catch and fix errors before they can do real damage.

Error tolerance is an achievable condition, whereas error elimination is not.

Fitness for Duty

One of the primary purposes (and effects) of establishing a human factors program is to provide a framework for ensuring that AMTs, inspectors, and supervisors are really up to the task of maintaining airplanes. This sounds almost nonsensical or, at the least, states what might be considered a redundant capability. After all, AMTs are professionals and would never knowingly work on an airplane if they feel they are not capable of performing their jobs.

However, there are many factors that affect one's fitness for duty. Everyone already knows about the obvious factors like alcohol, prescription (and other) drugs, and fatigue. Unfortunately, there are a number of other factors that can impair a person's ability to do their job. Many of these factors, like time stress, lack of experience performing particular tasks, and even task knowledge improperly passed across shifts...can mask the AMTs' knowledge that they are impaired.



A human factors program can raise everyone's awareness of non-obvious fitness for duty factors and provide tools to assess individual fitness and deal with it when it is less than adequate.

Maintenance Resource Management (MRM)

Aircraft crews have been trained in Crew Resource Management (CRM) for at least the past 15 years. In fact, CRM is in its fourth generation of development. CRM provides crews with the perspective, awareness, and tools to deal with non-normal situations that might arise during flights. It does this by training individual crewmembers to watch each other's actions, provide feedback when things don't appear to be "right", and to assist each other to deal with abnormal events. That is, the entire crew is a team that identifies and uses the resources available to them.

The aviation maintenance equivalent of CRM is Maintenance Resource Management, or MRM. The goals and tools of MRM are very much aligned to their CRM counterparts. The concept of error tolerance (see above) includes the idea that all maintainers work together to identify emerging errors and correct them before they propagate to cause damage.

Proactive and Reactive Processes

The ICAO SMS framework includes some elements that are meant to identify hazards and risks before they cause harm, as well as elements that investigate incidents to identify their causes and “fix” them so they cannot cause problems in the future. These processes are sometimes called “proactive” and “reactive”, respectively.

Resilience

The term “resilience” is certainly not new, but it has recently been applied to the domains of safety and human error. We often use the term “error tolerance” (see above) to describe the ability of an organization to safely operate in the presence of human errors. Resilience is a broader concept and refers to the ability of organizations to adapt to sudden safety or operational challenges and then adapt back to operating in a more benign environment.

A very good example of resilience in the aviation environment is what happened to the air traffic control system in the United States on September 11, 2001. The system handled an unprecedented situation without specific procedures, but with a very high level of safety and professionalism. When the threat lessened, the ATC system reverted back to its normal level of operation.

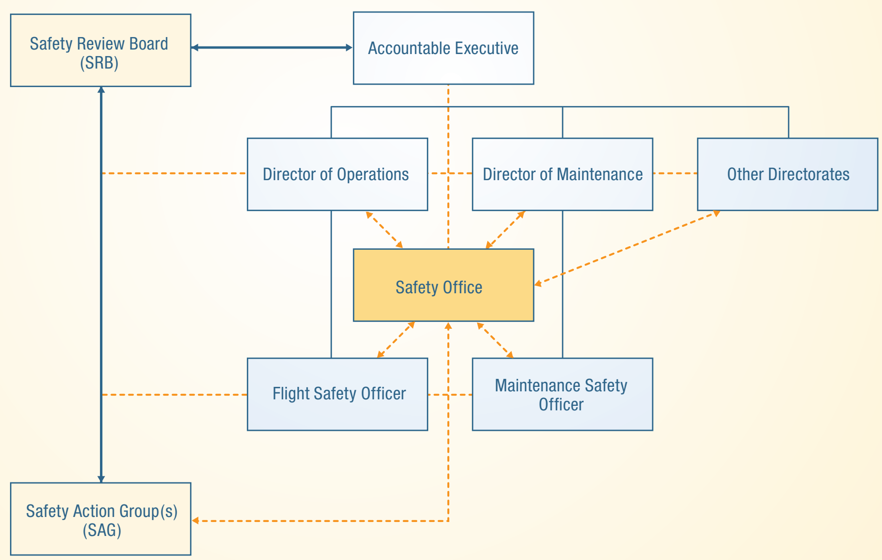
Safety Culture

Error tolerance is the idea of establishing a “safety culture”. This refers to building a corporate culture in which the primary motivation is maintaining the safety of workers and the public. There are many elements of a safety culture, but the general idea is that everyone who works in an organization is motivated and empowered to detect and fix situations that might cause injuries.

Management in organizations with a safety culture encourages and rewards workers who call attention to potentially unsafe conditions. Every worker knows that safety is their responsibility and they feel they are empowered to speak up and take other actions necessary to remedy unsafe conditions. Anybody in the organization can call a halt to activities until an unsafe condition is eliminated—and they are encouraged to do so.

Safety Management System

A Safety Management System, or SMS, is a combination of organizational structure, policies, procedures, and people set up in such a way that the safety of company employees, contractors and the general public is maintained at or above a predetermined level. The International Civil Aviation Organization (ICAO) has established a framework for SMS's.



SMS Responsibilities: An example

METHODS

Safety versus Quality

In the Safety Management System (SMS) framework of the International Civil Aviation Organization (ICAO), one of the primary components is "safety assurance". In the Transport Canada SMS framework, this component is called "quality assurance." There is sometimes a tendency to confuse the terms "safety" and "quality", but these have very different meanings in the domain of aviation maintenance.

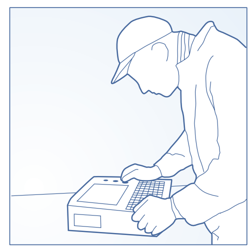
According to the ICAO definition, "Safety is the state in which the risk of harm to persons or property damage is reduced to, and maintained at or below, an acceptable level through a continuing process of hazard identification and risk management." This definition implies that an acceptable level of risk has been established within an organization and that processes have been put in place to ensure that this level of risk is maintained or improved on a continuous basis.

Safety focuses on reducing hazards and risks. Quality focuses on the products of an aviation maintenance program.

Socio-Technical System (STS)

AMTs are familiar with technical systems. They work with (and on) them every day. However, it has become apparent to researchers working with technical organizations that the "people" aspects are often at least as important as the technology in reducing errors, increasing motivation, and creating a good workplace. The combination of technical systems with the people-to-people elements of the workplace has come to be known as a "socio-technical system", or STS.

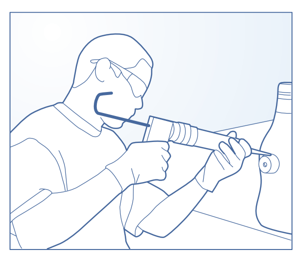
The methods associated with establishing a human factors program tend to support the requirements of a safety management system (SMS), rather than aiming at a particular usability or performance issue. The SMS is concerned with identifying hazards, estimating and reducing risks, and identifying accident causes. Therefore, the methods described here are oriented toward those programmatic goals. These methods are presented in alphabetical order.



Critical Incident Reporting

People who work in a particular job day in and day out have the opportunity to see many "near accidents", i.e., situations that almost lead to an accident, but for some reason do not. This is particularly true for maintainers—not just in aviation, but in any domain. The human factors term for these near accidents is "critical incidents" and they are very important in maintaining a high level of safety.

Critical incidents are considered "precursors" for major accidents. Big accidents seldom occur without precursors, that is, situations in which the same conditions pertained, but the accident didn't happen for some reason. If the critical incidents are reported and analyzed, then we stand a good chance of avoiding the big accidents.



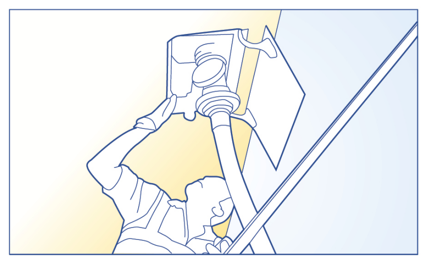
There are two common methods of acquiring critical incident reports. The first is to use paper report forms and questionnaires that AMTs (and others) can fill out anonymously and then either send to a safety group or place in a container designated for that purpose. The second method for critical incident reporting is any of a number of computer-based systems designed for that purpose.

Human Error Risk Assessment

Recall that the ICAO SMS framework calls for both proactive and reactive processes. A process is considered proactive if it attempts to identify hazards and risks before something bad happens. Critical Incident Reporting (see above) is a proactive method. It is observational. That is, people simply need to observe a near accident and then report it.

Human Error Risk Assessment is also a proactive method, but it is analytical rather than observational. The term "Human Error Risk Assessment" is quite general and is given to a variety of individual methods. The FAA is presently evaluating a particular technique called Human Error Safety and Risk Assessment (HESRA) that is tailored to the maintenance environment. However, there are a number of human error risk assessment tools that can be used for this purpose.

All human error risk assessment methods require some type of task analysis (See the Human Factors chapter) as one of their initial steps. Since human error implies that somebody commits an error while they are attempting to do something, we need to know what they're trying to do. Task analysis identifies the tasks and steps required to complete a particular job.

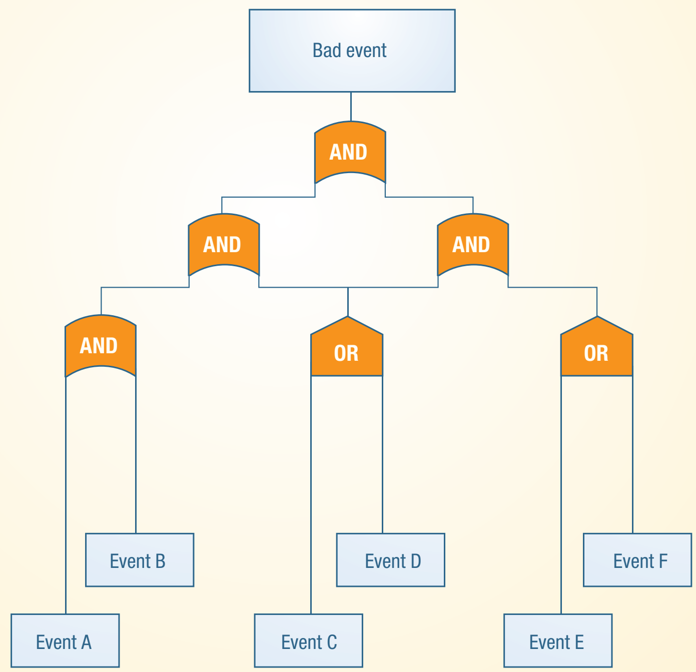


As part of the human error risk assessment process, analysts assign a rating associated with the likelihood of a particular human error occurring. There can be many sources of data upon which to base this estimate, including critical incident reports and historical incident and accident reports. Other very good sources of data are usability tests performed on the same or similar products or systems.

Incident Investigation

Incident investigation is what most people think of when they think of safety management. Something bad happens and we investigate to figure how it happened and what we need to do so it doesn't happen again. Probably the best-known category of incident investigation methods is called "root cause analysis" (RCA), sometimes referred to as "fault tree analysis" (FTA).

Nearly all of these techniques require some type of diagrammatic representation of the factors that might contribute to an incident or accident. This type of investigation is typically depicted as a hierarchical tree with the incident at the top and the contributing factors spreading hierarchically below (hence the name "fault tree").



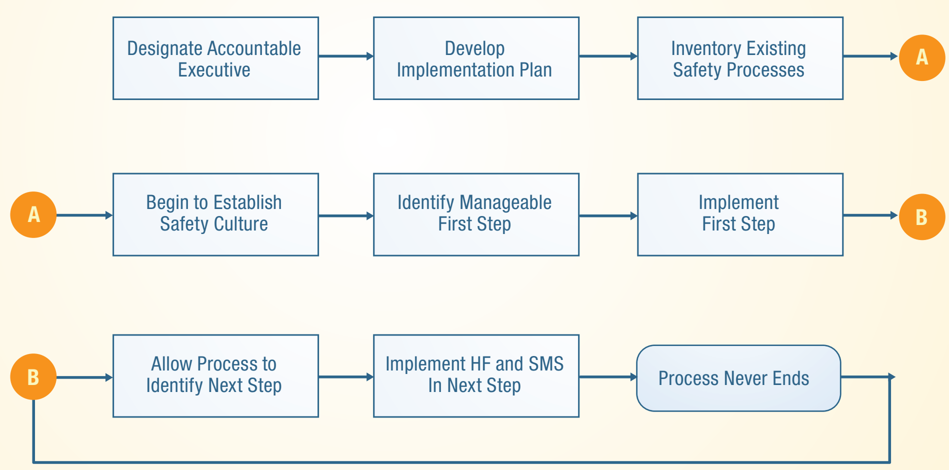
Generic Fault Tree

GUIDELINES

Implementing a human factors program is an integral part of establishing a Safety Management System (SMS). An SMS, however, can include more than the maintenance organization. In an airline, for example, the SMS must include both operations and maintenance. Because of the breadth of safety management systems and the individual character of aviation maintenance organizations, it is neither feasible nor necessarily desirable to provide detailed procedural guidelines related only to implementing the human factors program.

Instead, the guidelines provided below are given at a relatively general level. However, they are sound and based on experiences in implementing both error-reduction programs and other broad-based efforts to increase safety in maintenance organizations. They apply to implementing both the overall SMS and the HF program that is part of the SMS.

These guidelines are given in their approximate order of initiation.



Section Flowchart

Start at the Top

The ICAO SMS framework specifically identifies an "accountable executive" for an organization's SMS. They did this for a very good reason. A viable and effective SMS must be driven from the top of the organization. Senior management must be committed to making the SMS work, which means the company is willing to dedicate enough resources to get the job done.

Develop a Plan

The ICAO SMS framework is just an outline of required functional elements. There are many ways in which these functional elements can be implemented (and even defined). Therefore, prior to beginning to implement an SMS and its constituent human factors program, the group designated by the "accountable executive" should develop an implementation plan. This plan defines how the organization will meet each of the functional SMS requirements, including naming (or describing) the precise elements, procedures, policies, and other components that will become part of the SMS. The plan should also define who will be responsible for accomplishing each requirement, a schedule for implementing each component, and a map of how it will all fit together and operate.

Take an Inventory

One of the first tasks in establishing a human factors program that will fit properly in the SMS is to take an inventory of what already exists. The ICAO SMS framework contains many different elements. An aviation maintenance organization is likely to already have at least some of these elements in place, albeit under different labels perhaps. Other elements will have to be put into place from scratch. That is, there might be no current process, procedure, policy, or method that will accomplish the specific ICAO requirement. There is probably a large middle ground occupied by existing components that will have to be modified to address the ICAO requirements.

Change the Culture First

The term "safety culture" is commonly used to refer to the broad and deep commitment of an organization to do what is necessary to establish and maintain a high level of safety. We could use the term "culture" to refer to any set of values that an organization's management thinks is worthy, including the precepts of an SMS. However, it is not possible to change the culture of an organization by ordering an SMS to be implemented. Rather, the culture must be changed before a complete SMS is established. This can be done by heavily involving all people in the organization while putting the SMS in place and by demonstrating (by deed, not just by word) that senior management values the SMS culture.

Start Small

One of the primary causes of failure for many large organizational programs is that the program champions try to implement the finished program rather than start small and proceed incrementally. This is true in many domains, but none more so than in the world of large information technology programs. There are many (many, many) documented cases of really good "big ideas" failing dismally in large part because they are big and were not implemented in an incremental manner. A very good case in point is the now-failed FBI software case management application, which was abandoned after wasting tens of millions of dollars.

Pick a reasonable, high-payback area and put in place the human factors and SMS elements related to that area only. Get it working. Figure out what went right and what went wrong. Implement the next piece or layer.

Keep the Goal in Mind

Too often, large programs such as the SMS take on such a life of their own that people forget why it was put in place. Entire organizations get created, policies are established, procedures are written, requirements are put into place, etc. Before long, it's all too easy to loose the fundamental focus of an SMS, which is to maintain and improve safety. One way to minimize this phenomenon is to often revisit the bases upon which the SMS and human factors programs are based.

It's good to remind ourselves that we're trying to protect the health and safety of workers and the general public. Another reasonable idea is to establish a safety review committee whose job is to question every procedure, form, policy, and other artifact that is added to or removed from the SMS or human factors program. What are we trying to do with this element? Why is it needed? How are we doing it now? In what way does it increase safety? Are there other ways we could achieve this goal? Etc.

The Job is Never Done

The state of safety is rarely static. Therefore, the appropriate view of the SMS and its human factors components is that they cannot be applied only once and then never applied again (until an accident occurs). Consistent with the PEAR model, the overall level and state of safety routinely changes as people, the work environment, job tasks, and tools and other resources change. The proactive elements of the SMS, which include a number of human factors methods, must be applied and re-applied on a regular basis in order to keep up with these changes.

WHERE TO GET HELP

FAA

There are a number of human factors resources within the Federal Aviation Administration. The most direct link for aviation maintenance is the Senior Scientific and Technical Advisor for Human Factors in Aviation Maintenance.

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International Civil Aviation Organization (ICAO)

ICAO is the international organization that has developed and published the primary requirements and supporting documentation for implementing Safety Management Systems. Aircraft maintenance organizations can easily obtain ICAO standards, guidelines and other documents.

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Transport Canada

Transport Canada is the Canadian equivalent of the U.S. FAA. They have been very proactive in injecting human factors into their aviation regulations. They have also taken a leading role in establishing SMS programs.

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EXAMPLE SCENARIO

There have been a number of accidents over the past two or three years that seem to have come out of nowhere. The circumstances surrounding these accidents, some of which have caused injuries to our AMTs, don't appear all that unusual, but we can't seem to get ahead of the curve. We've conducted some pretty significant investigations for these accidents and have identified a number of causes. We try to fix these causes and it appears at the time that we have done so, but slight variations of the same causes combine again at a later date to cause other accidents.

Issues

1. Why don't we know about these accident conditions before they combine to cause an accident?

2. Why did fixing the causes identified by the previous accident investigations not end the accidents?

3. Is there anything we can do to get a jump on preventing similar accidents?

4. How can we be sure that the things we "fix" because of one accident or incident won't cause other accidents?

Responses

1. We don't know because we probably didn't ask. It is very unusual for a serious accident to have no precursors, i.e., near accidents involving conditions similar to those that eventually cause an accident. AMTs see such "near misses" on a fairly regular basis. However, it is likely that we don't have an established process to gather, analyze, and disperse those near-miss information. It is doubtful that the AMTs are surprised to see these accidents occur, since they've seen them almost occur in the past. However, the accidents are likely to be a surprise to management.

2. By looking at each accident in isolation and "fixing" the causes so identified, we have likely done a good job of ensuring that those precise accidents are unlikely to occur. Since slight variations of these accidents continue to occur, it is obvious that we are missing something fundamental in our accident investigations. By broadening our accident investigation techniques, which is the goal of the SMS framework, we stand a much better chance of identifying broader underlying causes and eliminating entire categories of accidents.

3. Yes, this is the essence of the types of proactive processes identified in the SMS framework. The most common human factors technique for gathering "near miss" information is called the Critical Incident Technique. This involves putting in place a formal process for soliciting and analyzing near-miss reports from AMTs (and other workers). Viable critical-incident programs typically include anonymous reporting, open analysis, and soliciting worker opinions and suggestions regarding eliminating potential accident causes.

4. This is one of the most difficult issues associated with accident investigations. It is virtually impossible to make these types of assessments without a thoroughly integrated SMS. The oversight provided by an SMS makes it much more likely that the results of a particular accident investigation will be compared and combined with analyses from other incidents. In this way, systemic issues can be identified and corrected.

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CHAPTER 3: FATIGUE AND FITNESS FOR DUTY

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LANDING PAGE

Fatigue is one of those human performance concepts that seems easy to recognize (in others), but not so easy to define. Because it is so difficult to agree on a formal definition of fatigue, we tend to define it operationally. That is, we infer from the decrease in a person's ability be attentive or to mentally focus on job tasks that they are fatigued.

Fatigue can be both mental and physical. Certainly, prolonged physical activity, such as lifting heavy objects, can result in physical fatigue. However, of more interest from a human factors perspective is the type of mental fatigue that lessens our ability to safely and effectively perform our job. This type of fatigue is extremely common among workers in all domains, including aviation maintenance. It is almost universally present in shift workers.

Fatigue can come in all shapes and sizes. It can be a temporary condition that modestly affects one's ability to concentrate on a job task. It can also be a chronic medical condition that confers significant physical and mental disability. Fatigue is often confused with sleepiness or tiredness. While these might be symptoms of fatigue, it is possible to be dangerously fatigued without feeling sleepy or tired. The most common cause of fatigue is lack of adequate daily sleep.

In this chapter, we explore the concepts associated with fatigue and discuss ways to both avoid fatigue and counteract it.

INTRODUCTION

The aviation maintenance environment is ideally suited for producing fatigue in the workforce. It is an endeavor that takes place around the clock, every day of the year.

The nature of the aviation business is such that much of the routine and heavy maintenance for commercial aircraft is performed at night, that is, during periods in which the planes are not scheduled to be carrying passengers or cargo.


It is also the case that the current economic climate has squeezed maintenance organizations to reduce staff, thus trying to do more work with fewer people.

In addition, the industry is dealing with both high-technology equipment, such as composites and sophisticated digital electronics, as well as aging aircraft issues that necessitate more, and more extensive, inspection and overhaul activities. Maintenance is often time sensitive. This is especially true for ramp maintenance, but it is also true for depot and heavy maintenance. Airplanes don't make money when they are not flying and one or two extra days in a maintenance hangar can cost a carrier tens of thousands of dollars in lost revenue.

The net result of these factors is that AMT's, Maintenance Engineers, and non-certificated maintenance workers tend to work long hours, work at night and often perform detailed, lengthy, and highly technical tasks under time pressure and, sometimes, challenging physical working conditions. Add to this the psychological stress of an organization in (or on the edge of) bankruptcy, intense competition for work from other maintenance organizations, and typical worker-management issues.

It should come as no surprise that fatigue is just as much a part of the aviation maintenance workplace as job cards, scaffolding, and toolboxes. Years of research, surveys, observations, and self-reports confirm that fatigue is common among aircraft maintainers. From decades of human factors research, we also know that fatigue degrades performance—both mental and physical. This is where the "fitness for duty" aspect of fatigue comes into play.

The major effects of fatigue include the following:

- Increased anxiety
- Decreased short-term memory
- Slowed reaction time
- Decreased work efficiency
- Reduced motivation

- Decreased vigilance
- Increased variability in work performance
- Increased errors of omission, including forgetting or ignoring normal procedures
- Increased risk tolerance
- Reduced problem solving ability

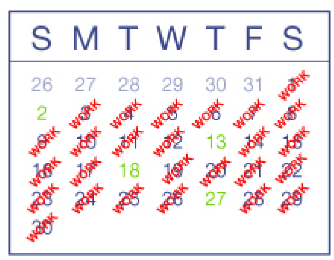
There is a very common tendency to think of "fatigue" and "sleepiness" as synonymous. However, these phenomena are not equivalent. Sleepiness can be taken as an indicator of fatigue. Fatigue can include feelings of sleepiness, but people can be dangerously fatigued and yet not feel sleepy.

In this chapter, we examine the most relevant aspects of fatigue. We will also describe various methods that have been developed to identify the presence of fatigue and some more or less effective ways to counteract it.

REGULATORY REQUIREMENTS

There appears to be only one FAR that relates directly to work schedules for AMTs and other aircraft maintenance workers. Part 121.377 states that "...each certificate holder shall relieve each person performing maintenance ... from duty for a period of at least 24 consecutive hours during any seven consecutive days, or the equivalent thereof within any one calendar month." In essence, this rule requires that maintainers be given at least one day off per week or four days off per month.

There are no restrictions (at least in the FARs) regarding how many hours a maintainer can work in a given day. If the letter of the cited rule is observed, an AMT could work continuously for six days, if they are given the seventh day off.



The international regulatory framework, which has been adopted by the European Aviation Safety Authority (EASA), contains no restrictions regarding working hours. In neither domestic nor international regulations are there requirements that aviation maintainers be unhampered by fatigue while they perform their jobs.

Other than the well-known rules against alcohol and drug impairment, there are no regulations, either domestic or international, that deal directly with "fitness for duty", i.e., the state of being prepared to perform one's job safely and effectively. There are many rules regarding one's qualifications to perform specific maintenance tasks and to hold a regulatory certificate to do so. However, these regulations typically deal with training, experience, and demonstrated skills, rather than being hurt, sick, or simply too fatigued to do the job.

CONCEPTS

Fatigue is an often-misunderstood condition that can affect one's ability to safely perform his or her job. The most common cause of fatigue is lack of adequate daily sleep, which is why most people who perform shift work, especially at night, are particularly susceptible to fatigue and its effects.

The concepts below are associated with the topic of fatigue.

Alertness

The term "watchful" can be roughly substituted for "alert". Thus, alertness is the condition in which we are aware of what is going on around us and likely to see and hear events that are taking place. Alertness is one of the conditions necessary for proper situation awareness. Fatigue typically reduces alertness so that we are not as likely to see and hear things that we need to see and hear to perform a job safely.

Attention

When we "pay attention" to something, we are directing our perceptual and mental resources toward it. Attention is both the act of focusing these resources on a particular topic, task, person, etc., and the ability to do so. The effects of fatigue on attention are similar in some respects to the psychological condition known as attention deficit disorder (ADD). Fatigued individuals find it difficult to be attentive to job tasks for extended periods of time.

Circadian Rhythm

All mammals, including humans, exhibit constantly changing physical and mental states. A number of variables, such as body temperature, blood pressure, heart rate, blood chemistry, attention, sleepiness, and others, change according to a periodic pattern that lasts slightly longer than twenty-four hours. This cycle is called a "circadian rhythm". The word "circadian" means "approximately one day." Our desire and ability to work and rest is highly dependent on where we happen to be in our circadian cycle.

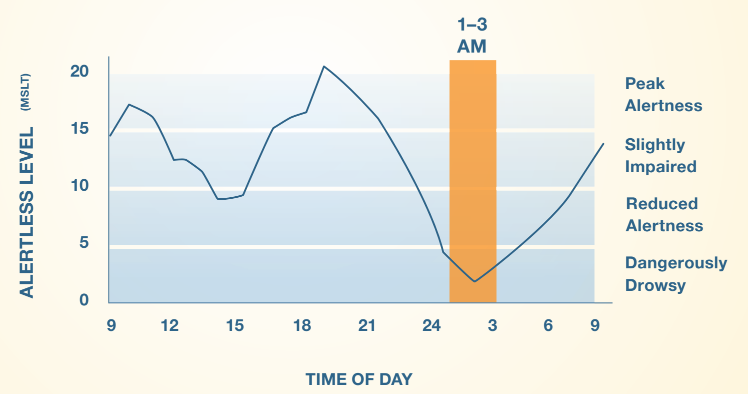


Figure 3-1. *Alertness level vs. time of day*

Cognition

Cognition is a general term given to the ability to perform mental work. Cognition can take many forms. Most commonly, cognition amounts to thinking through a task, troubleshooting, reasoning and other logical processes, doing mental calculations, etc. Fatigue reduces cognitive abilities and makes a person more susceptible to mental traps.

Competence

Competence, from an aviation maintenance perspective, is the quality of having the knowledge, skills, abilities, and experience to perform a specific job or task. Competence does not necessarily imply that a person is either “qualified” to perform a task or in the appropriate physical and mental condition to perform it. In the regulatory world, “qualification” has a very specific meaning (see below). Being qualified doesn’t necessarily imply competence.

Fatigue

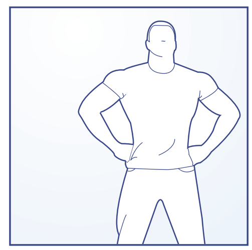
Fatigue has no commonly accepted, objective definition. Rather, it is typically defined operationally (see “operational definition”, below) as a decrease in the ability to perform one’s job safely and effectively due to a lessening of perceptual, cognitive, or physical abilities. The International Maritime Organization defines fatigue as “A reduction in physical and/or mental or emotional exertion which may impair nearly all physical abilities including strength, speed, reaction time, coordination, decision-making, or balance.” Sounds bad and is bad.

Fatigue Countermeasures

As with any countermeasure, fatigue countermeasures are methods, practices, materials, substances, or other elements that can counteract the effects of fatigue. The most commonly used fatigue countermeasure is caffeine. While caffeine is somewhat effective as a fatigue countermeasure (at least for short periods of time), other methods used to combat fatigue can actually worsen its effects.

Fitness for Duty

In its most general form, this term encompasses all those elements that render a person willing and able to perform their job tasks. Being "fit for duty" implies that a person is competent, qualified, and physically and mentally up to the challenges of doing their job. Often, the term "fitness for duty" is used in connection with drug- or alcohol-related performance issues. In this Guide, we are more concerned about AMT's being well rested enough to safely perform their job.



Judgment

Judgment is the ability to assess the appropriateness of particular actions in the prevailing situation or environment. It is a valued commodity in the aviation maintenance world, as it is in any safety-related domain. Exercising judgment implies that one avoids unnecessary risks and errs on the side of caution when assessing the most desirable course of action. At the heart of judgment is the understanding that the ability to do something does not mean it is always the most appropriate thing to do.

Maintenance Resource Management (MRM)

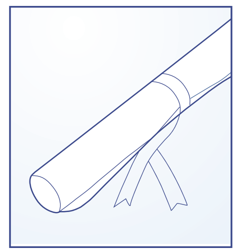
Maintenance Resource Management, or MRM, is the maintenance analog of aircraft crew resource management (CRM). MRM consists of a number of techniques that aim to foster better communication and team coverage among AMT's and AME's. As with CRM, MRM provides ways that maintenance team members can properly communicate important information to one another and monitor each other's job performance. With respect to fatigue and fitness for duty, MRM is a primary method for identifying fatigued co-workers and dedicating the resources required to ensure all maintenance tasks are done properly and safely.

Operational Definition

An operational definition is one in which something is defined in terms of observable behavior, instead of in terms of words and theoretical concepts. Operational definitions are most often used for concepts for which we either do not understand the underlying theoretical constructs or cannot identify an unambiguous set of objective defining elements. The basis for an operational definition is "If we observe these things, then (whatever we're trying to define) must be present." Prior to the availability of reliable portable blood alcohol tests, drunken driving was operationally defined in terms of observed driver behavior.

Qualification

Qualification, in the aviation maintenance world, is the process by which an authoritative person, group, or organization, has evaluated one's ability to do particular tasks and found that ability to exceed some minimum accepted standard. The typical evaluators for qualification are the FAA (or EASA) and the maintenance organization for which an AMT or AME works. The FAA confers qualification via a license. An aviation maintenance organization can evaluate its workers' qualifications using various criteria, such as time on the job, time under the supervision of an already-qualified person, etc.

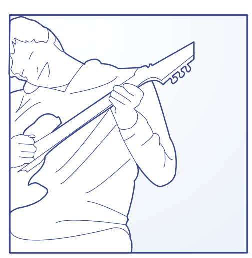


Sleepiness

This is a familiar sensation to most of us. Sleepiness is the feeling of having to close one's eyes and go to sleep. Drooping eyelids, nodding off, and the inability to maintain focus commonly accompany sleepiness. Sleepiness is associated with the presence of the chemical melatonin and occurs at low points of the circadian cycle.

Surrogate Task

A "surrogate" task is used as a substitute for a real task. In the context of fitness for duty testing, a person's performance on a surrogate task is taken as a good indicator of their ability to perform safely and effectively on a real job task. Usually, a surrogate task contains some (or all) of the physical and mental elements required for the real job task. For example, if the real job task requires detailed eye-hand coordination, then performance on any task that requires similar eye-hand coordination, such as on a hand-held video game, might provide an indication of a person's ability to do the real job task.



METHODS

Without known exception, researchers agree that the very best way to deal with fatigue is to avoid it. The only proven method for avoiding fatigue is to get the proper amount of sleep each day and to avoid the other factors, such as stress and overwork, that are known to induce fatigue. Unfortunately, we tend to live busy lives and it is often difficult to get the recommended 8-9 hours of sleep each day and to avoid all those stress-inducing situations. The picture is even more complicated for people who work at night, when most of the population sleeps. The major issues related to shift work are addressed in another chapter of this Guide. However, in this chapter we will examine various methods of avoiding fatigue or counteracting it.

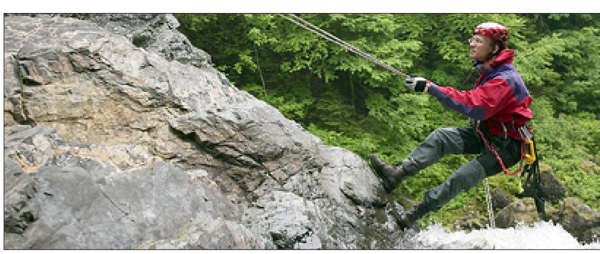
Fatigue

Fatigue has been studied in a number of different domains. Recent work related to commercial truck drivers, commercial and Coast Guard ship bridge crews, and aircraft crews has identified just how common workplace fatigue is and how easy it is to become fatigued. Fatigue is pervasive and its effects are insidious. For example, a high proportion of commercial ship collisions have been attributed directly to the effects of fatigue in bridge crewmembers.
A very recent study (April, 2007) has concluded that the rate at which an individual becomes fatigued and their ability to concentrate and perform job tasks when they are fatigued have a genetic basis. If this work is supported by future studies, it provides a physiological explanation for the existence of "morning people" and "night people". It might also lower expectations for being able to mitigate the effects of fatigue in certain types of individuals.

Avoidance

There's an old American vaudeville comedy routine in which a person visits his doctor, flexes his arm, and says, "Doc, it hurts when I do this." The doctor replies, "Well, don't do that. Fifty dollars please." This is precisely the most common advice given for countering the effects of fatigue, i.e., don't become fatigued.

While this might seem like a "Duh!" prescription for fatigue, it has a solid technical basis. We know most of the causes of fatigue. We also know that counteracting fatigue after it occurs is extremely difficult. Therefore, the smart thing to do is to avoid this very dangerous condition. However, eliminating or avoiding the known causes of fatigue is normally difficult and often impossible.



The primary cause of fatigue is the lack of adequate, high-quality sleep. In fact, chronic sleep deprivation occurs with epidemic frequency in the United States. Even in the best of circumstances, it is often difficult to get the required 8-9 hours of sleep per night. Add common life circumstances like working on a night shift, raising small children, having an active social life (or any life outside work), participating in hobbies, etc., and getting enough sleep becomes virtually impossible.

In the Guidelines, we will touch on a few ideas for avoiding fatigue. In general, however, we should proceed on the assumption that fatigue will be present in the workplace, at least on some occasions.

Drugs

The most common fatigue countermeasure is consuming drinks that contain caffeine, such as coffee, tea, carbonated beverages, and, more recently, “energy” drinks. Caffeine does in fact mitigate the effects of fatigue and lack of sleep, at least for a short period of time. It, or the foods containing it, also has side effects that can compromise job performance, such as stomach upset, headache, nervousness, etc. Other drugs, such as over-the-counter decongestants containing pseudo-ephedrine, and prescription drugs, such as amphetamines, also offer short-term relief from the symptoms of fatigue.

The consumption of caffeine is likely to remain the most common fatigue countermeasure. However, caffeine and other drugs have at least one very serious bad consequence. Their residual effects make it more difficult to sleep when one is off shift when sleep is both appropriate and necessary.

MRM

The best hope for avoiding the effects of fatigue once it is present is for aviation maintainers to adopt a team mentality and take advantage of the collective capabilities of everyone on shift. This is one of those issues for which common wisdom actually works. Two heads really are better than one. Co-workers can actively look for signs of fatigue in themselves and others and then take the appropriate steps to compensate.

The essence of Maintenance Resource Management (MRM) is to train workers to think and act as a team, to question the actions of co-workers when they appear to be unsafe, and to actively seek the help and oversight of others. MRM is generally treated as a training issue. Structured MRM training programs are available from commercial sources—especially other aviation maintenance organizations that have implemented MRM programs.

Napping

Taking a nap is one of the few things that actually works to temporarily reverse the effect of fatigue without bad side effects. A number of studies by NASA and others have shown that a short nap (20-30 minutes) can have significant effects in overcoming fatigue and sleepiness. While a nap is not equivalent to uninterrupted, high-quality sleep, it has remarkable restorative effects that extend for hours. Afternoon naps are common in a number of cultures. A recent study of men in one such culture identified a statistically significant decrease in cardiovascular disease among individuals who routinely took a short nap each day.

Physical and Social Activity

Participating in activities can increase alertness and mitigate other effects of fatigue, if only temporarily. Appropriate activities include physical exercise, such as running, walking, and stretching, social interaction, which fits nicely with MRM, and frequently switching among job tasks that are highly demanding and those that are less physically and mentally demanding.

The inability to interact socially or participate in physical activities is also a good outward indicator that a person is fatigued to the point where there might be safety implications. Among the many good features of MRM is training oneself to identify the symptoms of fatigue in coworkers (see Observations, below).

Fitness for Duty

The idea that a person's fitness for duty (FFD) can be objectively measured is very attractive from a safety perspective. Certainly for some factors that degrade one's ability to do their job, there are well-defined physiological tests that can determine whether an individual is within or beyond pre-established fitness for duty limits. The best example is probably blood alcohol concentration (BAC). There are also physiological tests that can assess some indicators of fatigue and sleepiness. However, these tests are often time-consuming, typically given only once (at the beginning of a shift), and of questionable applicability in the aviation maintenance domain.

There are also many policy questions associated with FFD testing. They are beyond the scope of this Guide, but will likely figure prominently in any decisions related to fitness for duty. A few examples are listed below:

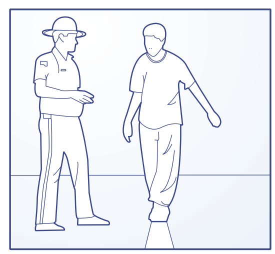
- When would FFD testing be administered?
- What happens if an individual is deemed not fit for duty?
- What if a person is deemed fit for duty at the beginning of

their shift, but becomes unable safely perform their job later in the shift?
- Is FFD testing accurate enough to allow supervisors to depend on the test results?
- What happens in emergency situations, i.e., extraordinary circumstances that require AMTs to work past their normal shift times?

We simply do not know the answers to these, and other, questions. However, regardless of the policy decisions regarding FFD testing, the information that follows provides a technically sound view of the current state of FFD tests.

Observations

Observational techniques have many advantages over more formalized or technology-oriented FFD tests. They can be administered at any time and without specialized equipment. They can be administered repeatedly, not just at a single point in time. They have face validity. That is, it just seems intuitively correct that we should be able to judge a co-workers fitness for duty by observing their behavior. On the negative side of the equation is that observational techniques have never been shown to actually work.



Regardless of the intuitive attraction to the observational concept, there is little scientific evidence that we are capable of judging dangerous levels of fatigue in our self or others. It is true that we are often able to judge our own or others' level of sleepiness, but it is possible to be dangerously fatigued and yet not overtly sleepy. One of the primary effects of fatigue is to lessen our ability to accurately evaluate our own or others' abilities.

When fatigue reaches extreme levels, there tend to be obvious cognitive and physical symptoms, such as failure to pay attention, running into things, etc. However, at lower, but still dangerous, levels, there does not appear to be any proven observational method that can accurately assess an AMT's fitness for duty.

Performance Tests

The idea behind performance FFD tests is very simple. If fatigue degrades job performance, then test an AMT's performance on representative job tasks. If the AMT can perform these tasks well, then, by definition, they are not too fatigued to do their job.

There are at least two obvious problems with this simple idea. First, it is not OK to test an AMT's job performance on real aircraft, so it would be necessary to find some way to measure those task skills in some sort of test setup. Second, there is the question of when a performance FFD test should be administered. The obvious answer is to administer the test just prior to the start of a shift. If we do that, then we have to ask what can happen to that person's fitness for duty over the course of a shift. Suppose an AMT is very fatigued at the start of their shift, but can pass the FFD test. If they start out fatigued, then there is a good chance they will reach a point sometime during their shift when their job performance is unacceptable.

As for the first issue of just what tasks we can used to measure fitness for duty, there has been a lot of work to develop a reasonable approach. The primary result of those efforts is a battery of tests known as the Automated Performance Test System (APTS). This is a series of so-called “surrogate” tasks that mimic the core abilities of many types of real world tasks.

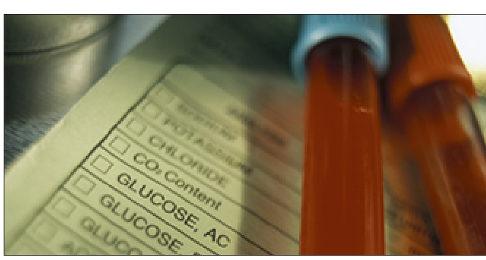
For example, suppose one’s job requires the ability to use short-term memory to keep track of several consecutive procedural steps. Since we can’t know the exact type of procedures that will be used for every job, the APTS substitutes a generic short-term memory test. There are eight components to the APTS that include physical, memory, math processing, geometric reasoning, etc.

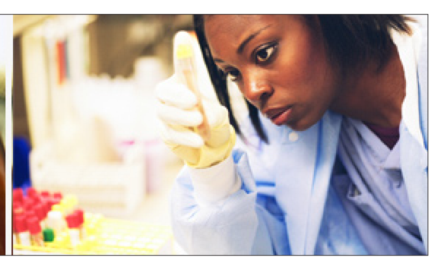
The big problem with using the APTS is that it’s been mainly validated against alcohol usage. In many ways, the effects of fatigue on job performance are similar to the effects of alcohol. However, when the APTS was tested with people who had been forced to stay awake for 24 hours, it was much less valid than for alcohol effects. This leads to a situation in which the most well-developed performance test that might be used for FFD testing has not been validated in the aviation maintenance environment and may not be reliable.

Physiological Tests

The third major category of FFD tests is physiological, or tests that measure one, or more, physical characteristic that is known to vary with a person’s current level of fatigue. There are many common physiological tests used to measure medical conditions. Probably the best example is measuring blood glucose level to determine required insulin dosage for diabetics.

The most common physiological test related to performance impairment is the blood alcohol test, which is used to measure blood alcohol concentration (BAC). There are very strict limits on acceptable BACs for AMTs (essentially zero). The concept of having physiological tests to measure fatigue is attractive because they are objective and do not require the person being monitored to do anything other than submit to the test.





Tests such as those for blood glucose and blood alcohol levels are termed "invasive". They require blood to be drawn and analyzed. Imagine having to undergo a finger prick at the start of each shift and maybe even at intervals during a shift. As it turns out, there is no reliable invasive test that relates any component of any bodily fluid to one's current level of fatigue. However, there are certain non-invasive tests that might hold some promise in this regard.

Certain characteristics of the human eye are related to sleepiness and fatigue. Tests that measure these characteristics are generally called "ocular" tests and they have several attractive features. They assess a person's current level of fatigue. They are sophisticated, but typically require only a few minutes to administer. Some actually require only 30-90 seconds. Since they measure involuntary ocular characteristics, such as pupil latency, it is not possible to "game" the tests.

The main drawback for all ocular measurement methods is that they require an optical measuring apparatus, which can be relatively expensive. One such measurement system costs about $30,000. Also, these methods have not been validated in the aviation maintenance workplace.

GUIDELINES

Providing guidelines related to fatigue is both easy and nearly impossible. On the easy end of the scale, the simplest guideline is "Don't become fatigued." This is, in fact, the most common guidance provided on the topic. Once you are fatigued, the odds of mitigating the effects are not good...and they get worse as time passes without enough rest to recover.

The guidelines presented here are provided to increase your self-awareness of the causes and effects of fatigue. There few methods available to enable one to work safely in the presence of severe fatigue and none, short of getting some sleep, that will allow you to eliminate the underlying cause of fatigue-related performance problems.

Your body doesn't know the difference

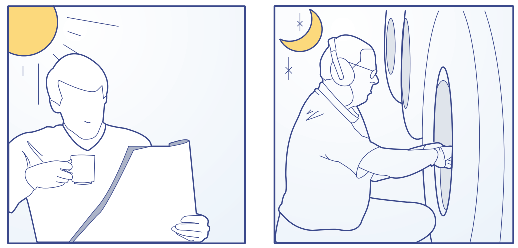
Fatigue, at least the kind of fatigue that is likely to affect job performance, is caused by the lack of adequate rest and sleep. For most of us, our job is the most well-planned part of our life. That is, we pretty much know which days we're going to work and what time we're going to start and end work each day. There are exceptions, of course, but typically work doesn't consume so much of our time that it is not possible to get an adequate amount of rest. The real problem is often the part of our life that occurs outside of work time.

It is the nature of life that it is often chaotic. Our non-work hours are filled with activities, such as hobbies, organized sports, family outings, kids, and other things that could be simply described as having a life. As far as fatigue is concerned, your body doesn't make a distinction between work and non-work activities. If you work 8-10 hours, commute for an hour, spend 2 hours taking your kids to a soccer game, watch television for 2 hours, work on a woodworking project for 2 hours, and just hang out with your family for another couple of hours, that leaves only 6-8 hours for you to sleep before you start all over again.

Your body doesn't care that you spent only 8-10 hours of that time working. It knows only that you got 6 hours of sleep, or 4 hours, or less, depending on how much time you really spent doing non-work stuff. It's probably not fair, but it is a fact that we have the most control over our non-work activities, so that's where we have to arrange things so we can get enough rest to avoid fatigue.

Are you one of the "Night People"?

Do you consider yourself a "day" person or a "night" person? Recent research has shown that there is a genetic basis for being one or the other. That research also showed that certain people tend to become fatigued more quickly with lack of sleep. These same individuals have more difficulty performing their jobs when they are fatigued.



While you cannot do anything about your genetic predisposition related to fatigue, you can and should recognize that your performance might be affected more than other people. Recognition of your own vulnerability to fatigue will allow you to plan your non-work activities so you can achieve the required level of sleep and rest before and after your workday.

Yes, you DO need 8 hours of sleep.

You've no doubt heard people say they don't need very much sleep to "get by." You might have said the same thing yourself. Unfortunately, there's no technical basis for this phenomenon. It is true that there is a range of sleep time required to provide adequate rest for specific individuals. However, that range is on the order of 7-9 hours rather than 3-8 hours. Consistently short sleep periods result in chronic sleepiness and fatigue.

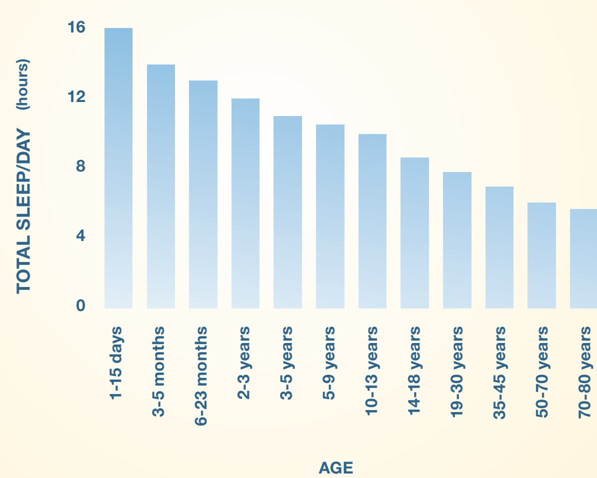


Figure 3-2. *Average hours of sleep per day vs. age*

You're on a team—use it.

Once a person is fatigued, there are only three real choices to make regarding job tasks. The first is to simply not continue to work. Go home and get some rest. This is exactly what the crew of a British Airways flight did in April, 2007. They claimed they had been unable to get enough sleep the previous evening because of noise at their hotel, so they declined to fly until they'd gotten more rest...and the airline backed their decision.

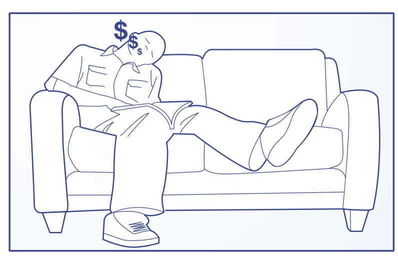
It's not clear that leaving work is a realistic option for most AMTs. If the decision is made to continue working, then the most effective options are to increase the emphasis on teamwork among the AMTs on shift or to take a short nap (see below).

The term "maintenance resource management", or MRM, is often used to denote the formalized use of teamwork in aviation maintenance. Specific methods have been developed as part of an overall MRM program. These include techniques that ensure full and appropriate communication among team members, the ability to give and accept constructive advice, encouragement for individual AMTs to raise questions about specific work elements that cause them to be uncomfortable with quality or safety, etc.

The central tenet of MRM is that the collective ability of a team of AMTs, inspectors, supervisors, etc., is greater than the sum of the individual team members' abilities. This approach can be as simple as asking someone to verify your interpretation of a job card or as formal as increasing the number of required inspection items (RIIs) for work done on the midnight shift.

Naps—They work.

The simplest and by far the most effective guideline regarding fatigue management is this "Don't get fatigued." The only proven way to avoid fatigue is to get a consistent amount of high-quality sleep. Likewise, the only proven way to overcome fatigue is to get some sleep. The most practical way to get some sleep in a job setting is to take a short nap.



This is not just wishful thinking. Napping has been shown to be effective in a number of settings, especially in the aviation environment. Studies by NASA and the FAA have consistently shown the restorative effects of naps. A recent study by the FAA showed that longer the nap on midnight shift, the more dramatic the restorative effect. A napping period of 45 minutes to 2 hours can restore your ability to safely do your job.

The effects of "power naps", i.e., naps as short as 20 minutes, have not been scientifically demonstrated to be restorative in workplace environments. However, midday naps of about 30 minutes duration have been shown to decrease mortality, so the potential value of power naps shouldn't be discounted.

The most problematic aspect of napping while at work is likely to be procedural. How should we treat the time spent napping? Is that paid or unpaid time? What happens to the rest of the work crew when one, or more, person is napping? Will this be a fairness issue, i.e., why does one person get to take a nap while others do not? These issues are probably best addressed in a collaborative, MRM-type environment. However, one thing is not open to objective debate - naps work to overcome fatigue and sleepiness.

WHERE TO GET HELP

FAA

There are a number of human factors resources within the Federal Aviation Administration. The most direct link for aviation maintenance is the Senior Scientific and Technical Advisor for Human Factors in Aviation Maintenance.

Dr. William B. (Bill) Johnson, PhD
Senior Scientific and Technical Advisor for Human Factors in Aviation Maintenance
+1 770.458.3022
bill.johnson-dr@faa.gov

Human Factors and Ergonomics Society (HFES)

The HFES is the only organization in the United Stated dedicated specifically to the Human Factors profession. The HFES was formed in 1957 andtypically maintains about 5,000 members. The organization headquarters is in California.

Human Factors and Ergonomics Society
PO Box 1369
Santa Monica, CA 90406
USA
+1 310.394.1811
info@hfes.org
http://www.hfes.org

National Sleep Foundation

The National Sleep Foundation is a non-profit organization that provides information and resources related to sleep disorders and the effects of inadequate sleep.

National Sleep Foundation
1522 K Street, NW, Suite 500
Washington, DC 20005
+1 202.347.3471
nsf@sleepfoundation.org
http://www.sleepfoundation.org

EXAMPLE SCENARIO

Two people on your shift seem to be consistently tired, maybe too tired to do their jobs. They're both young and have very young children at home. You'd think that, since they work the midnight shift, they'd be able to get plenty of rest during their off times. After all, their wives are home at night with the kids. You've seen both of these guys fall asleep at the break table and you've subtly let it be known that other AMTs and inspectors might want to keep a close eye on their work. You're not really sure what else you should do.

Issues

1. Are these AMTs really fatigued—to a level that might compromise safety?
2. Why aren't they getting enough sleep when they're at home?
3. Is extra scrutiny of their work a good idea and is this the way to do it?
4. What else can and should you do about the situation?

Responses

1. The short answer is "yes". These people are very fatigued. The tip-off here, aside from other behavior, is falling asleep at the break table. People who fall asleep quickly, especially in work environments, are at the ragged edge of fatigue. Technically, the amount of time it takes to fall asleep is called "sleep latency". The shorter the latency, the more sleepy one is. There are likely to be a number of other symptoms, such as the inability to concentrate on a topic for more than a few minutes, "zoning out", losing the thread of a conversation, and, more ominous, sloppy work without the recognition that it's sloppy.

2. This is a likely to be a complicated issue. They work all night while their wives are dealing with young children who don't sleep through the night. When they come home after their shift, their wives are tired and want to get some sleep. When one spouse's sleep/wake cycle is interrupted, the effects tend to propagate to the other spouse. Just the presence of young children in a household can disrupt sleep periods any time during the day or night. Also, people want to spend time with their kids, so trading off sleep for interaction time is not likely to be viewed as a bad thing.

3. Yes, by all means, extra scrutiny is absolutely necessary in this case. The "unofficial" route is probably OK in the short term, but it won't be effective over time, nor is it likely to catch all the work problems that might be caused by fatigue.
4. This is an example where MRM can be used to full effect. These individuals need to structure their lives so they can function safely on the job. Perhaps they need to come to work an hour early and simply take a nap before their shift. Maybe they can spend an extra hour on shift and take a nap in the middle of the shift. The entire team needs to be considering how to compensate for this fatigue. For example, these two individuals should never be paired to work on a particular job.

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CHAPTER 4:
FACILITY DESIGN

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LANDING PAGE

The types of physical facilities in which aviation maintenance is performed include both common and unique designs. The various “shops” that are used to house specific functional tasks are not conceptually or physically different from maintenance shops found in other domains. Shop-centric maintenance includes elements such as landing gear, avionics, hydraulics, brakes, engines, and other components.

Ramps, while typically larger than corresponding work areas in other domains, are not particularly unique in their design. Many industries operate in outdoor environments and perform maintenance in these conditions. Certainly, the time-critical nature of aircraft ramp maintenance is a critical feature of the aviation domain, but other industries also work under time pressure.

The one type of physical facility that is unique to aviation maintenance is the hangar. These are very large, open floor plan buildings that can accommodate large aircraft. Some modern hangar facilities are among the largest free-standing structures in the world. At the high end of the size spectrum, Emirates Airways just opened an new maintenance facility that will house seven Airbus A-380s at once—with the hangar doors closed. Conceptually, hangars are really large garages. Instead of cars and trucks, however, they can accommodate the largest aircraft in the world.

Facility design is a very broad topic that is well beyond the scope of this Guide. However, there are a number of elements of facility design that are subject to human factors methods and guidelines. Aviation maintenance facilities are, after all, places where people work. The perceptual, cognitive, physical, and psychological needs of aviation maintenance technicians and engineers (AMTs and AMEs) are really no different than those of workers in other domains and in other types of facilities.

This chapter describes the fundamental concepts related to facility design. It also relates these concepts to specific issues in the aviation maintenance environment. Finally, it provides guidelines that can help readers base routine facility-related decisions on sound human factors principles.

INTRODUCTION

Within the aviation maintenance industry, there are three major categories of workplaces, namely hangars, ramps, and shops. Of these, ramps are the least controllable in terms of workspace and environmental factors such as lighting, noise, humidity, etc. Technical shops, such as those in which avionics components are repaired, are most like an office environment. They are relatively easy to control for workspace layout and environmental factors. Hangars represent a middle ground for controllability of work factors.

There are several components that need to be considered when discussing facility design. First, the content and layout of the overall workspace needs to be evaluated. Second, the fixtures, tools, and work platforms that are either stored in or part of the overall workspace need to be considered. Third, the atmospheric, lighting, and sound environments (and their controls) should be characterized. Finally, individual workplaces within the overall workspace need to be evaluated.

Previous evaluations of aviation maintenance facilities have identified habitability and usability problems that can be solved by applying human factors methods and data. These issues are not unique to aviation maintenance. A study of the maintainability of nuclear power plants, revealed that nearly 20% of critical incidents (serious near-accident type occurrences) were directly related to some aspect of facility design.

Because of the sheer scale of aircraft maintenance facilities, we sometimes lose sight of the fact that they must accommodate people as well as airplanes. Issues related to physical compatibility, such as anthropometry and biomechanics, are discussed in the Human Factors chapter. Guidelines in this chapter contain data that facility designers can use to fit various facility features to maintenance workers.

Within the Human Factors and Ergonomics Society, the Environmental Design Technical Group (EDTG) http://edtg.hfes.org/ is concerned with all aspects of the "built" work environment. The "built" environment includes buildings and all the things that go in or on them. Most aircraft maintenance organizations have access to a "facilities" group that is generally responsible for design and construction of all facility-related elements.

In practice, facilities people and architects rarely interact with human factors professionals. A legitimate question arises, however, as to whether human factors facility design guidelines differ from published architectural guidelines. If they do, does it really make any difference which guidelines are followed? One study that addressed this issue found that facility users rated classrooms that met human factors guidelines as more pleasant and usable than those that met only architectural guidelines.

The truth is, many technical specialties have valuable skills and knowledge that can be applied to facility design. As with other complex endeavors, a professional team approach provides a much higher probability of a successful result than any individual profession acting alone. Thus, architects, construction trades workers, human factors practitioners, industrial engineers, and maintenance workers all have something to contribute to facility design.

REGULATORY REQUIREMENTS

There are three main sources of regulatory requirements directly related to the design of aviation maintenance facilities:

- OSHA Regulations
- National Building Codes
- Local Building Codes.

The Occupational Safety and Health Administration (OSHA) regulations are contained in the Code of Federal Regulations (CFR), Title 29, Parts 1900 to 1910. Many of these regulations have been cited in Workplace Safety. Table 4-1 lists the OSHA regulations that apply directly to facilities.

None of the OSHA regulations directly address temperature and humidity control, heat stress, or related topics. Various types of ventilation are covered, but only as they relate to toxic or explosive environments. There are several sources of guidance for HVAC-related issues, including the National Safety Council. These are cited in the Guidelines section.

The second source of facility-related regulatory requirements are national building codes, such as the National Electrical Code. These codes generally relate to the detailed structures and systems that comprise maintenance facilities. The purpose of these codes is to ensure that both residential and commercial facilities meet minimum standards of construction. They are not primarily concerned with, nor do they generally affect, human performance within maintenance facilities.

Finally, there are a number of local building codes with which any facility must comply. Local codes usually invoke all requirements of the national codes and may add certain provisions mandated by local governments. As with national codes, local building codes are primarily aimed at ensuring that construction meets minimum safety and functional standards. No local codes are cited in the Guide, since they generally do not affect human performance within aircraft maintenance facilities.

Table 4-1. Facility-related OSHA regulations.

Topic	Covered In
Ingress and Egress	Subpart E
Access, including Aisles and Passages	Sections 35-40 and appendix
Storage and Retrieval	Section 22 Subpart N
Ladders, Work platforms and Scaffolds	Section 176
Elevating, Rotating, Vehicle-Mounted Platforms	Sections 25-29, 31
Sound and Noise	Sections 66-67
Lighting Near Exit Signs	Section 95 and Appendix
Lighting in Spray Booths	Section 37
Minimum Lighting for Operating Forklifts and Other Industrial Trucks	Section 107

CONCEPTS

Adaptation

Humans have the innate ability to adapt to their work setting in a number of ways. The most common form of adaptation is our vision adjusting to the overall level of ambient light. When we first walk into a darkened movie theater, it is very difficult to see anything, but after 15-20 minutes, we can see quite well (see figure 4-1). When we go back outside, especially if the day is sunny, it takes a few minutes for our eyes to adjust back to the high light level. A similar type of adaptation occurs for ambient temperature.

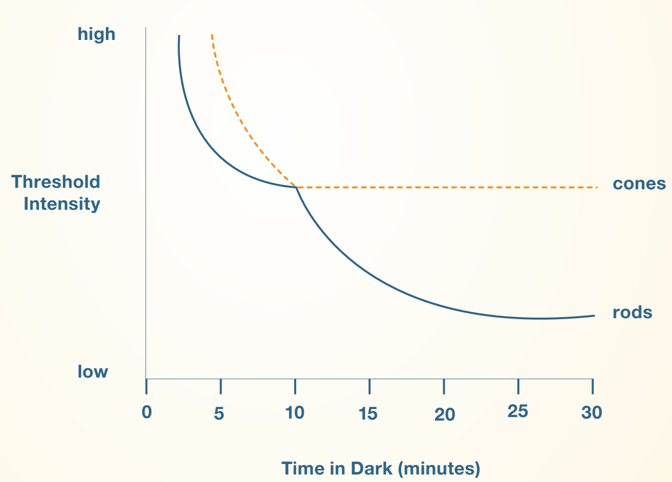


Figure 4-1: *Dark Adaptation Curve*

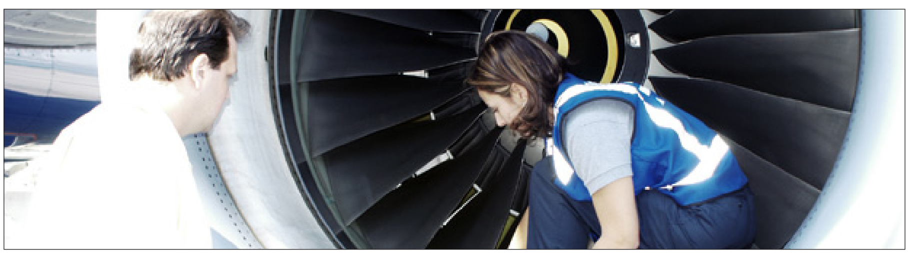
The important things to remember about adaptation are that it occurs only within a certain range and that it does not occur instantaneously. Also, we do not adapt to some elements of our environment, such as noise.

Color Rendition

Color rendition is crucial in some maintenance tasks. For example, many electrical wires are color-coded so they can be properly connected and traced. The perceived color of an object depends on the color content of the light falling on or being produced by it. Different types of light sources have different color compositions. This is common knowledge among people picking out house paint, wallpaper, furniture fabrics, etc. The color of these items in the store is sometimes not the same as when they are in a home.

Environmental Stress

The concept of stress was discussed in the Human Factors chapter. One type of stress is caused by elements in a worker's environment. Examples include cramped physical spaces, poor lighting, noise, heat, cold, humidity, and lack of airflow. Environmental stress can cause both physical and mental impairments. For example, excessive heat causes the inability to concentrate, as well as the more obvious symptoms of physical distress.



Frequency of Use

The term "frequency of use" means that the parts of a facility that are used most often should be placed so they are the most convenient to access. In practice, the most frequently used areas are those that are used by many people in order to do their jobs.

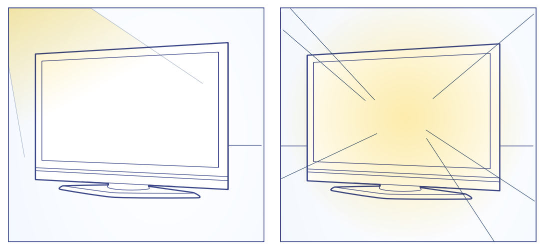
Functional Grouping

The essence of the concept of functional grouping is that things that are used together should be placed together. In the context of facility design, functional grouping requires that parts of the facility needed for performing particular job tasks should be located near one another. For example, wheel and tire storage areas should be located near the tire shop.

Ilumination and Luminance

The concepts of illumination and luminance are associated with the quantity of light falling on or emanating from a surface, respectively. Illumination is related to the amount of light falling on a surface or an object. Luminance is related to the amount of light coming from an object, such as a video display terminal or a wall. Luminance is associated with our subjective impression of brightness.

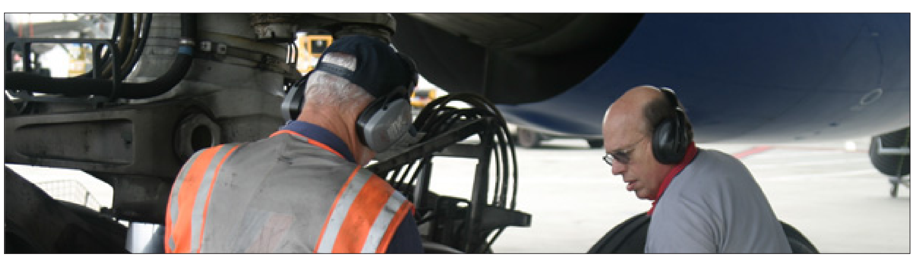
The farther you move away from a light source, the more the intensity of illumination. In fact, it decreases as the square of the distance. If you double the distance between an object and a light source, the illuminance measured at the object drops to one-fourth its previous level.



Luminance, on the other hand is associated with the object itself. Our impression of the brightness of an object depends on its luminance. Luminance does not decrease as we move further away from an object, at least within a reasonable range of distances. The reason for this has to do with the way luminance is defined mathematically. Our experience confirms that a wall doesn't become less bright simply because we move away from it.

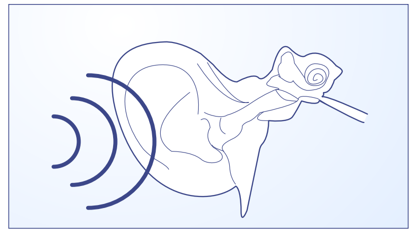
Noise-Induced Injuries

Noise causes a number of different types of injuries. Some noise-related injuries are temporary, but many are permanent. Almost all depend on a person's exposure to high levels of noise over some period of time. This time-intensity relationship is the reason OSHA noise exposure standards are stated as time-weighted averages (TWAs). The so-called "action threshold" of 85 dB is an 8-hour exposure level. That is, if a worker is exposed to less than 85 dB continuously for up to 8 hours, then OSHA requires no mitigating action.



Sound Pressure Level

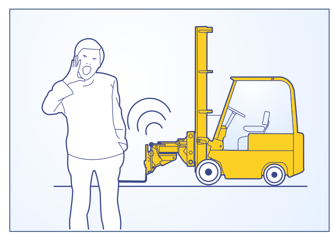
Sound is a pressure-related phenomenon. The subjective sensation of hearing sounds is really caused by the components of our ear converting pressure waves into electrical impulses. The subjective notion of loudness is related to the physical measure of sound pressure level, or SPL. The unit of measure for SPL is the "decibel."



The important thing to understand about the SPL (and the decibel) is its logarithmic nature. Doubling the pressure of a sound doesn't usually double its SPL. Actually, doubling the pressure of a sound increases the SPL by only 6 decibels (dB). Therefore, the pressure of a sound with an SPL of 80 dB, which is below the OSHA action threshold, is only half the pressure a sound with an SPL of 86 dB, which is above the OSHA threshold.

Speech Interference

Noise does more than just cause injuries based on its SPL. Certain types of noise, and even certain aspects of facilities, make normal speech communication very difficult. Human speech is concentrated in a relatively narrow band of frequencies. If noise is present in those frequency bands, then it tends to mask the words that are being spoken. Since person-to-person speech is such an important part of many maintenance tasks, the speech interference effects of noise might be more troublesome than its potential for causing injury.



The dimensions and interior materials of buildings can also have a marked effect on the intelligibility of the spoken word. Most of us have had the experience of listening to a loudspeaker in a public address (PA) system without being able to understand a single word being said. Often, this lack of intelligibility is caused by reverberations from walls and floors. Large aircraft hangars have all of the characteristics that cause such reverberation—large volume; large, flat surfaces; and hard materials that reflect, rather than absorb, sound.

Task-Oriented Design

The most fundamental human factors concept related to facility design is that a facility should be viewed as a place where human workers perform job tasks. This seems simplistic and, perhaps, too obvious even to be mentioned. However, it is important to realize that maintenance facilities are much more than just places to park airplanes or store parts. A properly designed facility helps maintenance workers do their jobs. A poorly designed facility hinders workers.

Work Comfort Zone

It's not the heat; it's the humidity. As it turns out, this old saw has a basis in fact. Humans have a fairly narrow envelope or "zone" of temperature, humidity, and airflow within which they can work comfortably. There is a slightly larger zone within which it is possible to work, but at a reduced level of output.

The basic concept of work comfort zones is simple to understand. After all, we all have experiences of being too hot or too cold while performing certain types of work tasks. We also realize that appropriate dress for one climate is not appropriate for a very different climate. Temperature, humidity, and airflow conditions can combine to become uncomfortable, unsafe, or even life-threatening.

METHODS

Checklist Audit

In the Human Factors chapter, Table 1-3, relates to the physical work environment. While task analysis checklists can be quite useful for analyzing specific tasks, they tend to be cumbersome when the intent is to evaluate the whole of the workers' environment. In these cases, specific checklist-based audit materials have been developed to support facility evaluations.

Critical Incident Technique

People who work in a particular job for any extended period of time know of incidents that caused injuries or equipment damage. Sometimes, situations arise that almost cause injury or damage, but something happens to allow the bad consequences of the situation to be averted. In common parlance, recounting such incidents or situations is known as telling "war stories." In human factors, we've put some structure around retelling war stories and call this the "critical incident" technique.

The idea behind the critical incident technique is quite simple. First, we want to identify incidents or situations that have caused, or have almost caused, personal injury or equipment damage. We do this by asking workers to tell us about such incidents. Once the incidents are identified, we try to understand how and why the incident occurred. If one of the contributing factors to the incident is facility-related, then we can focus our efforts on eliminating or mitigating the contributing facility component.

Direct Measurement

Many facility characteristics are amenable to direct measurement. For example, illumination and sound levels, temperature, humidity, airflow, stair angles, and linear dimensions can be determined by measurement. In some cases, measuring a facility element requires some expertise, especially where sophisticated measuring instruments or techniques are involved. A good example of a fairly tricky measurement is that of sound levels. The person performing these measurements can radically affect their outcome depending on how the measuring instrument is used. Other direct measurements require no particular technical training. An example is measuring the rise and run of a stairway.

Link Analysis

Link analysis was described in the Human Factors chapter. As opposed to overall facility audits, link analysis allows us to determine important associations among various objects. Link analysis was originally used to help designers lay out control panels like those in aircraft cockpits and process plants. However, this technique is especially useful for facility-layout problems related to performing a specific task or set of tasks.

Link analysis is a conceptually simple method that requires observers to record the movements of workers as they perform certain job-related tasks. As more and more tasks are recorded, the observation data are combined to form a statistical picture of important associations among various areas in a facility. Once these associations are known, we can arrange facility components (and task elements) to minimize the distance among those areas with the strongest "links."

Questionnaires

This method was also described in the Human Factors chapter. For facility design, questionnaires can be used to gather critical incident information and to solicit suggestions related to existing or planned facility changes. This may seem like a simple-minded approach to identifying facility problems—and it is. However, the most straightforward way of finding out what workers like and dislike about the facilities in which they work is to ask them. Workers are an extremely valuable information resource. After all, they perform their jobs in these facilities every day. Over time, they've seen what works and what doesn't. Questionnaires are a relatively cheap way to gather a lot of information quickly.

Structured Interviews

A time-honored method of getting information is simply to ask another person. In fact, face-to-face interviews are the predominant means of gathering certain types of data. Structured interviews can be valuable for facility design. Nobody knows more about the good and bad features of a facility than the people who work in it. The general idea of a structured interview is, first, to convene a group of maintenance technicians and inspectors and, then, to ask for specific information regarding the facility. The "structured" part of the technique means that a facilitator guides the interview, using an outline of the topics that should be discussed.

GUIDELINES

Facility Audit

A facility audit is intended to define the "as-built" state of the facility. This is not a design activity, since the facility has to be completely functional in order to perform such an audit.

A facility audit shouldn't be confused with a job or task audit—the goals of each of these are different. A facility audit doesn't address any particular task. Rather, its intent is to look at the overall facility to determine whether it meets certain criteria. Although these facility criteria are certainly related to worker performance and safety, they are not task-specific.

Facility audits consist of a series of activities, each of which is designed to gather specific types of information. An audit should include the following activities:

- Direct Measurements
- Questionnaires/Opinionnaires
- Structured Interviews
- Checklist Walkthrough

Some of these activities can be conducted in parallel. For example, there is no need to wait for all direct measurements to be made before sending out questionnaires. However, it is a good idea to gather all of the easily obtained information before conducting structured interviews. Guidelines for each audit activity are described below.

Direct Measurements

Table 4-2 provides a list of all direct measurements that should be made during a facility audit. Where particular expertise is required for the measurement, this is noted in the table. The location and value of direct measurements related to lighting, sound, and HVAC should be noted on a simplified drawing of the facility. To get a true picture of the facility, direct measurements should be made in actual working conditions and at various times during the day and year. For example, if work is performed during nighttime hours, then the light and sound measurements should be made during those hours. The goal is to understand the facility in worst-case, best-case, and average-case conditions.

Table 4-2. Direct measurements for a facility audit	
Lighting (requires special expertise)	
Illumination	Measure at work level at locations distributed over the entire facility. Take special care to measure in areas that might be shaded. Record in ft-c and lux.
Reflectance	Measure illumination on and luminance of surfaces. Calculate reflectance in %. Measure ceiling, floors, walls, partitions and equipment at various locations.
Glare	Measure direct viewing angle to lighting fixtures. Measure indirect glare for any high-reflectance (>70%) surfaces.
Color Rendition	Use color vision cards, such as Ishihara plates, or direct color measuring equipment to determine whether color rendition is appropriate.
Sound (requires special expertise)	
Ambient Noise	Use a frequency-band sound level meter to determine sound levels and frequencies at various locations distributed over the facility. Record in dBA.
Reverberation	Measure reverberation time using ISO-3382 method only if reverb is judged to be a problem by workers. Record in seconds.
HVAC (some items might require special expertise)	
Temperature	Measure at floor level, work level, and head level at locations distributed over the entire facility. Record in degrees Fahrenheit and Centigrade.
Relative Humidity	Measure at work level at the same locations as temperature measurements are made. Record in %.
Airflow	Measure at work level at the same locations as temperature measurements are made. Record in feet/second (ft/sec) and meters/second (m/sec).
Ramps, Steps and Ladders	
Inclination Angle	Measure using an incline meter (available at any building supply store). Record in degrees.
Rise and Run	Measure using a ruler or tape measure. Record in inches and centimeter (cm).
Step Overhang	Measure using a ruler or tape measure. Record in inches and cm.
Tread Width	Measure using a ruler or tape measure. Record in inches and cm.
Handrail Height	Measure using a ruler or tape measure. Record in inches and cm.
Tread and Handrail Diameter	Measure using a caliper micrometer. Record in inches and cm.
Work Platforms	
Height	Measure using a tape measure. Record in feet and meters.
Width and Length	Measure using a tape measure. Record in inches and cm.
Floor Material	Observe and Note
Aisles, Corridors and Exits	
Width	Measure using a tape measure. Record in inches and cm.

Questionnaires/Opinionnaires

Direct measurements tell us whether certain facility conditions are within the recommended range. They don't tell us whether the workers believe that these conditions, or other facility features, cause them problems during their work; also, they won't tell us whether the assumptions used to develop the recommendations are realistic. By using questionnaires and opinionnaires, we can ask workers to tell us how they feel about various facility features and how they work and dress. Used in this way, questionnaires can help identify faulty assumptions and potential problem areas within the facility.

An example of a combined questionnaire/opinionnaire that you can use during a facility audit can be downloaded using the FAA site. This table is partly adapted from work done by Koli and Drury. It contains items that ask for specific information, items that ask for opinions, and a final item that serves as a critical incident report. Note that the name, job title, and other fields that might be used to identify individual workers are completely optional. Allowing respondents to remain anonymous increases the chance that you will get information that reflects reality, rather than what workers think you want to hear.

Structured Interviews

After you analyze the information provided by questionnaires, there are likely to be a number of topics that need to be explored in greater detail. Structured interviewing is a good method for addressing certain subject areas in depth. The structured interviews will take on the general topical outline of the questionnaire forms, i.e., the type of information to be gathered is pretty much the same.

Structured interviews provide the flexibility of a person-to-person conversation, also allowing the people being interviewed to interact with one another. The major disadvantage of structured interviews is that they are subject to the interpersonal dynamics of any group discussion. People with strong personalities tend to dominate such discussions, even though the information they provide is typically no better than that of people with more retiring personalities.

To compensate for the effects of various personalities in an interview setting, a facilitator needs to be present to steer the discussions in the proper direction and to mediate any disagreements that arise. The facilitator should be someone who is trained in interviewing techniques and who is not part of the participants' organization. Table 4-4 shows a typical outline for a facility-related structured interview. There can be several interviews conducted with different participants. Ideally, each interview should include between 6 and 12 people, not including the facilitator.

Table 4-4. Typical Topical outline for structured interview.
Introduction of facilitator and participants
Purpose of the interview
Rules of the interview
Description of the facilities to be discussed
Temperature, humidity, and airflow
Noise levels and the ability to communicate
Lighting
Stairs, ramps, and ladders
Work platforms
Aisles, exits, and general access
Critical incidents
Summary

Structured interviews should last about one-half day, and the output should be the responsibility of the facilitator. The products of an interview should consist of written notes covering the essence of what participants discussed or decided. Generally, the participants' identities should not be associated with the output of the interview. It is not a good idea to record structured interviews on audio or video tape. Recorders make the participants nervous and reviewing the recordings is very time-consuming.

Checklist Walkthrough

Using the methods we've already discussed, it's possible to gather a lot of facility information. However, it's also possible to miss a lot, since we have to know which questions to ask before we begin those activities. If we fail to ask something important, we might or might not get data associated with that issue. The checklist walkthrough addresses this issue.

A facility review team conducts a facility walkthrough. This team is typically composed of the following types of individuals:

- Facilities
- Maintenance Planning
- Supervision
- Crafts
- Training
- Personnel
- Human Factors

The review team actually walks through the maintenance facility with a structured checklist. The information they seek is keyed to the checklist. The big advantage a multi-disciplinary review team offers is that they can notice things that aren't on the checklist. While the checklist provides structure, it doesn't preclude examining other aspects of the facility that might catch team members' attention.

An example of a structured walkthrough checklist is provided in Table 4-5. This checklist is partly adapted from work done by Koli and Drury. Each team member should carry a copy of the checklist while conducting the walkthrough. One member of the team, or an assigned secretary, should keep the "official" team notes. However, each review team member should also jot down a short note regarding any facility feature they find either significantly good or bad.

This checklist is a bit misleading, since it tacitly assumes that each topic area, such as "Lighting," will be addressed in serial order. In fact, this would be an inefficient way to conduct a walkthrough. What is more likely is that the review team will start in one part of the facility. They will examine every applicable topic for that area before moving to another area. They repeat this process until all relevant facility locations have been examined. Given the nature of this process, it is a good idea to make several copies of the checklist and to use one copy for each area to be audited.

After a round of walkthroughs is completed, the facility review team should meet to discuss its findings. In fact, the facility audit team, which might be the same as the review team, should meet to discuss the results of all audit activities. Facility problems should be identified, discussed, and prioritized. A plan should then be devised for addressing the highest-priority issues.

Establishing facility design standards is somewhat tricky. On the one hand, standards serve a useful purpose by giving designers consistent design rules that ensure a minimum level of usability. On the other hand, standards lock designers into doing things in a way that may not be best for all situations. The following guidelines address some of the most fundamental facility design issues. They present values that are not likely to change frequently, since they are tied either to human physiological performance or to established regulatory policies.

Facility Standards

These recommendations are derived from a number of sources, including applicable OSHA regulations, Wesley Woodson's Human Factors Design Handbook, Alvin Tilley's The Measure of Man and Woman, and MIL-HNDBK-759. Where multiple recommendations existed, these were selected and combined to provide a reasonable range of dimensions. Where OSHA regulations are specific and prevailing, those values are used. No recommendation in this section violates an OSHA requirement.

Aisles and Corridors. People move along certain paths in a facility. In open areas, these pathways are called aisles. In walled areas, people move along corridors. The fundamental guidance for aisles, corridors, and ramps is that they have to be (a) unobstructed and (b) wide enough to accommodate the types of traffic they will support. Figure 5-9 illustrates recommended widths for various types of aisles and corridors.

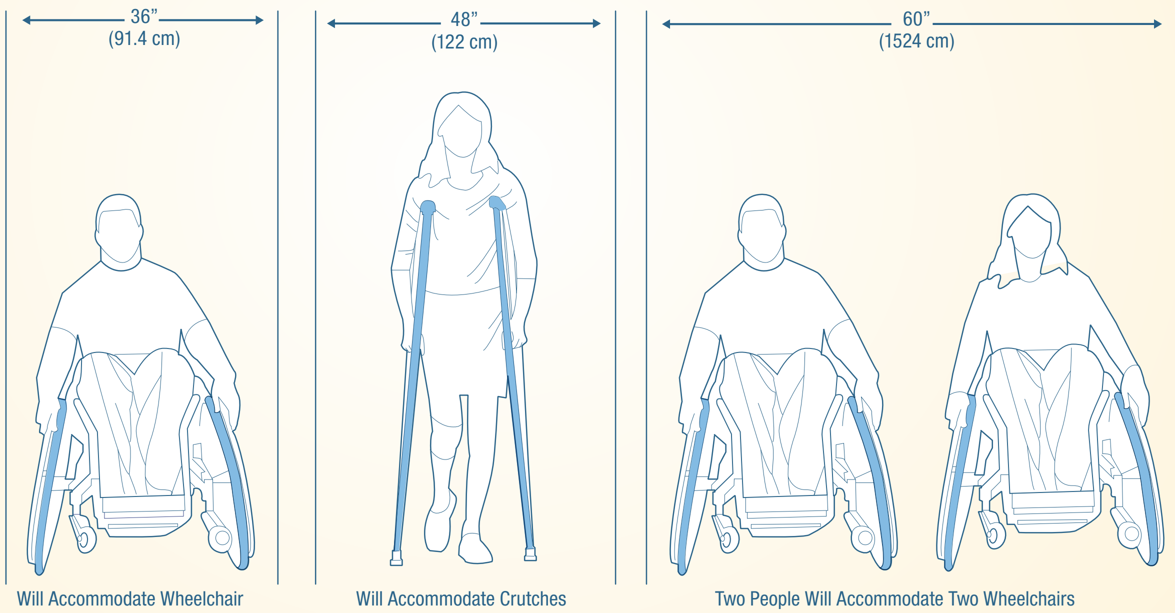


Figure 4-2: *Recommended width for aisles and corridors*

When equipment is routinely moved along aisles and corridors, the pathway must be wide enough to allow people and equipment to use it simultaneously. In some cases, two pieces of equipment must be able to pass in the aisle. A common industrial requirement is for aisles to accommodate forklifts or tugs. Figure 4-3 illustrates the sizing requirements for aisles and corridors that must be used by people and equipment.

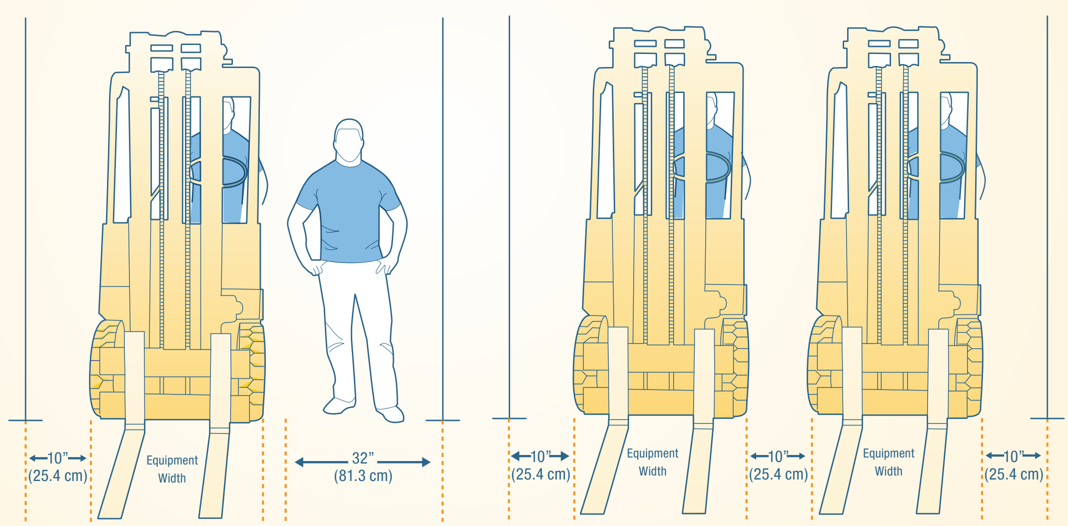


Figure 4-3: *Aisle and Corridor width when equipment maneuvering is required*

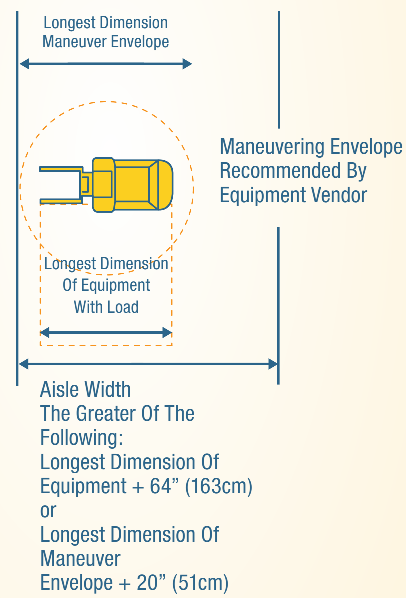


Figure 4-4: *Aisle and Corridor width when equipment maneuvering is required*

Of course, the recommended dimensions shown in Figure 4-3 don't guarantee that there is enough room for any particular type of equipment to maneuver. Where equipment must turn around or handle loads within an aisleway, use the recommendations in Figure 4-4. These recommendations result in aisles with enough room for people to move around equipment, even equipment stuck crossways in the middle of the aisle.

Ramps. Ramps provide a smooth transition between two floor elevations. There are a number of reasons for using ramps instead of stairs, including accommodating wheeled industrial equipment and people with disabilities who cannot negotiate stairs. Both of these purposes cannot always be accommodated with a single set of design standards.

OSHA recognizes two different classes of ramps, cleverly named Class A and Class B. They vary mainly in their slope and width. Both Class A and Class B ramps are too steep for wheelchair access. The general recommendation for wheelchair ramps is for the slope not to exceed 1 in 12, nor for the longest run to a landing to exceed 30 feet. In addition, OSHA regulations require that any powered industrial truck driven up or down a ramp with a slope exceeding 10% be driven with the load upgrade.

Figure 4-5 shows ramp dimensions that accommodate both powered equipment and wheelchair users.

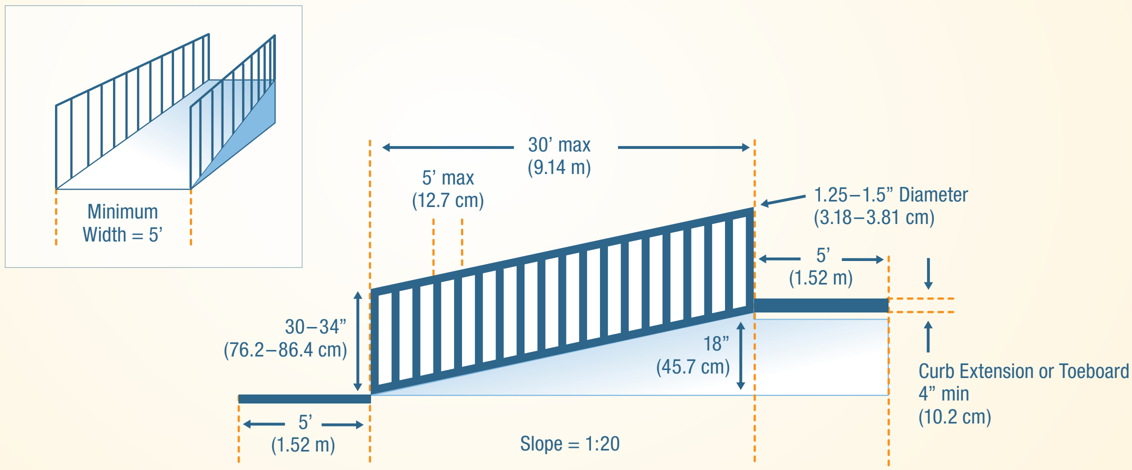


Figure 4-5. *Ramp dimensions that will accommodate powered equipment and wheelchairs*

Exits. Aside from the implications associated with the facility's structural integrity, the most obvious safety concern is people's ability to get out in an emergency. In OSHA terminology, this safety factor is known as "emergency egress." The most oft-cited situation requiring emergency egress is a fire. This is the most common actual situation, as well.

An individual egresses by leaving the facility via an exit. The requirement for an exit's width is directly linked to the number of people who might have to use it in an emergency. OSHA has provided a formula for determining the required width of an exit. A "unit" of exit width is defined as 22 inches. Fractional units cannot be counted, except for adding 12 inches (one-half unit) to one or more full unit. Each unit of exit width has the capability of accommodating between 60 and 100 facility occupants. Flat routes and Class A ramps can accommodate 100 people per unit of exit width. Class B ramps can accommodate only 60 occupants.

In addition to the exit capacity calculation, there is a requirement that any exit must have a minimum width of 28 inches and a minimum ceiling height of 7 feet 6 inches. Figure 4-6 graphically depicts these exit requirements.

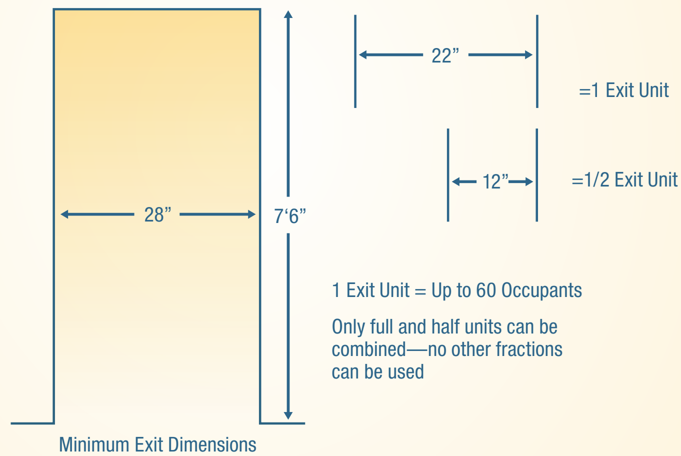


Figure 4-6. *Minimum exit requirements and egress capacity calculation*

Stairs and Ladders. Another way of moving between floor elevations is to use stairs or ladders. Actually, a range of devices can be used to bridge two elevations. The preferred device depends on the vertical distance to be spanned and the available horizontal distance within which the transition can be made. OSHA allows fixed stairs to be angled between 30 and 50 degrees from the horizontal. Portable ladders should be placed at an optimum angle of 75 degrees from horizontal. Fixed ladders can be placed between 75 and 90 degrees from horizontal.

As a practical matter of comfort and energy expenditure, fixed stairs should be angled between 30 and 35 degrees from the horizontal. Spanning the angular range of between 35 and about 75 degrees are special industrial stairs called "stair ladders." In the aviation workplace, stair ladders would most likely be used as part of portable or fixed work platforms. In the range of about 68 to 80 degrees, portable ladders are the best bet. Beyond this range, use fixed ladders.

Figure 4-7 shows the angular ranges for different types of vertical transitions. In choosing a particular transition method, keep in mind that OSHA doesn't allow portable ladders to be used for routine, i.e., frequent or everyday, movement of people or materials.

Figures 4-8 through 4-11 show the recommended dimensions for fixed stairs, stair ladders, portable ladders, and fixed ladders.

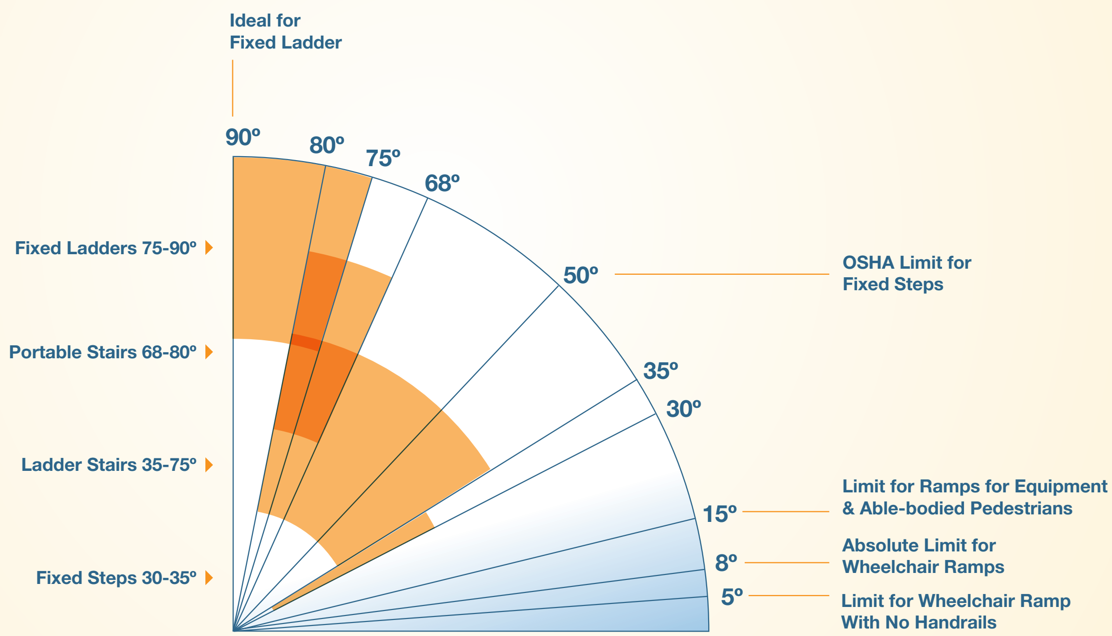


Figure 4-7. *Angular limits and recommendations for vertical transitions*

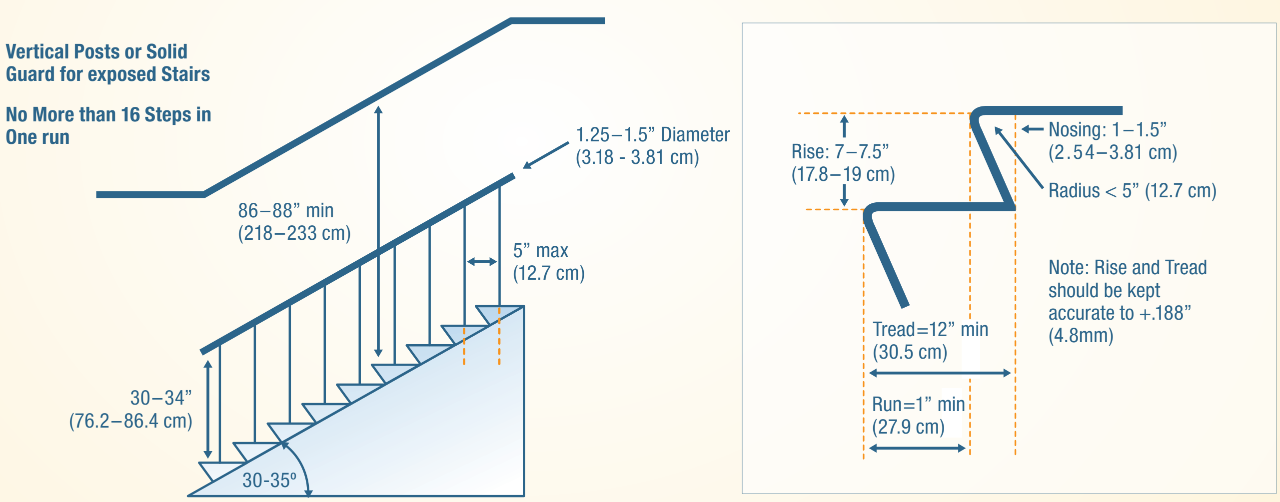


Figure 4-8. *Recommended dimensions for interior stairs*

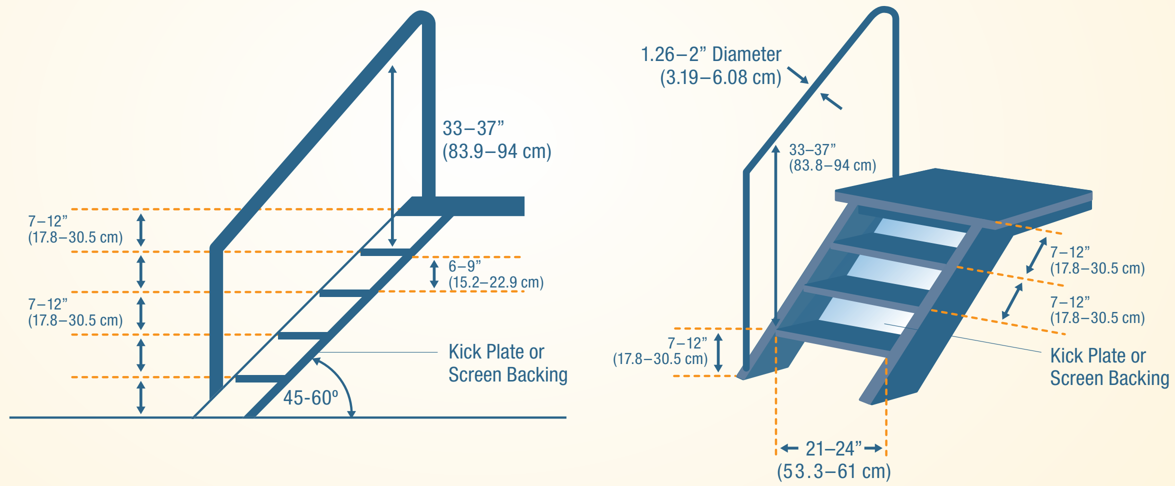


Figure 4-9. *Recommended dimensions for stair ladders*

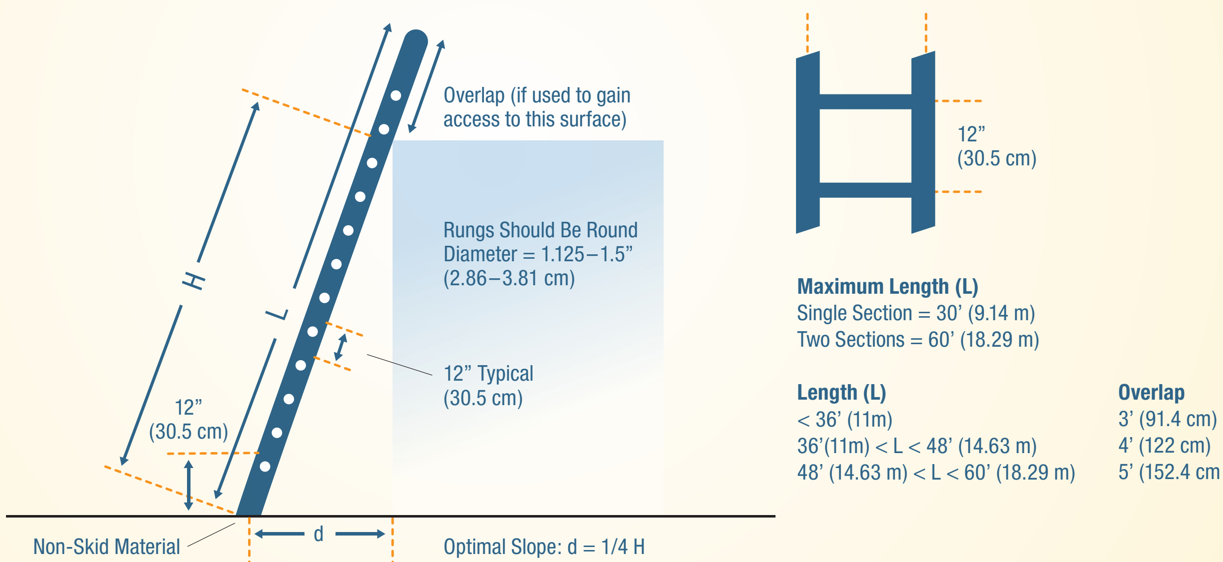


Figure 4-10. *Recommended dimensions for portable ladders*

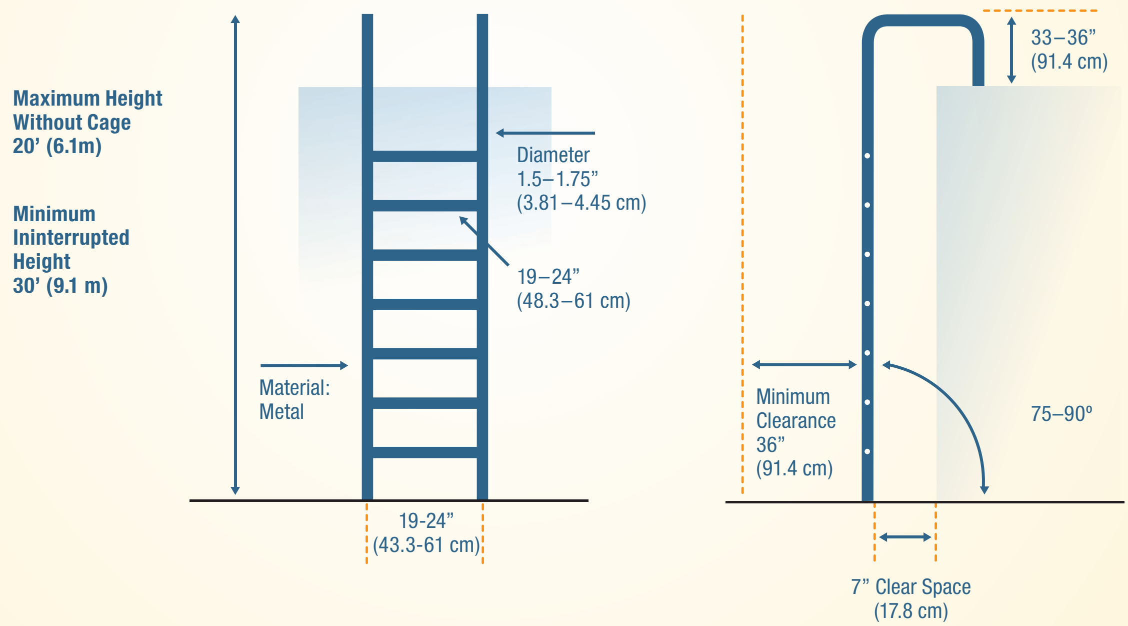


Figure 4-11. *Recommended dimensions for fixed ladders*

Work Platforms. Aviation maintenance facilities use a number of different work platforms. These platforms enable technicians and inspectors to get close enough to aircraft parts to do their jobs. In many cases, work platforms are elevated above ground level. The act of getting up to and down from fixed work platforms is addressed by the recommendations for stairs and ladders. However, work platforms themselves have characteristics that are subject to human factors design principles.

There are three important human factors aspects of work platforms: overall size, conformance to the work area, and guarding against falls. Of these characteristics, only the overall size of the platform depends on the tasks to be performed and the workers performing them. For example, the work area required by a single individual dressed in normal work clothes and carrying a few tools is much less than that required by several workers dressed in bulky protective clothing and using large test equipment. Also, a worker in a wheelchair requires more area than a standing worker.

Conformance and guarding can be considered to be universal requirements, regardless of the task. For example, if the platform is located 10 feet or more off the floor, safety harnesses should be used in addition to guard rails—regardless of the task(s) being performed. Figure 4-12 shows the recommended dimensions for each aspect of work platforms.

The floor of a work platform should either be made of or coated with a non-slip material such as expanded metal or abrasive tile (respectively).

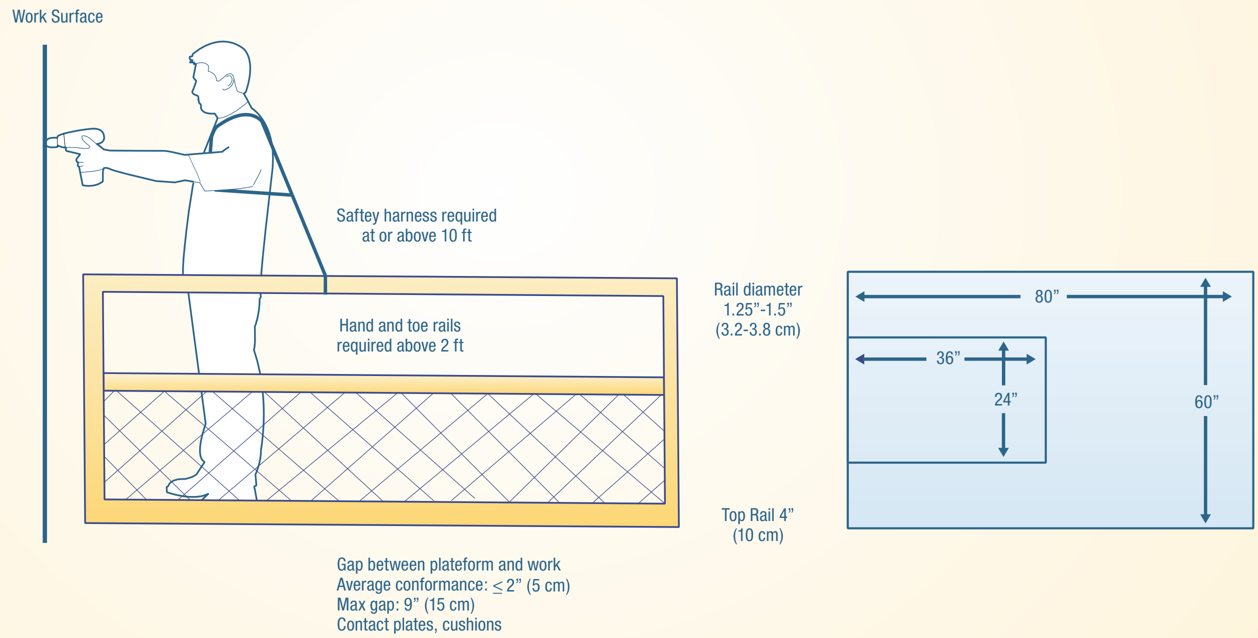
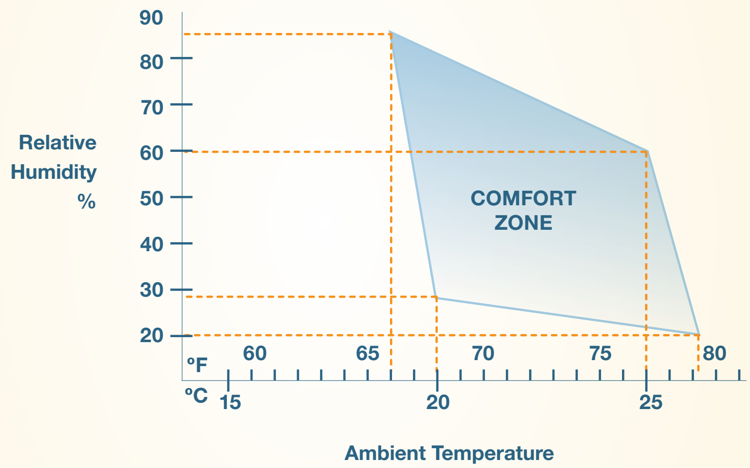


Figure 4-12. *Recommended dimensions and features of work platforms*

Environmental Controls (HVAC). The issue of establishing a safe and comfortable working environment might seem conceptually simple. The heart of the matter is maintaining a worker's internal body temperature, the so-called "core" temperature, within a certain narrow range.

While establishing a comfortable work environment is fairly straightforward for individual jobs and tasks, it is not so easy for an entire facility. In a maintenance hangar, different types of jobs are being performed simultaneously. Therefore, a comfortable environment for a technician performing eddy current testing on a wing skin might not be the same as a comfortable environment for a mechanic drilling and riveting inside an aircraft. About the best we can do from a facility standpoint is to try to keep its atmospheric variables within a reasonable envelope.

Once the envelope is established, we have to depend on the workers to alter their clothing or their local workspaces to account for major departures from our assumptions. Figure 4-13 shows a commonly accepted thermal comfort zone. These values apply to work periods of up to 8 hours. For extended work beyond 8 hours, the comfort zone should be pulled in slightly (by about 1 degree F on each side).



Assumptions:

Light Work = (60-90 cal/m)
Air Velocity = 50 ft/min (0.2 m/sec)
Clothing = 0.6 clo Heat
(long light-weight trousers—open neck shirt w/long sleeves)
1.25 do COLD
(light-weight coveralls over cotton underwear)
No radiant heat

Figure 4-13: *Thermal Comfort Zone for Typical Hangar-type Work*

Lighting. Workers' ability to perform various types of maintenance and inspection tasks largely depends on appropriate lighting in their work areas. Lighting is characterized by its intensity and its color rendering ability. Lighting can also be characterized as "facility" or "task" lighting. Facility lighting is the illumination provided by the common facility lighting system, including light fixtures and windows. Task lighting is illumination supplied for a specific task. It includes drop lights, portable light stands, interior aircraft compartment lights, and flashlights.

Intensity. The intensity of illumination is measured in lux, The level of illumination that is "adequate" depends on the type of task being performed. To give an idea of the range of "adequate" illumination, consider the following:

- OSHA requires that EXIT signs be illuminated with no less than 50 lux.
- Difficult inspection tasks or fine bench work can require illumination of up to 5000 lux.

Even for general facility lighting, there is no single minimum illumination that can be cited as appropriate. Some experts recommend that infrequently visited areas such as storage rooms can be lit sufficiently with as little as 150-200 lux. However, if we assume that it is not desirable to have to provide supplemental lighting for every task being performed in a hangar, the overall illumination level should be maintained at between 750-1000 lux.

Distribution. It is important to keep light levels fairly even throughout the work areas. The most common recommendation is to keep the ratio of highest to lowest illumination in and around a work area to 3-to-1 or less. In general, we want to provide even, diffuse, shadow-free, glare-free illumination in all areas of a facility used by people. The best way to diffuse light and minimize shadows is to use a large number of small light sources rather than a few large fixtures. By itself, however, the placement of fixtures will not eliminate shadows or bright spots.

Regardless of the placement of light fixtures, the floor area beneath the wing of a large transport aircraft is likely to be shielded from full direct lighting. To raise the illumination level in such areas, the hangar's ceiling, walls, floors, and fixed equipment must be painted so that they reflect a good part of the light falling on them. Reflectance is normally specified in "percent." A reflectance value of 50% means that the surface reflects half of the light falling on it. Figure 4-14 shows the recommended reflectance values for these facility elements.

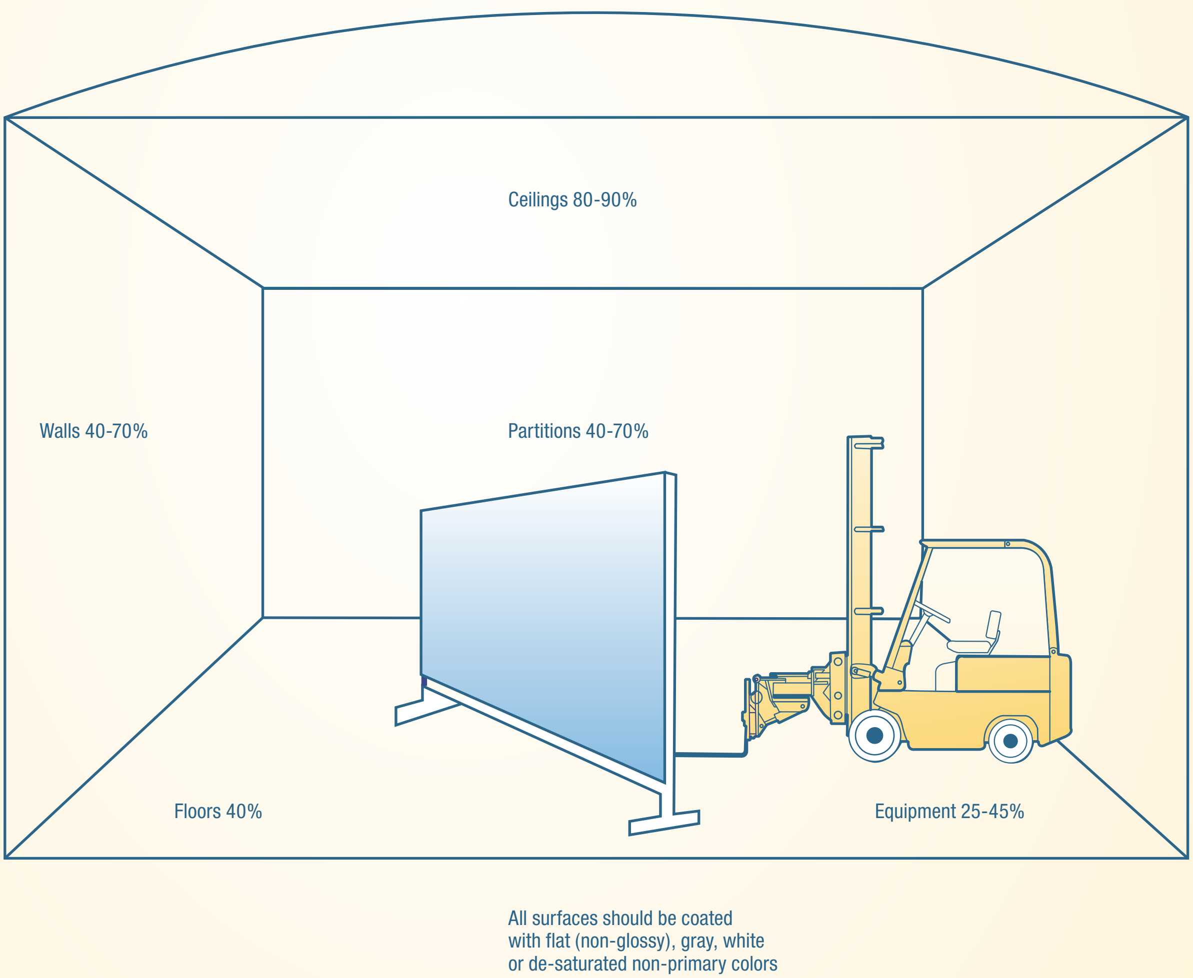


Figure 4-14: *Recommended reflectance values for facility elements*

Glare. Preventing glare is a prime concern in workplace lighting. There are two types of glare—direct and indirect. Direct glare occurs when people look directly at light sources, either windows or light fixtures. Indirect glare is caused by light reflected from highly reflective surfaces. Figure 4-15 illustrates both types of glare. The problems caused by direct glare increase as the light sources get closer to a viewer's normal line of sight. The worst performance problems occur when a light source is directly in the viewer's line of sight. These problems decrease as the light source is raised above the line of sight. The so-called "direct glare zone" is taken as that between 0 and 45 degrees above the line of sight. In practice, light sources should be placed at the highest available angle to the viewer's line of sight.

Because of the high clearances found in aircraft maintenance hangars, most light fixtures are placed well above the floor. By a judicious selection of fixture type, diffusers, reflectors, etc., direct glare problems can be minimized. Figure 4-16 shows the recommended viewing angles that will prevent direct glare problems. It also shows an example calculation of the horizontal and line-of-sight distance of an observer from a fixture that meets the recommended viewing angle criterion.

The effects of indirect glare, while not generally as debilitating as those of direct glare, can drastically reduce performance. Indirect glare is relatively easy to control, however, by coating reflecting surfaces with flat paint, by moving light sources out of locations where they cause reflections, or, if light sources can't be relocated, by equipping them with diffusers or polarizing lenses.

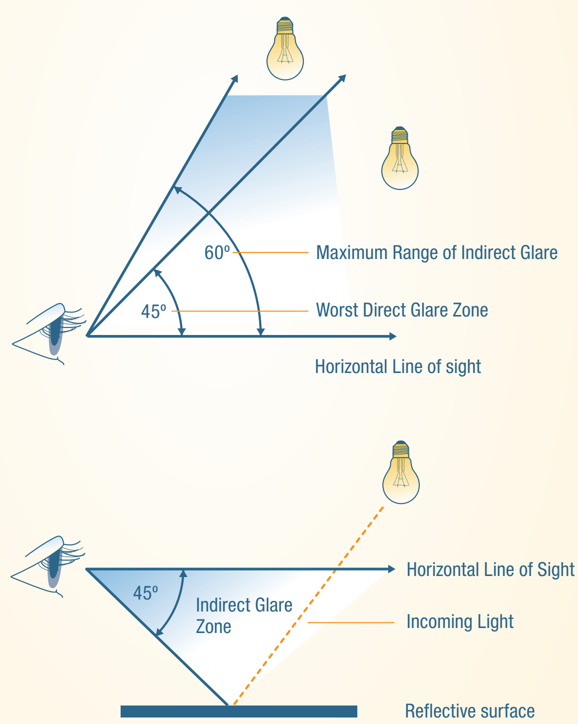


Figure 4-15. *Direct and Indirect Glare*

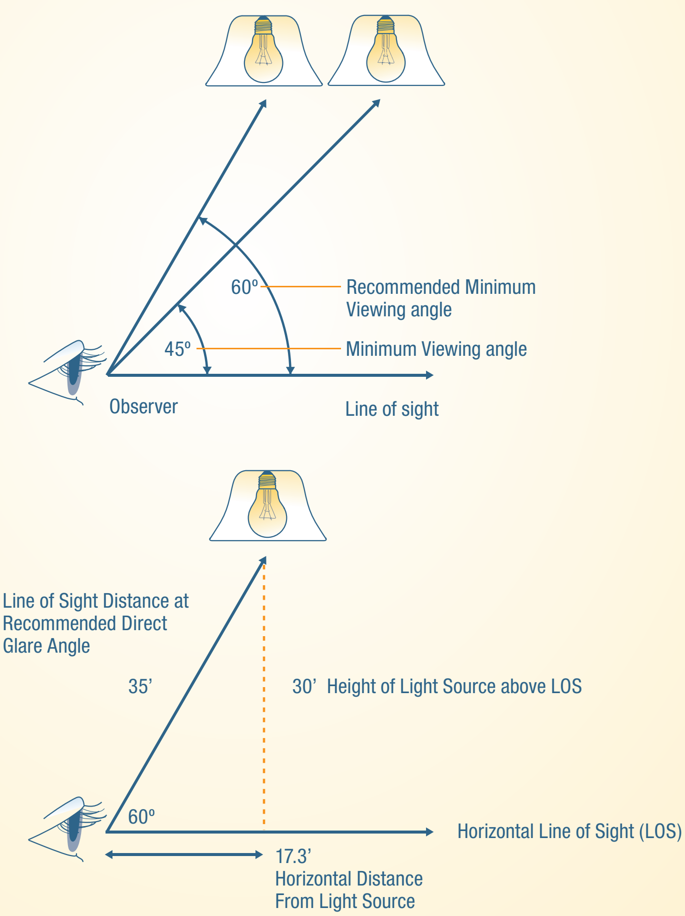


Figure 4-16. *Recommended viewing angles to aviod direct glare*

Color. The final issue related to lighting is color rendition. Different types of light sources have varying abilities to render certain colors. Natural daylight has the best color rendering ability, since it contains all natural (spectral) colors. Each artificial light source emits a particular spectrum of light. That is, each source contains more of some colors than others. For example, mercury vapor lights have very little red in their spectrum. An object such as an electrical wire that appears red in daylight appears orange (or even black) when viewed under a mercury vapor light.

The basic problem for designers is that the lights providing good color rendition, such as incandescent bulbs, tend to be very inefficient. Efficient light sources convert a given amount of electrical power to more visible light than inefficient sources. Conversely, lights that tend to be very efficient, such as high-pressure sodium, are notoriously poor at reproducing certain colors. Daylight fluorescent lights, which are fairly good at reproducing colors, are in the middle of the available efficiency range.

There are two approaches to solving the color-rendering problem. The first is to use a large number of light fixtures and to mix them among at least two different, high-efficiency, types. For example, alternating mercury vapor and high-pressure sodium lamps provides a broad color spectrum at the hangar's working level. The second approach is to use a very efficient type of lighting for the overall facility, regardless of its color rendering capability and to supplement color-sensitive tasks with task lighting. The task lighting to be chosen must have a broad color-rendering capability.

This section has covered a lot of recommendations related to lighting. These issues are condensed in Table 4-5.

Table 4-5. Recommendations related to facility lighting.		
Lighting Levels		
Lowest recommended level	150-200 lux	Should be used only for infrequently used areas
Normal recommended level	750-1000 lux	Adequate for many normal maintenance tasks
Illumination Ratio		
Maximum recommended ratio	3-to-1	Brightly lit areas no more than 3 times the illumination of dimly lit areas nearby
Distribution of Illumination		
Use a large number of regularly-spaced small lights rather than a few large lights. All finishes should be matte.		
Recommended reflectance of various surfaces	Ceiling Walls and partitions Floors Equipment	80-90% 40-70% 40% 25-45%
Glare Prevention		
Direct Glare	Place lights so they are at least 45 deg. above the horizontal line of sight. 60 deg. is better.	
Indirect Glare	Place lights so they are not in the reflected viewing path.	
Color Rendition		
Try to balance the color spectrum of lighting. Do not use only sodium or mercury vapor lamps. Either mix light types or use deluxe daylight fluorescent.		

Sound and Noise. Much of the information that aviation maintenance technicians and inspectors need to do their jobs comes to them in the form of audio communications. We include in this category person-to-person voice exchanges, telephonic transactions, information received via radio and public address links, and audio tones from test equipment or automatic monitoring systems.

Intensity. As we noted in the CONCEPTS section, the intensity of sound, called its sound pressure level (SPL), is measured in decibels. The decibel scale is logarithmic, not linear. A sound that has an SPL of 40 dB is 10 times more intense than a sound with an SPL of 20 dB. Figure 4-17 shows SPLs for some common sounds.

From a facility design perspective, the overall task is to minimize unwanted sounds, which we call "noise," and to maximize the probability of workers being able to hear required audio information. OSHA regulations define a worker's noise exposure in terms of "dosage," based on the well-tested premise that the effects of noise exposure are cumulative and increase in proportion to the time-weighted average (TWA) of the worker's exposure. For workers who incur an 8-hour noise dose equivalent to 85 dBA, companies must begin an active program of hearing conservation. The "A" in dBA means the noise is measured using a particular spectral weighting (the A-scale) in the measuring instrument. For continuous noise of 90 dBA or above, workers must wear some form of hearing protection device.

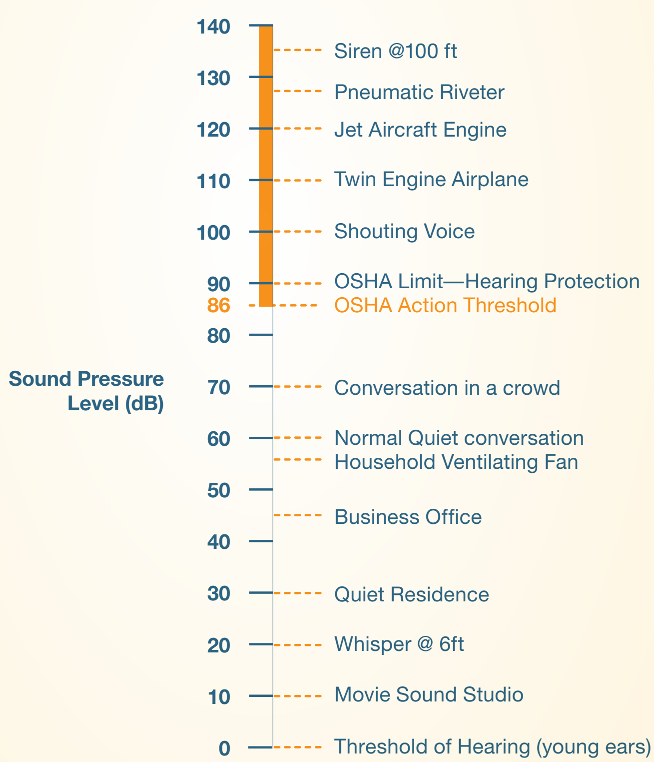


Figure 4-17: *Sound Pressure levels for some common sounds*

Noise Reduction. There are three opportunities for reducing the noise exposure of individual workers (see Figure 4-18).

Noise can be reduced:

- At the source
- Between the source and the worker
- At the worker.

Source noise control is the most attractive of the three methods because we don't have to worry about controlling noise that isn't produced. Source noise control is most effective when it is addressed as a purchasing issue. That is, if we specify that purchased equipment must be quiet, we avoid the problem of noise exposure. If we have to control noise at the worker level by using hearing protection devices, then we have essentially conceded that we cannot control ambient noise in the facility. Therefore, only the noise control method of focusing between the source and the worker can be addressed with facility design.

There are three ways of reducing noise between the source and the worker: location, insulation, and reflective absorption. These methods are summarized in Table 4-6. They can be used alone or in combination.

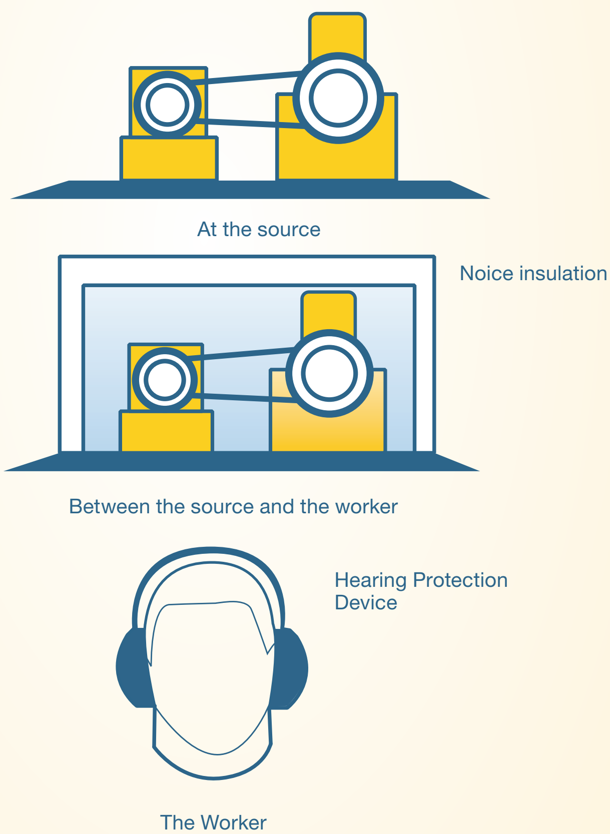


Figure 4-18: *Methods for reducing facility noise*

Location refers to placing noise-producing equipment away from the place(s) where workers are located. A common example of this method is locating air compressors outside buildings and running compressed air lines to locations where they are needed.

Insulation amounts to putting sound-absorbing material between the noise source and the worker. The sound waves must pass through this material to reach the worker. Also, certain types of equipment can be mounted on vibration isolators, which reduce the sound coupling between the equipment and the facility.

Reflective absorption is a fancy term for putting sound absorbing materials on walls, ceilings, floors, and other surfaces that can reflect sounds. Large, flat, hard surfaces reflect sounds that are directed toward them. Reducing the reflected sound levels can significantly reduce the overall facility noise level.

The final method of reducing noise is to provide workers with some type of hearing protection device (HPD). If the noise SPL is 90 dBA or higher in a particular area, OSHA regulations require the use of HPDs. The most common types of HPDs include plugs inserted into the ear canal, caps which seal the ear canal near the outside opening, and muffs which completely enclose the outer ear. Two common complaints regarding HPDs are that they are uncomfortable and that they interfere with speech communication.

Table 4-6. Methods for reducing facility noise.

Method	Description	Example
Location	Place noise-producing equipment far awey from locations where workers are performing their jobs.	Placing air compressors outside the facility
Insulation	Place sound-absorbing material between the noise source and the workers. Isolate the noise source from the structure of the facility.	Mount rotating equipment on vibration isolators. Surround equipment with enclosed, sound-absorbing housings.
Reflective Absorption	Place sound-absorbing materials on large, flat, and hard reflecting surfaces, such as ceilings, walls, and floors.	Use acoustic tile on suspended ceilings.

The effectiveness of HPDs has been shown to decrease significantly because of users' inability to properly insert them into the ear canal. A recent study has also shown that HPDs can interfere with speech. Ironically, those HPDs that provide the greatest protection at high noise levels also interfere with speech at lower noise levels. Newer hearing protection technologies such as active noise cancellation are under development now and might reduce or eliminate some of these problems.

Workers' ability to transmit and receive audio information depends on two factors: low overall noise level and intelligibility of the audio sources. We've already discussed ways of reducing noise levels in a facility. Making audio systems intelligible is another matter entirely.

Facility elements that relate to audio systems include public address (PA) systems and "quiet" locations that can be used for telephonic or radio communication. Three characteristics determine the intelligibility of public address systems: loudness, frequency reproduction, and reverberation.

Loudness. Loudness is the subjective impression associated with the objective SPL of a sound. Loudness does not correspond directly to SPL. That is, a sound with an SPL of 80 dBA will not necessarily be perceived as one-third louder than a sound with an SPL of 60 dBA. To be heard and reliably understood, speech has to be about 10 dB above ambient noise levels.

Frequency. Human speech is not spread evenly across all sound frequencies. Instead, it is concentrated at frequencies between about 200 and 4000 Hz. Public address systems that emphasize speech (as opposed to other audio signals) must concentrate their power in these frequencies.

***Reverberation*.** Reverberation is a phenomenon that prevents sounds from decaying as rapidly as they should. The common perception of reverberation is the familiar "echo" present in airline terminals, auditoriums, etc. Reverberation is characterized by its time constant, sometimes called the "reverberation period." The reverberation period is the time it takes for a sound to decay 60 dB from its original level.

As the reverberation period gets longer, its negative effect on speech intelligibility becomes greater and greater. The acceptable reverberation period increases as the volume of the facility increases. Figure 4-19 shows how the acceptable maximum reverberation time varies with facility volume. Even for very large volumes, reverberation periods over about 2 seconds are considered unacceptable. Reverberation periods of 4-6 seconds render speech almost completely unintelligible.

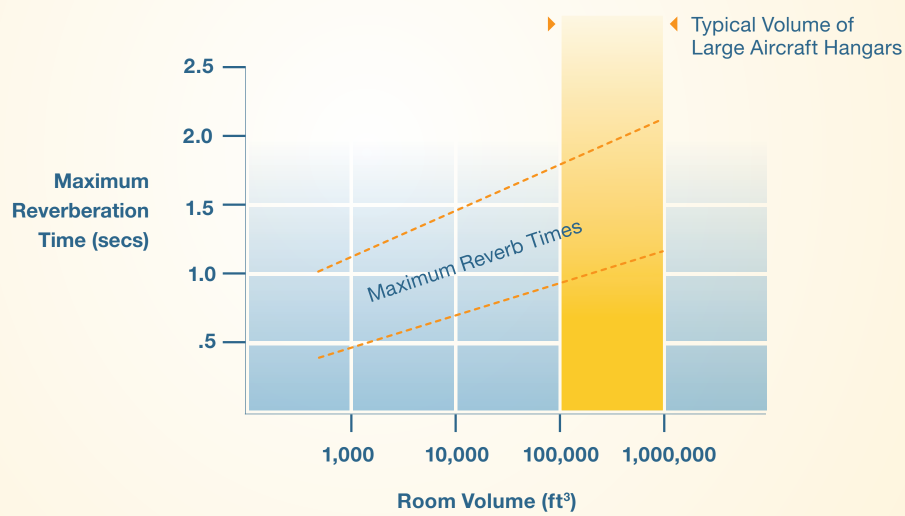


Figure 4-19: *Acceptable maximum reverberation periods for different volumes. Adapted from Everest, 1978.*

In order to minimize the effects of reverberation, facility PA systems should embody certain features. First and foremost, a PA system should consist of a large number of small speakers instead of a few large speakers. The speakers and amplifiers should be designed so that they concentrate most of their output into the range of frequencies most common in human speech. The speakers should be mounted so their output fields slightly overlap. These design features allow the sound level of each speaker to be set relatively low, and the overall sound pattern in the facility will be much more even and diffuse. It should be possible for a listener walking along a path passing by several speakers not to detect much difference in loudness.

The low power from individual speakers reduces any tendency for reverberation because the sound from any individual speaker decays before it can reflect from surrounding surfaces. If this design is combined with the placement of sound absorption material on large reflecting surfaces, the PA system should be adequately loud and understandable. One exception is workers who are wearing hearing protection. When ambient noise levels are below 85–90 dBA, most hearing protection devices interfere with understanding speech. At ambient noise levels above these values, PA systems aren't going to be heard anyway.

Even facilities with generally low ambient noise levels might have periods in which noise levels rise. To accommodate such periods, noise-insulated areas should be provided to allow telephone and radio communication. These areas can take the form of 3-sided booths or small, enclosed rooms in which ambient noise levels are reduced to below 70 dBA when facility noise levels are at their highest levels.

WHERE TO GET HELP

There are at least three sources of help for facility-related issues and questions. The Human Factors and Ergonomics Society (HFES) is a good source of general human factors information, including that related to facilities. The HFES is located at the address below:

Human Factors and Ergonomics Society
PO Box 1369
Santa Monica, CA 90406
Phone: (310) 394-1811
Fax: (310) 394-2410

Within the HFES, the Environmental Design Technical Group (EDTG) specializes in "the human factors aspects of the constructed physical environment."

For help with specific facility-related measurements, as well as with issues beyond the scope of human factors, both the National Safety Council (NSC) and the American Industrial Hygiene Association (AIHA) can be helpful. Industrial hygienists are often responsible for meeting regulatory policies related to noise, air quality, toxic emissions, etc.

Contact the National Safety Council at the following address:

National Safety Council
1121 Spring Lake Drive
Itasca, IL 60143-1315
Phone: (630) 285-1121
Fax: (630) 285-1315

Contact the AIHA at the following address:

American Industrial Hygiene Association
2700 Prosperity Ave., Suite 250
Fairfax, VA 22031
Phone: (703) 849-8888
Fax: (703) 207-3561

EXAMPLE SCENARIO

There's just not enough room in the existing storage areas to keep large, seldom-used parts, such as landing gear struts, APUs, etc. You would like to set aside a new area for storing these items, but the only place to do so is adjacent to an exit door. These items are normally palletized and moved with a forklift. The forklift is approximately 4 feet wide, 10 feet long, and can turn in a 12-foot circle.

Issues

1. What is the absolute minimum width of clear passageway that you must keep to the exit?

2. How wide must the aisle be to allow the forklift to move items into and out of the new storage area?

3. Can you locate the aisle so that there is enough room for people to pass, even with the forklift somewhere in the aisle?

Responses

This scenario combines issues of aisles, in which both people and equipment must co-exist, and exits, which have certain absolute requirements associated with them.

1. Since we're going to put this storage area near an exit, we must ensure that people can still get to the exit in an emergency. Figure 4-6 shows that the absolute minimum width of an exit, including the paths leading to and from it, is 28 inches. However, if we assume at least one individual in a wheelchair might have to leave through this exit, Figure 4-2 shows that it must have a minimum width of 32 inches. This minimum could be extended, depending on the number of people who need to get out of the area. In practice, we would have to know how many people need access to the exit in order to size it. A thirty-two-inch-wide exit will accommodate up to 60 people.

2. This second issue concerns the amount of room needed to maneuver a forklift in the aisle adjacent to the storage area. Figure 4-4 indicates that the aisle needs to be at least 20 inches greater than the longest dimension of the maneuver envelope of the equipment. We've told you that this equipment can turn in a 12-foot circle. If we assume that the pallet being handled by the forklift doesn't extend beyond the forks, we can say that our aisle must be 12 feet plus 20 inches wide.

1. This issue is pretty tricky. We have to assume a worst-case scenario to determine whether this is really possible. Let's assume that a person in a wheelchair must use this exit in an emergency. Assume further that a forklift stalls sideways in the middle of the aisle. From Figure 4-2, we know that we need an absolute minimum clearance of 32 inches for the wheelchair. Therefore, we need at least 32 inches on each side of a crossways forklift, which will occupy 10 feet of aisle width. Thus, if the aisle is about 16 feet wide, then we can be assured that a 32-inch path will always be available.

Also, although we really don't address this in the Guide, we have to ensure that the forklift doesn't block the exit doorway. We can do this in a number of ways. Probably the most straightforward is to place a physical barrier across the aisle about 5 feet from the doorway. This barrier needs to keep forklifts out, but let people in wheelchairs through. One possibility is to embed steel poles in the floor on 40-inch centers. If these poles are 4 inches in diameter and 3 feet high, then they will still allow 36-inch spaces between them.

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CHAPTER 5: SHIFTWORK AND SCHEDULING

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LANDING PAGE

The term “shiftwork” refers to the fact that certain jobs are manned by different groups of workers during different periods of the day. Shiftwork is common in many industries. In fact, any business that operates around the clock employs some form of shiftwork in their scheduling process.

A routine practice in many shiftwork-oriented businesses is to rotate employees among the various shifts. Shift rotation introduces a number of fairly serious problems, but rotation is typically not done in the aviation maintenance domain. AMTs are often assigned (or they bid into) a particular shift and they remain on that shift for months or years.

Even though AMTs are not routinely rotated among different shifts, those who work the “midnight” shift are subject to many of the same fatigue and “desynchronization” problems related to rotating shifts. The term “midnight” is commonly used to refer to the shift that encompasses the overnight hours, including the early morning hours from 2-6 AM.

In this chapter, we examine some of the significant issues related to shiftwork and to scheduling people to work on different shifts.

INTRODUCTION

If you’re an AMT or AME, it is likely that you work on a particular shift. For many domains, rotating shifts are the source of performance and personal problems. In aviation maintenance, however, shift rotation is not a primary source of shift-related problems. Aviation maintenance technicians typically work on shifts that do not change for weeks or months, or ever. The central problem in aviation maintenance is that many, perhaps most, routine tasks are performed during nighttime hours so that the aircraft can fly and produce revenue during the daytime. In addition, maintenance tasks often span more than one shift, requiring information to be passed from one shift to the next.

The physical and cognitive problems that we typically associate with shiftwork are almost exclusively attributed to body cycle disruptions arising from or connected with the night shift. Night shift problems boil down to on-duty sleepiness and off-duty insomnia, meaning poor quality and inadequate amounts of daytime sleep. The inability to obtain adequate off-duty sleep can lead to acute and chronic fatigue (see Fatigue and Fitness for Duty).

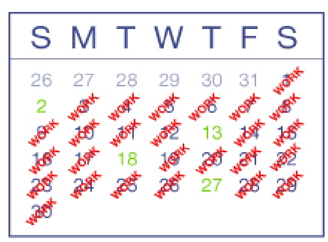
Shiftwork, particularly working on the night shift, can cause a number of physical, cognitive, and psychological problems. These include, but are not limited to, depression immune system dysfunction, high blood pressure, and increased cardiac mortality. In Japan, night shift work has been held to be a legally compensable cause of premature death. This is not a new problem; in 1584 an Englishman, Thomas Cogan, admonished his students as follows, “In sleeping and waking, wee must followe the course of nature, that is, to wake in the day and sleepe in the night.”

In this chapter, we discuss the general idea of shiftwork and how it can affect your job performance and your life outside of work.

REGULATORY REQUIREMENTS

There seems to be only one Federal Aviation Regulation (FAR) that relates directly to work schedules for AMTs and other aircraft maintenance workers. Part 121.377 states that “…each certificate holder shall relieve each person performing maintenance … from duty for a period of at least 24 consecutive hours during any seven consecutive days, or the equivalent thereof within any one calendar month.” In essence, this rule requires that maintainers be given at least one day off per week or four days off per month.

There are no restrictions (at least in the FARs) regarding how many hours a maintainer can work in a given day. If the letter of the cited rule is observed, an AMT could work continuously for six days, if they are given the seventh day off.



The international regulatory framework, which has been adopted by the European Aviation Safety Authority (EASA), contains no restrictions regarding working hours.

CONCEPTS

Circadian Rhythm

All mammals, including humans, exhibit constantly changing physical and mental states. A number of variables, such as body temperature, blood pressure, heart rate, blood chemistry, attention, sleepiness, and others, change according to a periodic pattern that lasts slightly longer than twenty-four hours. This cycle is called a “circadian rhythm”. The word “circadian” means “approximately one day.” Our desire and ability to work and rest is highly dependent on where we happen to be in our circadian cycle. The concept of a circadian rhythm is shown graphically in Figure 5-1.

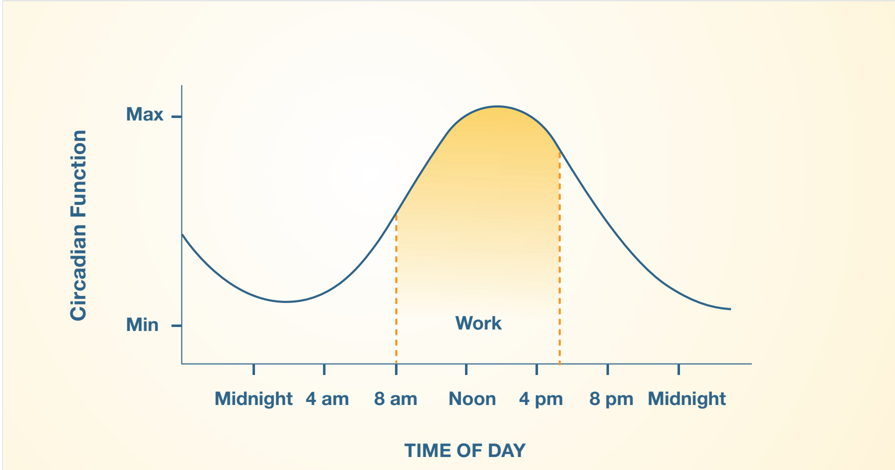
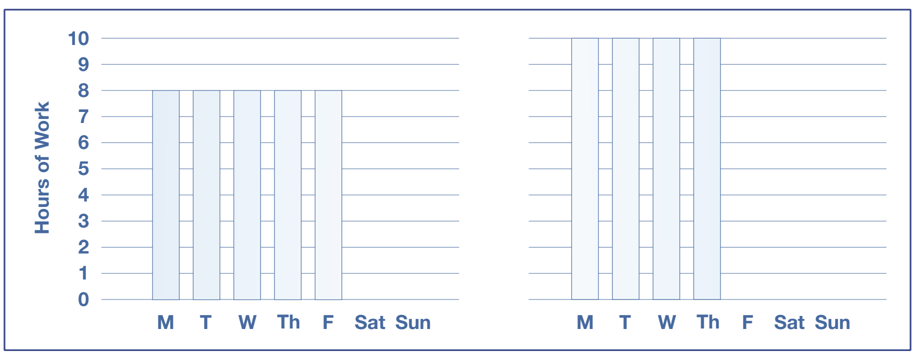


Figure 5-1: *Circadian Rhythm*

Compressed Schedule

A typical work schedule is nominally 40 hours per week, which is usually distributed over 5-6 days. The most common work schedule in the U.S. is 8 hours per day and 5 days per week. If the total number of weekly hours is obtained by working more hours per day for fewer days, the work schedule is "compressed". An example of a compressed schedule is working 10 hours per day for four days.



Desynchronization

As with other types of oscillations, circadian rhythms can be either in or out of phase with our physical surroundings. They are "synchronized" when the effects they produce, such as sleepiness or alertness, are appropriate for the time and work situation in which they occur. Being tremendously sleepy at 4 a.m. is not a problem if you are in bed and do not begin working for several more hours. Drifting off to sleep at 4 a.m. while you are in control of an airplane or a nuclear power plant, obviously, can cause major problems. Figure 5-2 shows anexample of work scheduled during a low point in the circadian cycle.

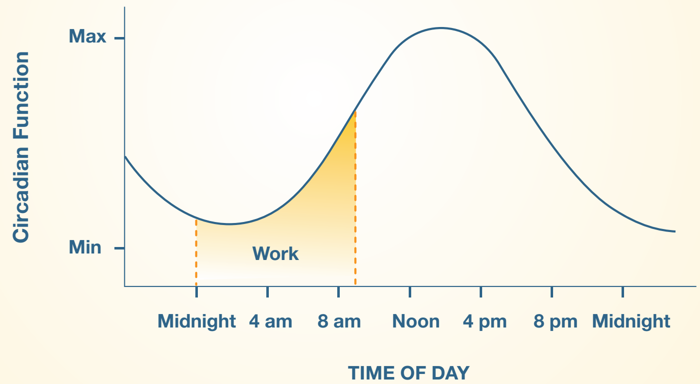
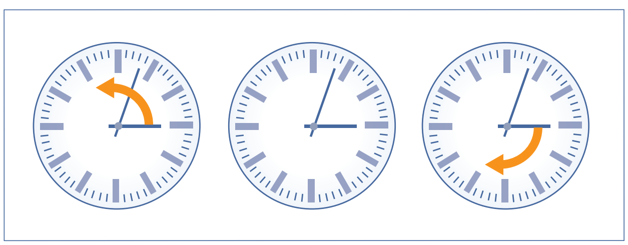


Figure 5-2: *Desynchronization*

Workers on rotating shifts routinely become desynchronized when they change shifts. Even workers who consistently work on the night shift can remain desynchronized indefinitely. While it is possible to become resynchronized, the time required to do so depends on many factors, including the dark-light environment in which one works.

Direction of Rotation

When shifts rotate, they can be moved either forward or backward. Forward rotation means moving from the day shift to the afternoon shift and from the afternoon shift to the night shift. Backward rotation is just the opposite. To confuse the issue, scientists refer to the forward rotation direction as “delayed” because such a rotation causes the phase of workers’ circadian rhythms to be delayed, i.e., they have to stay awake later and later in the day. The complementary term is “advanced” rotation.



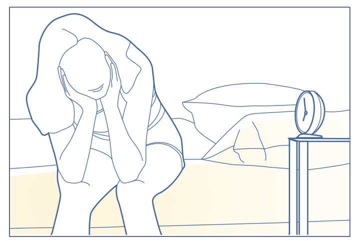
The prevailing wisdom, at least until recently, was that forward shift rotation resulted in fewer ill effects than backward rotation. However, recent research concludes that there is little difference in the effects of forward vs. backward rotation—unless workers are allowed too short a rest period when changing from one shift to another.

Quick Return

When changing from one shift to another, there is typically a time-off period of a day or two. However, certain shift rotation schedules require workers to come off one shift and then move to another, e.g., come off morning shift at 4 PM and then back into night shift at midnight, with only 8 hours (or less) of time off. This is called a quick return and it has been shown to be associated with relatively pronounced desynchronization problems.

Sleep Inertia

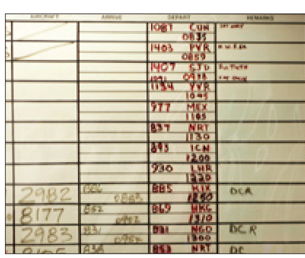
When you awaken from sleep, you are not immediately capable of performing the same type of physical or mental tasks as after you have been awake for a while. This performance decrement, known as sleep inertia, has been documented for a variety of tasks. It is especially acute for tasks requiring complex mental processing. The effects of sleep inertia can take several minutes to dissipate and are more pronounced after experiencing sleep deprivation or when one awakens in a low circadian cycle.



Shift Turnover

Aircraft maintenance tasks are defined in terms of functional “packets”, such as “Dismount engine from mounting pylon.” Such tasks are well bounded and practically meaningful. Some tasks take longer to complete than the time available in a single shift. Also, periodic heavy maintenance, which consists of hundreds or thousands of individual tasks, extends over days or weeks.

Since the work continues over boundaries of individual shifts, certain information must be passed from workers on the current shift to workers on the following shift. This process, which is typically formalized, is known as “shift turnover.” Instances in which information must pass from one person to another are prime opportunities for errors to be introduced. Proper shift turnover helps ensure the airworthiness of the aircraft undergoing maintenance and the safety of the workers performing the maintenance.



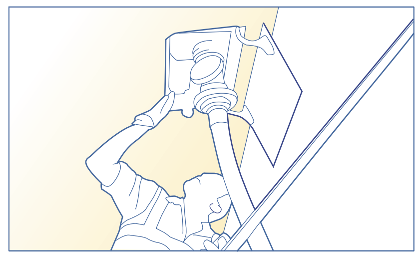
METHODS

There are no established human factors methods regarding how individuals should be assigned to shifts. There appears, however, to be a private-segment industry related to this topic. That is, there are lots of companies and individual consultants that will offer to help establish shift policies, procedures for assigning people to shifts, and even developing detailed shift schedules.

In the human factors arena, we are more concerned with the possible bad effects of particular shift policies and schedules.

Critical Incident Technique

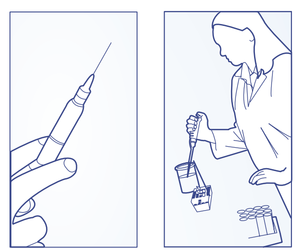
The critical incident technique asks workers to describe, in writing, accidents or near accidents they've observed, heard about, or been involved in while on the job. Although we're concerned about the effects of shiftwork and scheduling on job performance in this chapter, there are many other important aspects of job performance such as safety, productivity, efficiency, etc. The critical incident technique allows us to identify aspects of shiftwork that might directly affect the safety of workers or the flying public.



To be effective, critical incident reporting must be anonymous, or at least allow anonymity. A variation of the critical incident technique has been used for many years to allow cockpit crew members to report unsafe incidents or near-incidents. Critical incident reporting need not be complicated to be effective. A few items on a questionnaire can provide an easy vehicle for such reports.

Direct Measurement

Direct measurement can be considered as a method for evaluating scheduling and shiftwork effects. The general idea of direct measurement is that some aspect of schedule-related fatigue causes a physical or psychological change that can be objectively measured. This method is described in more detail in the "Fatigue and Fitness for Duty" chapter.

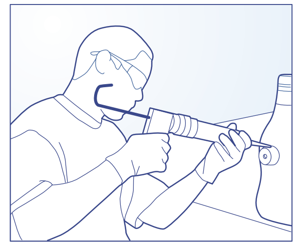


The biggest drawback of direct measurement is that it is extremely intrusive; the act of making the measurement can affect the factor being measured. For example, drawing blood to analyze melatonin will definitely cause an increase in the worker's arousal level.

Empirical Testing

In human factors, the preferred method of determining the effects of any condition, situation, substance, etc., is to have people experiencing that condition perform a realistic task. Such empirical testing is the cornerstone of all objective science. In the case of fatigue, for example, a reasonable empirical approach would be to cause fatigue in a group of people, perhaps through lack of sleep, and then have them perform a work-related task.

Again, this method is similar to the "fitness for duty" tests described in the "Fatigue and Fitness for Duty" chapter. Such testing must be subject to stringent safety precautions. It is not ethical to study the effects of alcohol on driving performance by giving people large amounts of alcohol and then letting them drive. Likewise, we cannot intentionally cause fatigue in a group of aircraft maintainers and then let them work on actual aircraft systems.

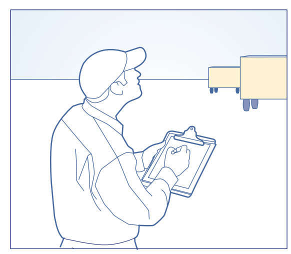


The second empirical testing strategy is to keep individuals in an actual work situation and observe their behavior on an abstract task, sometimes called a probe task. Probe tasks are designed to test some aspect of a person's ability to perform work, such as the ability to perform numerical calculations. Errors on the probe task are then analyzed to determine whether the condition, in our case fatigue, is associated with an increase in particular types of errors.

Empirical testing is objective and can provide very precise measurements of fatigue-related effects. It is difficult to design a test that measures only the effects of the condition we want to evaluate.

Error Reporting and Investigation

One very straightforward method of identifying shiftwork-related problems is to implement a formal error reporting and investigation process and track errors that seem to have shiftwork as a direct or indirect root cause. In the "Human Error and Event Reporting Systems" chapter, we describe a number of error reporting techniques and formal root cause investigative programs, such as MEDA.



With proper categorization of errors, we can identify problems that have connections to shiftwork-related issues. For example, we might identify a poor shift turnover procedure as one of the root causes of an error or accident. Likewise, we might identify lack of concentration due to poor sleep quality. There are a number of root cause characteristics that can be easily associated with various effects of shiftwork.

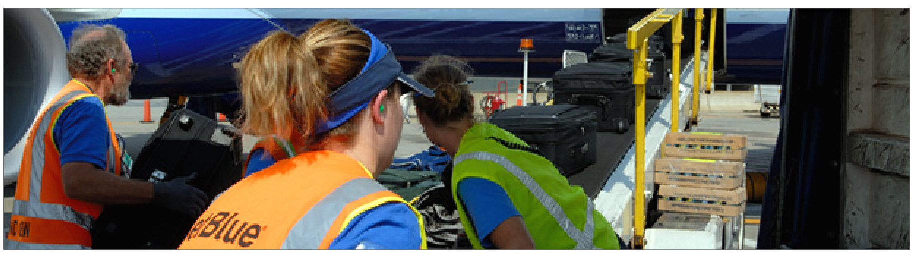
Maintenance Resource Management

Maintenance Resource Management, or MRM, is the maintenance analog of aircraft crew resource management (CRM). MRM consists of a number of techniques that aim to foster better communication and team coverage among AMT's and AME's. As with CRM, MRM provides ways that maintenance team members can properly communicate important information to one another and monitor each other's job performance. With respect to fatigue and fitness for duty, MRM is a primary method for identifying fatigued co-workers and dedicating the resources required to ensure all maintenance tasks are done properly and safely.

Questionnaires and Opinionnaires

The most common method of determining work-related problems or soliciting workers' opinions is simply to ask. Good managers solicit workers' comments and listen to their opinions and complaints. Face-to-face questioning has its drawbacks, however. First, workers are often intimidated by managers and find it difficult to criticize a work practice that their supervisor might favor. Second, individual interviews are so time-consuming that discussing workplace issues with each and every worker can be practically impossible. Third, since workplace interviews tend to be relatively unstructured, it is difficult to cover a variety of topics with appropriate detail without getting side-tracked.

An alternative is to develop structured questionnaires designed to allow workers to provide job-related information anonymously. Questionnaires typically contain items that solicit both objective information and opinions. Strictly speaking, written instruments that solicit opinions are called "opinionnaires." However, for simplicity, we refer to the composite document as a questionnaire. Questionnaires and opinionnaires are described in the Human Factors chapter.



GUIDELINES

Evaluating Shift Schedules

The most fundamental action that can be taken with regard to shift scheduling is to determine the present state of affairs. The most obvious reason for evaluating current shift schedules is to determine whether workers are experiencing excessive fatigue, or performance or safety problems. Another, less-obvious purpose might be to identify workers who might prefer to work on a different shift.

The easiest, cheapest, and most generally applicable evaluation method is the questionnaire. Questionnaires are routinely used in scientific studies of shiftwork effects. They are fairly easy to develop, reproduce, distribute, and analyze.

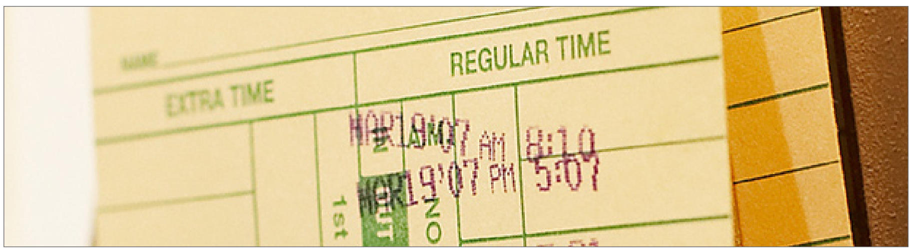
In addition to their ease of use, questionnaires use anonymous responses; this is an important consideration when you are asking workers to provide information that might adversely affect their performance appraisals. For example, admitting that one has fallen asleep on the job isn't ordinarily something one would like to admit to one's supervisor.

A typical shift evaluation questionnaire in shown in Table 5-1. Any evaluation that is more in-depth than the level we are describing here should be undertaken only with the help of a professional human factors practitioner.

One procedural issue you should note is that workers should be given an opportunity to respond to evaluation questionnaires while working on their shift. In fact, certain items can be replicated several times on a questionnaire and used to analyze workers' before-, during-, and after-shift feelings. A good example is an item related to the worker's present level of fatigue. One would expect subjective fatigue ratings to increase as a shift progresses. Thus, questionnaires could be divided into sections that can be answered at particular times during a shift.

Developing Shift Turnover Procedures

The quality, even the existence, of shift turnover procedures differs among various aviation maintenance organizations. Conceptually, the importance of good shift turnover practices is universally recognized. However, as a practical matter, there is little regulatory (or other) guidance regarding what constitutes a "good" shift turnover process. In this section, we provide a number of definitive guidelines related to shift turnover procedures. This material is derived from research done in the aviation maintenance setting, as well as applicable regulatory information and standards from the Department of Energy.



Conceptually, shift turnover can apply in three different situations, as follows:

• Operations are manned on multiple shifts and an outgoing shift must turn over job and task responsibilities to an incoming shift. This is the most common shift turnover environment.

• An incoming shift of workers must assume all responsibilities as the facility is made operational after being non-operational for some period of time. This might occur if a facility is not manned 24 hours a day.

• An incoming individual must assume a worker's job responsibilities because the worker has to leave before the scheduled end of their shift.

We will concentrate on the most common shift turnover condition—an incoming shift must relieve an outgoing shift. Except for the shift turnover meeting, however, all of the components of the shift turnover process are also applicable to other turnover situations.

Effective shift turnover depends on three basic elements:

1. The outgoing worker's ability to understand and communicate important elements of the job or task being turned over to the incoming worker.

2. The incoming worker's ability to understand and assimilate the information being provided by the outgoing worker.

3. A formalized process for exchanging information between outgoing and incoming workers and a place for such an exchange to take place.

DOE shift turnover standards stress two characteristics that must be present for effective shift turnover to take place: ownership and formality. Ownership refers to the requirement for individual workers to assume personal ownership and responsibility for the tasks they are performing. This is the antithesis of the "It didn't happen on my shift" attitude.

Formality relates to the level of recognition for shift turnover procedures. Formalism exists when shift turnover procedures are part of written operating rules and managers and supervisors are committed to ensuring that cross-shift information is effectively delivered.

An effective shift turnover process is composed of at least four components:

- Shift turnover meetings
- Turnover walkthrough
- Turnover checklists
- Work status markers

We will provide guidelines for each of these elements, below. All should be included in the turnover process.

Shift Turnover Meetings. The shift turnover process should include at least two meetings. It should begin with a meeting among incoming and outgoing supervisors. The purpose of this meeting is to acquaint the incoming supervisors with the general state of the facility and the status of all work for which each will be responsible. Outgoing supervisors should summarize any significant problems they encountered during their shift, especially any problems for which solutions have either not been developed or are still in progress. Table 5-2 lists the topics that should be covered in the supervisors turnover meeting.

Table 5-2. Topics for supervisors shift turnover meeting.

General Facility Status	General Manning Status
Construction	Coverage
Off-limit areas	Injuries
HVAC/Ventilation	Training
Hazardous storage	Other personnel issues
Workstands/Docks	Problems
Visitors	Outstanding/Status
General Job Status	Solved
Aircraft in facility	Information
Scheduled incoming/outgoing aircraft	AD's, AC's, etc.
	Manufacturers' notices
Deadlines	Company policy notices

After the outgoing and incoming supervisors meet, they should meet with the outgoing and incoming workers as a group. The purpose of this meeting is to summarize the progress of the outgoing shift and acquaint the incoming workers with any general considerations that might affect their tasks.

Prior to this meeting, the incoming workers should be assigned to the tasks they will be performing during the upcoming shift. The general topics to be covered during this meeting are essentially the same as those listed in Table 5-2.

During the combined shift turnover meeting, supervisors should make general announcements related to company policies, work schedules, etc. Both incoming and outgoing workers should raise issues they want addressed in a general forum.

Walkthroughs. While general issues are addressed in the turnover meetings, individual AMTs and Inspectors must exchange detailed information related to individual jobs and tasks. The most effective way to communicate this information is for the incoming and outgoing workers to go over task issues while examining the actual work location(s) and component(s). A mutual inspection and discussion of this nature is called a “walkthrough”.

Throughout their shift, workers should be thinking about what information should be included in the walkthrough with their counterpart in the succeeding shift. A number of topics should be covered during the shift turnover walkthrough. These topics will vary slightly between shop and floor technicians and between AMTs and Inspectors, but the general topical areas will be consistent across various job categories. Table 5-3 provides a reasonable topical outline with which to structure turnover walkthroughs.

Table 5-3. Topics for turnover walkthroughs.
Jobs/Tasks in process
Workcards being followed
Last step(s) completed
Problems encountered
Outstanding/Status
Solved
Unusual occurrences
Resources required/available
Location(s) of removed modules, parts, fasteners, etc.
Parts and tools ordered and when expected
Proposed next step(s)
Communication with support people, vendors, etc.
Communication with managers and supervisors

Work Status Markers. Almost all errors that can be traced to ineffective shift turnover are based on the lack of effective communication. A serious type of shift turnover error occurs when an incoming worker assumes that the outgoing worker has completed a job when it has not, in fact, been completed. A very simple way to address this potential error is to provide explicit work status markers that can be affixed to, or placed in the vicinity of, a worksite or component being repaired. This is the same idea as attaching "remove before flight" streamers to certain aircraft components.

Color-, pattern-, and shape-coded "work complete" and "work in progress" markers can be attached to each workcard. When an AMT completes all the steps in a workcard procedure, he or she places the "work complete" marker on the module or structure being worked. If a shift ends before the work is complete, then the "work in progress" card is placed on the work site. When a job is inspected, the inspector removes the "work complete" marker and returns it to the workcard control group.

Of course, this information should be transmitted during the walkthrough discussion. However, the idea is to provide more than one barrier to prevent human error from propagating through the system.

Implementing Countermeasures

The adverse effects of shiftwork can be somewhat mitigated by various supportive strategies. For workers who regularly rotate among different shifts, these strategies include structuring shift rotations and non-work activities so they are able to rapidly acclimate to shift changes. In aviation maintenance, workers are typically assigned to a particular shift for an extended period, so they must adopt countermeasures more appropriate to this situation.

Workers' overall physical and mental well-being are major determinants of the presence and magnitude of fatigue effects. The most effective countermeasures to shift-related performance problems are described below. Readers should understand that no countermeasure is 100% effective. The idea is to minimize rather than eliminate the bad effects of forcing workers to work at night. The best defense against shift-related fatigue is, always has been, and likely always will be to get enough rest to avoid fatigue in the first place.

Diet and Exercise. A major determinant of the effects of shift-induced fatigue is an individual's general physical well-being. Several countermeasures are related to the preparation of each worker for the rigors of shiftwork. A worker's diet should be nutritionally balanced, regular, and adequate in amount. Dietary rules for shiftworkers are actually the same as for non-shift workers – the major difference is that shiftworkers often eat meals at odd (non-traditional) times of day.

The pre-bedtime meal should be high in complex carbohydrates; the wake-up meal, high in protein. Workers should not use alcohol, caffeine, or nicotine for several hours prior to bedtime.

As we noted in our discussion of the concept of sleep inertia, we aren't capable of performing life or job functions at full capacity immediately after waking. Workers should be encouraged to take regular exercise, especially on arising. Regular exercise has been shown to contribute to a worker's overall sense of well-being. In addition, exercise after waking serves as a warm-up for the rest of the day's activities. Finally, regular, vigorous exercise makes an individual more capable of handling various types of physical and mental stress.

Resynchronization. Most problems associated with shiftwork are related to the chronic and cumulative sleep loss caused by a person's work schedule becoming de-synchronized with his or her circadian rhythms. One obvious countermeasure is to resynchronize work and circadian cycles as quickly as possible, but this is much easier said than done. Until recently, it wasn't clear that there are actions that consistently speed the synchronization process. Even now, there is only one safe and effective method to speed resynchronization.

It has been known for some time that the body's internal clock is reset by exposure to bright light. Recent research has shown that we can intentionally reset that internal clock by selectively exposing a person to very bright light. A person working during nighttime can cause his or her internal clock to reset by spending time in a brightly lit area. In this way, a person can minimize the fatigue effects caused by being de-synchronized and rapidly resynchronize his or her internal body cycles to the work schedule. Unfortunately, the resetting effect essentially can be destroyed by exposure to other bright lights, such as daylight, after the workday is finished.

Organizational Effects. Many of the effects of shiftwork, or at least the severity of certain effects, are moderated by a worker's psychological sense of well-being and belonging. Night shift workers often feel isolated from the rest of the organization. It is also common for night-shift workers to feel cut off from the rest of society since people socialize according to their work schedule.. If workers carry this perspective into the workplace, they can quickly develop an "us vs. them" mentality.

Managers can minimize these types of effects by including off-shift workers in briefings, presentations, etc. Day-shift workers have access to services and people that are often inaccessible to night-shift workers. For example, it is relatively easy for day workers to visit a credit union, get a benefits-related question answered, attend a training seminar, etc. As much as possible, these same opportunities should be made available to night-shift workers (see Table 5-4).

Table 5-4. Shift Support Functions
Fire Protection
Emergency Medical Care
Mechanical Maintenance
Phone/Radio Maintenance
Janitorial Service
Engineering
Safety
Security
Industrial Hygiene
Human Resources
Insurance
Vacation
Pay/Seniority
Job Openings
Cafeteria/Food Service
Credit Union
Company Store
Intra-facility Transportation

Managers should ensure that night workers are included in all social events and activities available to other employees. Workers should be encouraged to participate in an active social life tailored to their off-duty hours. The company can help by maintaining contacts with business and social organizations that cater to individuals who work during non-traditional hours.

Introducing Coping Methods

There is no countermeasure that completely eliminates fatigue and sleepiness during nighttime work hours, with the possible exception of getting enough sleep and being well-rested. Even with an ideal schedule, reasonable shift rotations, and diligent management attention, individual workers occasionally exhibit symptoms of fatigue.

Some of these symptoms are simply the result of individual differences; disruptions in wake-sleep cycles affect some people more seriously than others. Also, people occasionally stay up and watch television, socialize, or do other things when they should be sleeping. This is simply human nature.

Given that fatigue and sleepiness cannot be completely eliminated, it is important to teach workers how to recognize and cope with the symptoms.

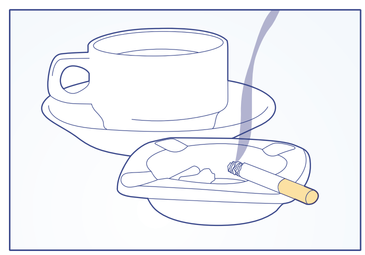
There are essentially four methods of dealing with the symptoms of fatigue (the most common symptom is sleepiness):

- chemical stimulants
- physical activity
- environmental sound
- short sleep periods (naps)

Each of these coping methods is discussed below.

Stimulants.One of the common symptoms of fatigue is a decrease in one's level of alertness or arousal. Certain drugs cause a measurable increase in alertness. The most familiar of these stimulants is caffeine, usually ingested as a component of coffee, tea, or carbonated drinks. Caffeine is also available in pill form, but the dosage and effects are similar to drinking beverages containing caffeine. Pseudo-ephedrine, which is a common component of decongestants, has effects similar to caffeine.

For most people, stimulants increase the overall level of alertness and improve one's ability to concentrate and perform complex mental processing. However, these effects are short-lived and any benefits can be easily overwhelmed by continuous use or overdoses.



Even when consumed in moderation, stimulants can make it more difficult to "come down" after work. The benefits of stimulants can come at the price of further disruptions in a person's wake-sleep cycle. Taken in moderation, they can improve short-term alertness and delay the onset of sleepiness. If used excessively, these drugs (and they ARE drugs) can cause performance problems as severe as the fatigue it is meant to reduce.

Physical Activity. It's within our common experience that time seems to move more quickly when we are busy. In fact, the enemy of alertness is boredom and inactivity, especially during the early morning hours. A worker can at least somewhat delay the effects of fatigue by staying active during a work shift. Also, fatigue symptoms can be temporarily reduced by a few minutes of vigorous physical activity.

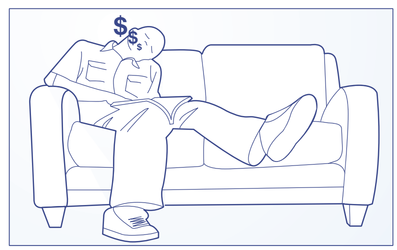
Workers should be encouraged to take regular breaks during their shifts and to walk around, go outside, stretch, and do other things to break the monotony of their work. Activity breaks are also beneficial for avoiding the soft tissue injuries associated with static work postures.

Sound. Certain types of sounds in our environment can cause us to remain alert, even when we are otherwise fatigued. Other sounds can cause us to become sleepy, even when we are not particularly tired. We are all familiar with the soothing effects of rain on the roof, ocean surf, and water running in a nearby stream. Likewise, we've all been kept awake by a creaking shutter, a dripping faucet, or other annoying noise.

A good example of reasonable type and level of environmental sound is playing music on a radio. It is a common strategy to play the radio when driving at night. While we will eventually become too fatigued to drive, the radio music will serve to increase our general level of alertness.

Unfortunately, many (probably most) industrial organizations have rules against doing un-work-like things (like playing the radio) in the workplace. Given the proven beneficial effects of music on alertness, these policies tend to eliminate one of the few coping mechanisms shown to be effective against the effects of fatigue.

Naps. Once a person reaches a certain level of fatigue and sleepiness, it is impossible for him or her to stay awake by an act of willpower. The effects of other coping techniques, such as physical activity and chemical stimulants, are only temporary. The ultimate coping mechanism for sleepiness is to fall asleep.



Although it is very difficult for most managers to accept the idea that workers should be paid for sleeping, at least one study of cockpit crews on long, over-water flights, has shown that performance decrements associated with sleepiness and fatigue can be drastically reduced when crew members are allowed to take a short nap during their shift. Fatigue effects were reduced when crew members were allowed to sleep as little as one-half hour during their watch.

In the aviation maintenance domain, there are few instances where workers' tasks include long periods of essentially no activity, like pilots on over-water flights. However, a work policy that allows workers to nap a certain number of times during the month (or year) might actually increase overall worker productivity. At the very least, workers should not be required, or even allowed, to continue working once they exhibit symptoms of severe fatigue.

WHERE TO GET HELP

Center for Research on Occupational and Environmental Toxicology (CROET), Oregon Health & Science University (OHSU)

OHSU is part of the university system in the State of Oregon. The CROET is an excellent source of shiftwork related research, guidlines, etc.

+1 503.494.4273
A contact form is included on their website.
http://www.ohsu.edu/croetweb/links.cfm?topicID=37

National Institute for Occupational Safety and Health (NIOSH)

NIOSH is the occupational research arm of the federal government. It is part of the Centers for Disease Control. Much of the research performed by NIOSH is used as the basis for regulations from the Department of Labor, particularly OSHA. NIOSH has no regulatory power, but many resources to offer for work scheduling issues.

1.800.232.4636 (inside U.S.)
+1 513.533.8328 (outside U.S.)

An e-mail form is included on the website.
http://www.cdc.gov/niosh/topics/workschedules/

National Sleep Foundation

The National Sleep Foundation is a non-profit organization dedicated to educating the public about problems that stem from the lack of adequate sleep. They produce a number of educational programs. They also deal explicitly with shiftwork issues.

Jessie Steinitz (ext. 209)
jsteinitz@sleepfoundation.org

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+1 202.347.3471

http://www.sleepfoundation.org

EXAMPLE SECNARIO

In the past few months, your inspectors have found at least three instances in which AMTs missed major steps in various C-check jobs. Investigations into these incidents point to poor handoff between shifts. When questioned, the AMTs involved in these tasks claim that any problems occurred on other people's shifts.

You have decided to stress the importance of shift turnover and have told your supervisors to bring up this topic in their pre-shift meetings.

Issues

1. From our description of the problem, does there appear to be any major element missing, either organizational or procedural, in your workplace?

2. Is this new emphasis on shift turnover likely to cause AMTs and inspectors to be more effective in passing important information between shifts?

3. Are there other shift turnover strategies that will be more effective than your plan? If so, what are they?

Responses

1. In the GUIDELINES section, we pointed out two essential requirements for effective shift turnover—ownership and formality. It is obvious from our description of this scenario that these AMTs lack a sense of task ownership. When questioned about work-related errors, their typical response is that it didn't happen on their shift. We would hope that workers care enough about their jobs to want them completed correctly—regardless of which shift on which they are completed.

2. Not likely! The proposed shift turnover process is probably no better than what currently exists. The GUIDELINES section stresses ownership, which we've covered above, and FORMALITY, which our new process lacks. In effect, we are telling our workers to make sure they pass along important information to the oncoming shift, but we're not giving them any tools or support elements to make sure this occurs. We are not setting aside any time for the shift turnover to take place. We are not providing any type of job aids. In short, we are not giving our workers any of the things they need to make sure our shift turnover strategy is effective.

3. Yes. In the GUIDELINES section, we give a list of four components that should be included in an effective shift turnover process: meetings, checklists, walkthroughs, and work status indicators. In this scenario, we would expect to see the following elements:

- planned meetings among supervisors and between incoming and outgoing workers
- a series of checklists for AMTs and inspectors
- planned walkthroughs involving incoming and outgoing workers sharing the same job tasks
- a plan to develop work status cards that will be attached to work cards.

REFERENCES

Department of Energy (1993). Guide to good practices for shift routines and operating practices, DOE-STD-1041-93. Washington, DC: Author.

FAA Operators Manual – Human Factors in Aviation Maintenance (Chapter 4). http://www.hf.faa.gov/opsmanual.

Moore-Ede, M. (1993). The twenty four hour society. Reading, MA: Addison-Wesley.

CHAPTER 6: PROCEDURES AND TECHNICAL DOCUMENTATION

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LANDING PAGE

The work life of an AMT or AME is almost entirely governed by written procedures. People in other occupations sometimes joke about there being a procedure for everything they do. In aviation maintenance, there really IS a procedure for every task. Most aviation maintenance procedures originate with an aircraft or engine manufacturer. These baseline procedures are then "tweaked" by the individual maintenance organization and made part of a set of procedures that are approved by the appropriate regulatory agency, such as the FAA, EASA, etc.

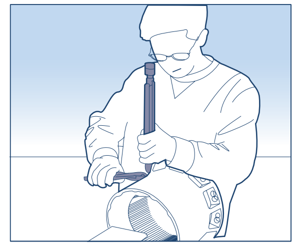
Given the heavy reliance of aircraft maintainers on written procedures, is should come as no surprise that these procedures are the direct or contributing cause of many maintenance errors. There is no shortage of examples of poorly written and poorly illustrated procedures. Every AMT and AME is likely aware of procedures that are just plain wrong.

In this chapter, we address the most common problems related to procedures and other technical documents. There are proven methods for producing procedures that are easy to use.

INTRODUCTION

Procedures are at the heart of aviation maintenance. Following procedures allows AMTs to use a set of rules that reduces the need for guesswork, which can lead to errors. In the pioneering days of flight, aircraft structures and systems were simpler and more obvious. We are long past that era. Today, aircraft are very complex. They are built with mixed alloy and composite structures and contain advanced avionics. These complex components and systems have non-obvious failures modes, which makes it imperative that maintenance procedures for aircraft, engines, and systems be designed to minimize error.

Procedure-related errors can arise from many sources including incorrect or forgotten AMT training, incorrect technical details in the procedure, failure to follow the procedure, and misinterpreting the procedure. All have been well documented in accident and incident investigations. Such errors have also been measured in controlled studies, with, for example, comprehension errors of documents ranging from 5% to over 50%.



There are many examples of poor procedure design. In the late 1990's the FAA issued an urgent fleet inspection directive for one of the more common aircraft types. The inspection had to be completed within a few days, so the documentation at one airline was written rapidly from engineering sources and not validated by AMTs. As each inspection was performed, the completed task-card was faxed to the FAA, who were horrified to find that 20.8% of task cards had errors on them. The task card (Figure 6-1) was analyzed to see how well it conformed to Human Factors guidelines for documentation design. The results were dramatic: where the human factors guidelines were met there were zero errors, but where they were not met the error rate on individual steps was 2.3%. A task card that met all the guidelines would have been error free! The message is clear: good design can error-proof documentation.

The solutions typically implemented for procedure and documentation errors do not seem to be 100% effective, as the same incidents and the same causal factors continue to appear with depressing regularity.

Airline:		FI no:
	Fleet Inspection:	ATA:
		DATE:

AIRCRAFT TYPE:	TITLE:	
	Reason for Request:	
	Special Instructions:	
Materials Req'd:		
		NO LATER THAN:

Work Instructions	Accomplished By	Checked By
1. Gain access to........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx		NOT REQ'D
2. Ensure all hydraulic power systems are depressurized		NOT REQ'D
3. Verify that.......xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx Correctly Installed YES ______ NO ______		NOT REQ'D

Page 1 of 6 Special FL Copies to: N/A

Figure 6-1: *A schematic of the two-page Fleet Inspection (FI)*

Airline:		FI no:
	Fleet Inspection:	ATA:
		DATE:

Work Instructions (continued)	Accomplished By	Checked By
4. Visually check........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx ....record info below Record Findings: xxxxxxxxxxxxxxxxx: YES ________ NO ________ If YES, dimensions: LENGTH ____ WIDTH ________ yyyyyyyyyyyyyyyyy: YES ________ NO ________		NOT REQ'D
5. This step can be signed off as N/A if step 3 is yes If...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx		NOT REQ'D
6. Close access panel...............................		NOT REQ'D
7. Fax a copy of completed FI to..............		NOT REQ'D

All FI Work Instructions accomplished, all sign-offs legible and information completed.
AIRCRAFT ___________ STATION ___________________ DATE ________
Logbook Page Number
LEAD MECHANIC OR SUPERVISOR ________ EMP# _______________

Page 1 of 6 Special FL Copies to: ____________N/A_______________

Figure 6-1 (continued): *A schematic of the two-page Fleet Inspection (FI)*

Finally note that the world's best-designed procedures and documents are useless if they are not used. Recent examples of inspections not performed, signoff irregularities, and "pencil whipping" attack the very basis of the continuing airworthiness system, and are rightly abhorred by almost all inspectors and AMTs.

Many instances of "not following procedures" arise from AMTs trying to find a better or more efficient way of doing a task. The danger is that this "better way" has never had the benefit of engineering oversight to determine whether it is in fact a safe alternative. All organizations have standard ways to modify procedures, although many are so cumbersome that they are rarely used. The solution is to fix the modification system, not to allow unauthorized deviations from the written procedures. Good procedure design is not a substitute for honest and competent management, but it can make management's job much easier.

This chapter provides the concepts, methods and guidelines for developing procedures and documents that are "error resistant". This advice is based on many years of evidence for what constitutes good design. Good design is based on hard evidence. It is not a matter of personal preference, pretty-looking documents, or the software that comes with the latest maintenance computer system. Before anybody tries to sell you a better idea for documentation, ask to see their error data, and remember that the word "data" is not the plural of "war story".

REGULATORY REQUIREMENTS

The FAA requires the each air carrier develop and maintain a manual that contains procedures and instructions for all aspects of their operation. These requirements for the air carrier manual are included in each relevant section of the Federal Air Regulations. For example, for Part 121 carriers, 121.133 states:

> (a) Each certificate holder shall prepare and keep current a manual for the use and guidance of flight, ground operations, and management personnel in conducting its operations.
>
> (b) For the purpose of this subpart, the certificate holder may prepare that part of the manual containing maintenance information and instructions, in whole or in part, in printed form or other form acceptable to the Administrator.

Further Part 121.135 states:

> a) Each manual required by §121.133 must—
>
> > (1) Include instructions and information necessary to allow the personnel concerned to perform their duties and responsibilities with a high degree of safety;
> > (2) Be in a form that is easy to revise;
> > and in 121.135, b, (17), one part of the required manual must contain: "Instructions and procedures for maintenance, preventive maintenance, and servicing."

Other regulatory agencies, such as EASA have similar requirements. Note that these regulations say nothing regarding the format, layout, language, word usage, etc., for maintenance procedures.

The Air Transport Association (ATA) has developed a standard (ATA iSpec 2200: Information Standards for Aviation Maintenance) that contains consistent conventions for formatting documents related to maintenance, but these recommendations do not carry the force of law.

European maintenance regulations are contained in Regulation EC 2042-2003. Specific requirements related to procedures are contained in Annex 1, Part M of this regulation. Procedures are specifically addressed in M.A.401 Maintenance Data, which lists and describes required and acceptable maintenance data. These regulations are no more specific regarding the format, layout, word usage, etc., than are the FAA regulations.

CONCEPTS

Accuracy

Accuracy implies correctness in procedures and documents. Accurate procedures use correct part numbers, location names, task sequences, and other elements. Procedures that are not accurate are, by definition, wrong and must be corrected.

Consistency

Consistency is the practice and characteristic of using the same layout, word choice, font, etc., for each procedure, job card, and technical document. It can be enforced by using established conventions (see below) and by adhering to established design guidelines. Consistency is one of the most important human factors considerations for procedures and documents, since it reduces ambiguity and uncertainty.

Convention

A convention is simply an agreed upon way of doing things. For procedures and documents, conventions can relate to the way various elements, such as notes, cautions, and warnings, are depicted. Simplified Technical English is itself a convention in the use and structure of language. Conventions make it easier to learn and understand procedures, job cards, and other documents. They also ensure that what is learned in one task card can be transferred to any other, without the error-prone process of unlearning.

Feed Forward

Although this term is used frequently in aviation maintenance, it might be better-phrased “feed outward”. Feeding forward means widely broadcasting the lessons real AMTs and inspectors learn while working on real airplanes. For example, suppose AMTs at a particular facility figure out a an easy, more effective way to find skin cracks in a hard-to-reach area. After the change is approved by engineering, they are encouraged to share that information with their co-workers and with other maintenance organizations working on the same aircraft type.

Job Card

A task card, also known as a task card or a workcard, is a specific maintenance task (or step) extracted from the maintenance manual and placed into a smaller document, which was originally an actual card, but is now more typically a document of a few pages or a computer-based equivalent. Job cards are easier to take directly to the work site than trying to copy pages from the approved maintenance manual.

Specificity

All examples of aircraft type share major classes of components, such as elevators and ailerons. However, the specific maintenance tasks related to these components vary (often significantly) depending on the particular aircraft to which the tasks is applied. Specificity, also called effectivity, means that the exact aircraft (manufacturer, type, generation, and tail number) to which the procedures apply are called out in the procedure.

Template

A template, when used in connection with procedures and documents, is a formatted outline into which procedure writers place information for specific tasks. A template typically contains overall sections on formatting, font types, indentation rules, etc.

Validation

A valid procedure is one that has been tested and shown to work properly on real equipment in a real-world environment. It is quite possible to write a procedure that cannot actually be performed on the aircraft for which it intended, with the tools available, in the actual maintenance environment, or some combination of these conditions.

Verification

A verified procedure is one that has been checked for accuracy and completeness. Verifying a procedure does not mean it can actually be performed (see Validation), but at least it contains all the material it is supposed to contain and that material is accurate.
Many of the methods used to develop good procedures and documents are common human factors tools described in other chapters. Here we describe how these methods specifically relate to procedure and document design.

Task Analysis

A typical maintenance procedure is basically a list of tasks that have to be performed in a particular order. Any single maintenance task consists of various decisions and actions, each of which has human factors implications. Task analysis (link here to the Task Analysis description in the HF chapter) is the technique used to identify, describe, and evaluate these decisions and actions. What is needed is a breakdown of the whole task into components or steps, with a plan that tells us how to choose the next step.

METHODS

The current industry standard for task analysis is Hierarchical Task Analysis or HTA. To better understand HTA, let's examine a visual inspection task. Visual inspection is known to all aircraft maintainers, but is still error prone and worth examining from a human factors viewpoint.

Figure 6-2 shows the top-level description of the overall visual inspection task as a hierarchy of things that must be done. At the top is the overall task objective "Perform Visual Inspection" and below this are six sub-tasks that must be completed for this top-level goal to be achieved. The Plan shows (for this example) that all six sub-tasks must be performed in the order given, although this is not always the case.

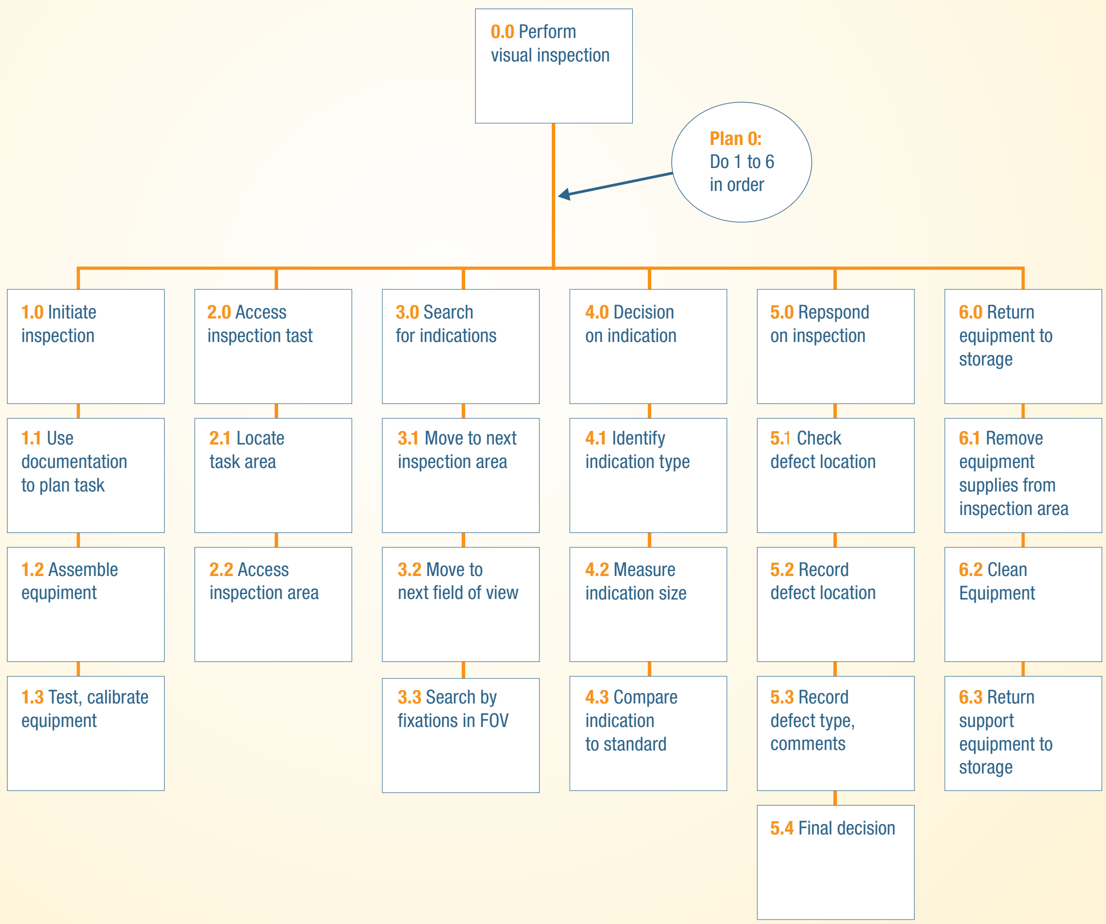


Figure 6-2: *Hierarchical Task Analysis of Visual Inspection, top level*

Below each sub-task is a set of smaller sub-tasks necessary for higher level sub-task completion. These can be further broken down as needed until we have a large number of very small steps. There is even good software available to help this task description process, e.g. TaskArchitect ©.

When the task breakdown has gone far enough, the analysis of each step in terms of the human factors issues can begin. For the Visual Inspection example we went straight to a set of Good Practices, as shown in one small example in Table 6-1. Note that each Good Practice has an explanation in the "Why" column. This is good human factors practice as it helps AMTs generalize the practice to new situations. This HTA methodology is the best starting point for writing procedures that make sense to both the engineer doing the writing and the AMT performing the task.

Table 6-1: Visual Inspection, examples of Good Practices for one sub-task: Search		
Process	**Good Practice**	**Why**
3. Search	Allow enough time for inspection of whole area	1. As shown in section 4.2.1, the time devoted to a search task determines the probability of detection of an indication. It is important for the inspector to allow enough time to complete FOV movement and eye scan over the whole area. When the inspector finds an indication, additional time will be needed for subsequent decision processes. If the indication turns out to be acceptable under the standards, then the remainder of the area must be searched just as diligently if missed indications are to be avoided.
3. Search	Provide clear instructions to inspector of expected intensity of inspection	1. The documentation should give the inspector enough information to provide a consistent choice of inspection intensity. Terms such as “general”, “area” and “detailed” may mean different things to different inspectors, despite ATA definitions. Well-understood instructions allow the inspector to make the intended balance between time taken and PoD. If the inspector looks too closely or not closely enough then PoD may not be that intended by the inspection plan.
3. Search	Inspector should take short breaks from continuous visual inspection every 20-30 minutes	1. Extended time-on-task in repetitive inspection tasks causes loss of vigilance (Section 4.2.1), which leads to reduced responding by the inspector. Indications are missed more frequently as time on task increases. A good practical time limit is 20-30 minutes. Time away from search need not be long, and can be spent on other non-visually-intensive tasks.
3. Search	If search uses a loupe, ensure that magnification of the loupe in inspection position is sufficient to detect limiting indications.	1. The effective magnification of the loupe depends upon the power of the optical elements and the distance between the lens and the surface being inspected. Choose a loupe magnification and lens-to-surface distance that ensures detection. This may mean moving the lens closer to the surface, thus decreasing the FOV and increasing the time spent on searching. The cost of time is trivial compared to the cost of missing a critical defect.
3. Search	Provide lighting that maximizes contrast between indication(s) and background.	1. The better the target / background contrast, the higher the probability of detection. Contrast is a function of the inherent brightness and color difference between target and background as well as the modeling effect produced by the lighting system. Lighting inside a structure mainly comes from the illumination provided by the personal lighting (flashlight), which is often directed along the line of sight. This reduces any modeling effect, potentially reducing target background contrast, so that lighting must be carefully designed to enhance contrast in other ways.
3. Search	Provide the inspector with approved tools to prevent tools being improvised.	1. Inspectors will improvise tools if the correct one is not available. For example, inspectors use a knife to check elasticity of elastomer seals, or use a rag that catches on frayed control wires to inspect for fraying. While these may be adequate, they have not been tested quantitatively. Wrong indications may result.

Process	Good Practice	Why
3. Search	Use a consistent and systematic FOV scan path	1. A good search strategy ensures complete coverage, preventing missed areas of inspection. 2. A consistent strategy will be better remembered from task to task, reducing memory errors. 3. Searching for all defects in one area then moving to the next (Area-by-Area search) is quicker than the alternative of searching for all areas for each type of defect in turn (Defect-by-Defect search), but the probability of detection is reduced. It may be difficult to help inspectors to work Defect-by-Defect.
3. Search	Use a consistent and systematic eye scan around each FOV	1. A good search strategy ensures complete coverage, preventing missed areas of inspection. 2. A consistent strategy will be better remembered from task to task, reducing memory errors.
3. Search	Do not overlap eye scanning and FOV or blade movement.	1. It is tempting to save inspection time by continuing eye scans while the FOV is being moved. There is no adverse effect if this time is used for re-checking areas already searched. But search performance decreases rapidly when the eyes or FOV are in motion, leading to decreased probability of detection if the area is being searched for the first time, rather than being re-checked.
3. Search	Provide memory aids for the set of defects being searched for.	1. Search performance deteriorates as the number of different indication types searched for is increased. Inspectors need a simple visual reminder of the possible defect types. A single-page laminated sheet can provide a one-page visual summary of defect types, readily available to inspectors whenever they take a break from the inspection task.

Task Analysis starts from any existing documentation of how the overall task is supposed to be performed—often documents written by original equipment manufacturers (OEMs). It then uses input from the AMTs and inspectors on how the task is performed in practice rather than in theory. These two sources need to be reconciled before proceeding. Is the OEM prescription best or have the AMTs learned better ways since the OEM documentation was originally written? Is the AMT taking shortcuts that look sensible but could lead to sneak paths for error? This brings us to Participative Design.

Participative Design

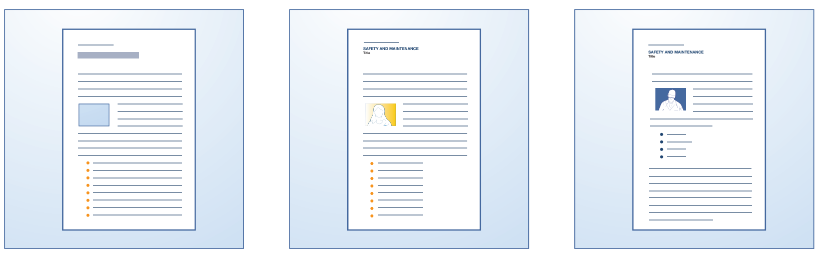
Any good procedure or document takes into account the needs of the end user. But what are those needs? Does the human factors engineer know best or the AMT? The answer is, as expected, that both need to collaborate using Participative Design. For example, AMTs know good sequences for task steps that match the realities of working the aircraft under realistic conditions. Alternatively, Human Factors engineers know that using ALL CAPITALS is an error-prone idea in designing task cards.

Participative design is much more than having an AMT validate a task card at the end of the design process. It requires involving all participants throughout the design process. In one airline, the design team comprised AMTs, engineers and human factors specialists but also people from the records department who had good knowledge of the errors actually found on completed task cards. A representative from QA who knew the overall process of maintenance and inspection was also included on the team.

Participative design means just what it says…everybody participates in the design.

Document Templates

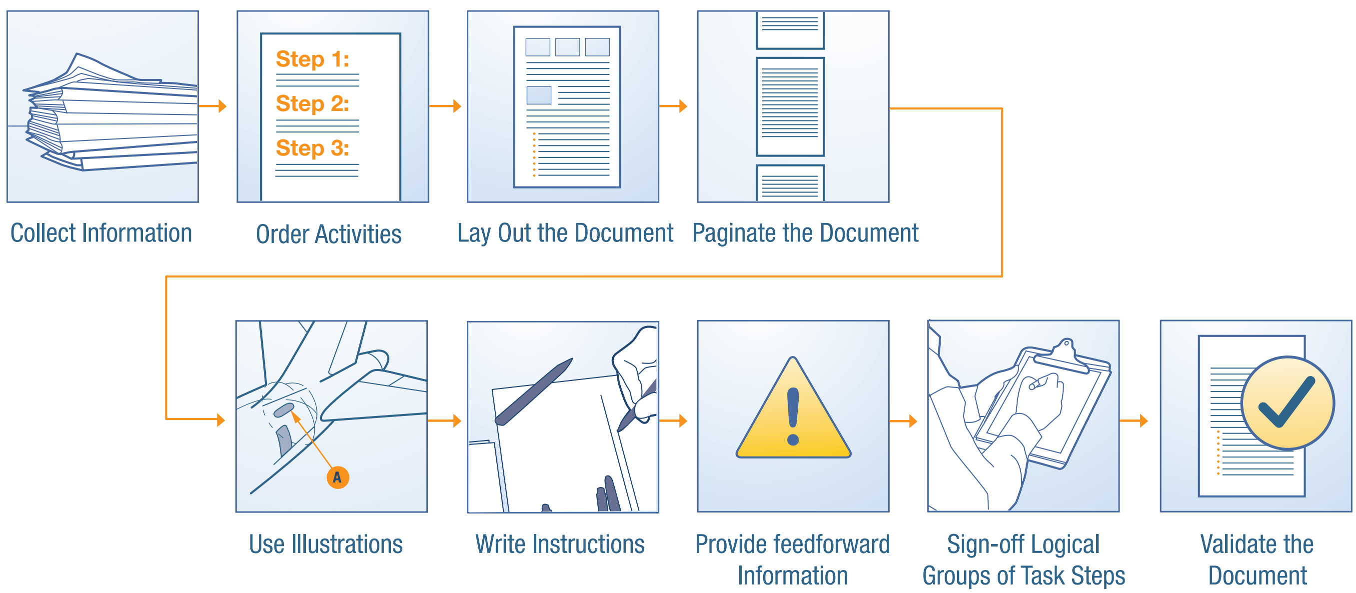
When there are many simple rules for designing better documents (layout, wording, fonts etc.) it makes operational sense to build these into a standard template. Many companies use templates for this anyway so it is often only a matter of modifying the templates and simultaneously training the document writing engineers on why they have been modified. That is only good participative design (above).



Document templates become a tool for achieving consistency, but they should not become a crutch for lazy writing. If parts of a particular procedure do not make sense in the standard template, then change the design so that it does make sense to the user. If there is any change from the standard template, though, warn the user in visually salient terms that changes have been made. In some companies there is an “x” marking in a “modifications” column where a change has been made, and this system can also be used for template modifications.

GUIDELINES

Designing procedures and documentation is not different in concept from the design of other tools and systems for human use: it all requires the application of good human factors. It needs to use human factors principles of how to involve the user and how to incorporate knowledge about human performance and behavior.



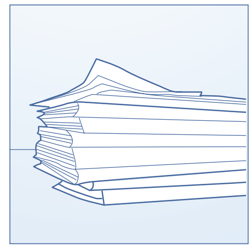
Design proceeds from the user outwards, not from the engineer downwards. Leaving the documentation design until the last part of the job, assigning it to the newest/rawest engineer, and imposing a rush deadline sets up even the most conscientious and capable AMT to make errors. In this section, we present a list of the steps needed to design and test a document for a procedure. These steps are a typical example of the user-centered design (UCD) process.

Note in the following guidelines, that the particular technology used to present the task cards to the AMT is not the main issue. These principles apply equally well to computer-based documents as to paper-based ones. A study comparing standard paper-based task cards with both well-designed task cards and computer-based task cards showed that 84% of the improvement was due to task card design, not to computerization. This should help you counter the argument that there is no need to redesign a task card as “we will soon be scrapping them and getting a computer-based system” which is often used as justification for putting off good design.

If you design the task cards correctly, then all of the effort is easily ported to the computer. In addition, you start reaping the reduced error benefits now instead of waiting for the inevitable changes and delays associated with any new software or hardware system. These guidelines will show where (and why) computer-based documents can have significant advantages, but none of these are worth delaying the design effort.

Collecting information for the procedure

A procedure can be no better than the information upon which it is based. The information must be accurate, specific and up-to-date. Modern aircraft come from the manufacturer supported by task details, diagrams and logic trees for performing maintenance and inspection tasks. These materials are updated frequently, indeed from an operator's perspective seemingly too frequently.



Obviously this information needs to be used, but it is not the only source of information. There are regulatory documents (e.g., ADs and ACs) that are used to identify tasks that apply to specific aircraft tail numbers. One must also take into account the training of AMTs. If the procedure is not consistent with the training, then errors are likely to occur. The solution is to change one to fit the other, not to expect the AMT to perform this reconciliation on the fly.

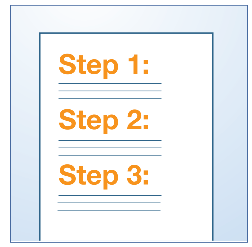
This consistency also applies in document wording, point of view in diagrams, ordering of procedure steps, and even to seemingly small changes such as where to place the sign-off boxes.

We need to make special mention of the specificity of each procedure. Each company's maintenance database contains lists of which equipment is on which aircraft in the fleet. There is no longer an excuse for written procedures that have several different sets of steps for different tail numbers. Again, if we do the work of sorting out the applicability / effectivity at the procedure design stage, we prevent confusion and errors by an AMT trying to determine which of several procedure steps to follow on a rainy midnight shift.

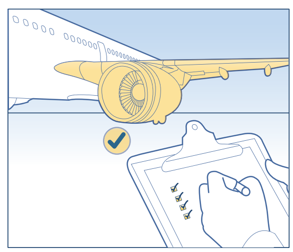
Finally, remember participative design. There are no reasons not to involve the AMT in the design of the procedure apart from time pressure and inconvenience. We have found procedures written for routine check inspections (e.g., overnight checks) that looked ridiculous to the AMT trying to follow them on the aircraft (see Ordering the Activities below). A few minutes with an AMT who performs these tasks would have saved much effort, confusion and error potential.

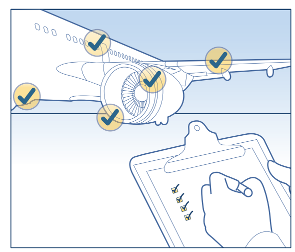
Ordering the activities in the procedure

Some activities have only one logical order. For instance, you cannot access a control run until you have removed the access panel. But many tasks are composed of activities that can be re-ordered without problems. For example, an overnight check on an aircraft comprises many individual inspections of many systems. There are all of the tires to check, all of the brakes, all of the interior seats, all of the fluid levels.



The natural way for an engineer to order these activities is by system, asking for all tire checks *then* all brake checks. But AMTs know this is not the most efficient way for them to perform the procedure, so they typically use a spatial sequence rather than a functional sequence. This means performing all checks on each landing gear unit together (tires, brakes, any fluid levels) before moving to the next unit. The illustrations below show this example.





Functional Sequence

Step	Task	Checked
4.0	**Check Tire pressure**	
4.1	Check tire pressure L Main Landing Gear	
4.1	Check tire pressure R Main Landing Gear	
4.1	Check tire pressure Nose Landing Gear	
5.0	**Check Brakes for condition**	
5.1	Check brakes for condition L Main Landing Gear	
5.1	Check brakes for condition R Main Landing Gear	
5.1	Check brakes for condition Nose Landing Gear	
6.0	**Check Hydraulic Fluid levels**	
6.1	Check hydraulic fluid level L Main Landing Gear	
6.1	Check hydraulic fluid level R Main Landing Gear	
6.1	Check hydraulic fluid level Nose Landing Gear	

Spatial Sequence

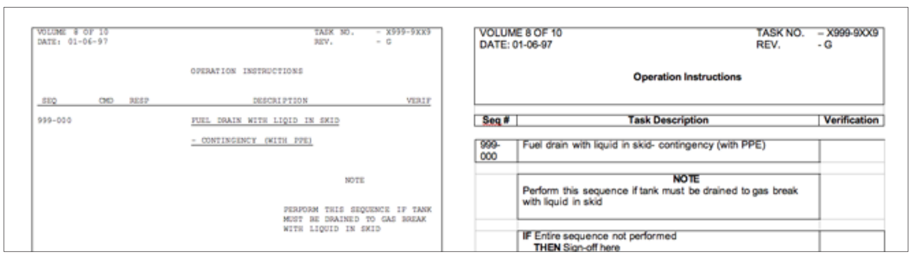
Step	Task	Checked
4.0	**Check Left Main Landing Gear**	
4.1	Check tire pressure	
4.1	Check brakes for condition	
4.1	Check hydraulic fluid level	
5.0	**Check Right Main Landing Gear**	
5.1	Check tire pressure	
5.1	Check brakes for condition	
5.1	Check hydraulic fluid level	
6.0	**Check Nose Landing Gear**	
6.1	Check hydraulic fluid level R Main Landing Gear	
6.1	Check hydraulic fluid level Nose Landing Gear	
6.1	Check hydraulic fluid level	

Writing the task card in the sequence that mechanics find natural prevents a mismatch between the task card and the AMT, thus preventing errors. Note also in the illustration that the number of sign-offs has been reduced (see Determining how many sign-offs are best later) In a study of an overnight check, AMTs much preferred spatial layout, and in controlled trials participants made fewer errors and used less time with a spatial layout.

Laying out the document

The overall goal when laying out a task card or an entire maintenance manual should NOT be to minimize the page count. Rather, the goal should be to make the procedure or document clear, unambiguous, easy to read, and easy to follow. A few pages more is not going to bankrupt the company or destroy the planet, but it could easily cause errors or lost time.

When using a task card, the AMT must be able to return to the correct point in the procedure after looking away, e.g., to perform a task step or answer a question. Anything that interferes with this ability to return to the proper location will increase the likelihood of errors, or at the very least add unnecessary delay.



VOLUME 8 OF 10 TASK NO. - X999-9XX9
DATE: 01-06-97 REV. - G

OPERATION INSTRUCTIONS

SEQ CMD RESP DESCRIPTION VERIF

999-000 FUEL DRAIN WITH LIQID IN SKID
- CONTINGENCY (WITH PPE)

NOTE

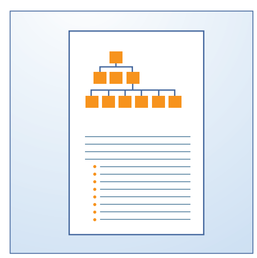
PERFORM THIS SEQUENCE IF TANK MUST BE DRAINED TO GAS BREAK WITH LIQUID IN SKID

VOLUME 8 OF 10 TASK NO. - X999-9XX9
DATE: 01-06-97 REV. - G

Operation Instructions

Seq #	Task Description	Verification
999-000	Fuel drain with liquid in skid- contingency (with PPE)	
	NOTE Perform this sequence if tank must be drained to gas break with liquid in skid	
	IF Entire sequence not performed **THEN** Sign-off here	

The best layouts have considerable white space and short paragraphs, like newspapers rather than novels. Check a newspaper (e.g., USA Today) to see how information is broken into small, self-contained pieces with frequent call-out headings and sub-headings so that readers do not lose their place after any interruption.



A good technique is to start the procedure with a flow chart so the user can understand the whole procedure before starting to perform it. When AMTs pick up a task card, they typically scan through the whole procedure to get this overall mental model in place. Providing a flow chart can help them do this better and more rapidly.

When a procedure is at all complex, such as an inspection task with different paths depending on whether a defect is found, a flow chart is particularly important. It shows the overall logic of the procedure at a glance. Tests of well-designed documents with flowcharts have shown a spectacular reduction in errors compared to good current airline practice of task cards.

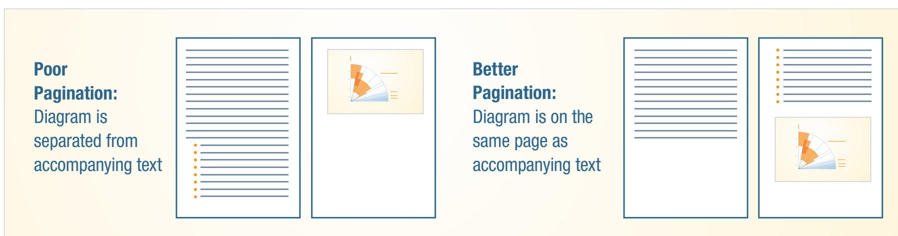
Within the procedure, clear indications of branching points are important. The convention in logic or computer programming is useful here with each branch starting with IF and the two outcomes starting with THEN and ELSE. Thus

> IF crack larger than 3mm is found on inner radius
> > THEN report crack and examine outer radius
> > closely for evidence of corrosion
> > ELSE continue to next component and inspect inner radius

Note also the use of indentation to make the choice point even clearer.

Paginating the document

Pagination means figuring out where page breaks occur in a document. Something as simple as pagination can make a difference in error rates. The concept here is that there should be a minimum need for page turning at critical points in the procedure. When the written instructions are on one page and the associated diagram on the next page, this put unnecessary load on "working memory" and can lead to errors.



Think through how the AMT will use the task card and paginate to avoid flipping backwards and forwards. When this was done for pilot procedures in Army helicopter actions, performance improved. This may mean that some space is "wasted" at the bottom of a page where an engineer concerned with minimizing paper costs could squeeze in a few extra lines of text. As noted above, however, this should not be an issue if the aim is error-proof procedures. In computer-based procedures, this is never an issue: one complete step per screen is an excellent working rule.

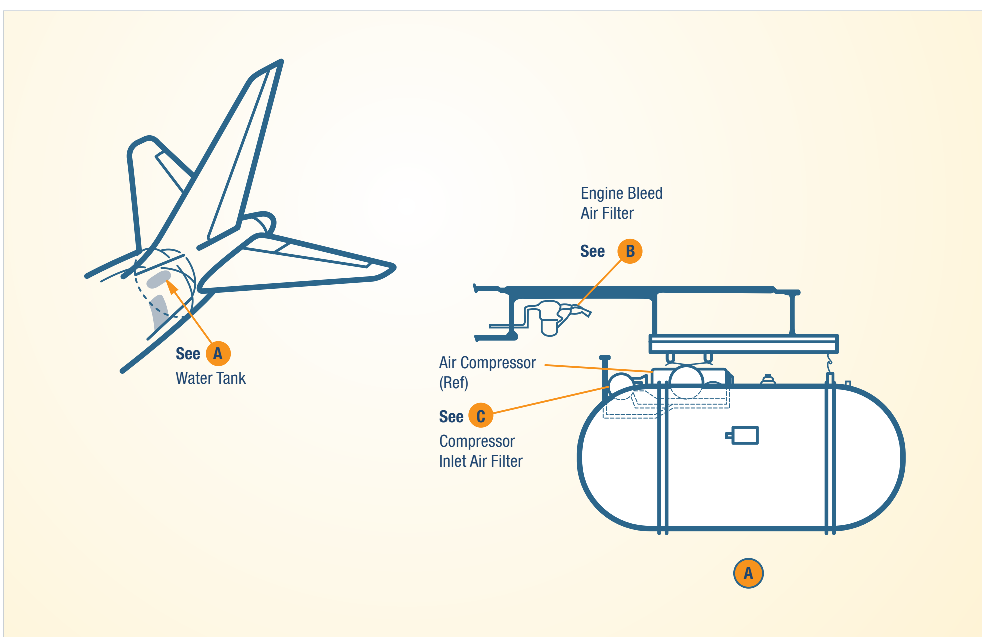
Using illustrations and call-outs

Procedures usually specify tasks that are inherently spatial in nature. For example, the instruction to "inspect the fuselage crown from station BS 83 to BS 85 between stringers 5L and 5R" is typical. The human brain has two distinct modes of operation—spatial and verbal—and moving between the two is inherently difficult and error-prone. We all know this from trying to receive driving directions, where hand gestures are a great addition to the verbal "turn the first left after Main Street" directions.

In procedures, diagrams and illustrations play the same role as hand gestures in driving directions. They prevent the error-prone translation of spatial into text instructions (by the procedure writer) and the equally error-prone translation (by the AMT) of text back into spatial positions. For this reason, diagrams and illustrations should be plentiful and well designed. We are long past the era of computers, programs and printers that were suited only to text so this principle should be standard procedure.

The design of the diagrams themselves needs to be carefully done, again to reduce errors. Any illustration of aircraft structure is best done in two parts: a callout from an overall picture of the aircraft structure (e.g. left wing, empennage or fuselage) to a larger view of the particular structure referenced in the text. The more detailed diagram should be shown from the viewpoint of the AMT performing the task, rather than from some standard or conventional viewpoint. Trying to puzzle out the relationship between the diagram in the task card and the actual structure visible to the AMT is again an error-prone activity.

Where there are specific tie-ins between the text and a diagram, these should be indicated by arrows from the text to the appropriate point on the diagram. In the helicopter example given above, each text step was placed in a box in order of performance down the left side of each page, with steps keyed to the diagram with arrows. This may not be possible within the software used to produce task cards for maintenance, so that arrows will typically be numbered with the step number of the name of the structure element or part. Note that these names need to be chosen carefully to be consistent throughout the procedure, and between procedure and training.

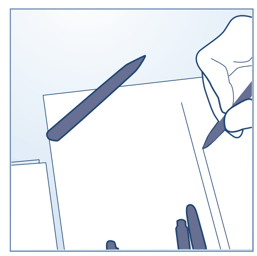


The same name needs to be used each time for each part. Using different names for the same part sets up the AMT for errors. If the diagram is from a source that uses a different name for a part, it needs to be edited to be consistent.

Finally, do not be tempted to save space and effort by including a diagram of only one side of the aircraft. Too often, the right wing or stabilizer will be shown even though both right and left sides need the AMT's attention. A sure giveaway line for lazy procedure writing is "left side similar" written under the illustration of the right side. We can easily transpose left to right on a computer, but having the AMT transpose manually while performing the task is introducing another easily-avoidable and well-known human error source.

Writing task instructions

The language of instructions is as important as their accuracy and layout. Poorly worded task cards create confusion and many avoidable errors for the AMT. The language of task cards is English for all US-based airlines, even if the actual maintenance work is performed overseas or by non-native English speakers inside the USA. Any improvement in the intelligibility of the written English will be an improvement for native English speakers just as much as for their non-native counterparts. Simplified English was developed for just this purpose.



Simplified Technical English. Simplified English (now called Simplified Technical English, or STE) was developed by The European Association of Aerospace Industries (AECMA) as a standard way to write instructions. The idea behind Simplified English was a specialized language for aviation maintenance, not just a simplified version of English. The goal is to make the reading task easier for AMTs under often-difficult environmental conditions, and also to be much easier to translate into other languages.

Note: The STE website is http://www.asd-ste100.org

Simplified Technical English consists of a set of writing rules, for example starting each with an action verb (check, tighten, install…), and a limited set of words for many of the verbs, nouns and adjectives used in maintenance instructions. Words in this set are the only ones allowed except for technical nouns such as part names (e.g., bracket) or equipment (e.g., eddy-current device). There are no synonyms, so that "start" is always used while "begin, commence, etc" are never used.

Tests of STE using AMTs, inspectors and even engineers have shown it to lead to drastically reduced errors related to task card comprehension. Other tests have shown that it is easy for engineers to learn and use STE. The only small downside is a slight increase in the length of task cards when procedures are spelled out fully, e.g., instructions for the left and right side are included in their entirety rather than using "left side similar" or "repeat for left side".

Table 6-2 A: Example of Non-Simplified Technical English
B. Remove Filter Element
(1) Provide electrical power (Ref 24-22-00_
(2)Remove pneumatic power (Ref 36-00-00)
(3)Open POT WATER CPRSR (6K21) circuit breaker on main distribution panel, P6. Attach DO-NOT-CLOSE identifier
(4)Open fill/overflow valve to depressurize water system, then close valve
Table 6-2 B: Simplified Technical English
B. Remove the Air-Filter Element
(1) Supply electrical power (Ref 24-22-00_
(2)Remove pneumatic power (Ref 36-00-00)
(3)Open this circuit breaker on main distribution panel, P6.
(a) POT WATER CPRSR (6K21)
(4) Attach DO-NOT-CLOSE identifier
(5)Open fill/overflow valve to depressurize water system,
(6) Close then close the fill/overflow valve after the pressure is released

Writing in Simplified Technical English should result in more readable text and lower text complexity scores. The usual recommendation is to use words with an equivalent reading level of 6th grade. This ensures that reading and comprehension are not compromised by poor environmental conditions, such as noise, interruptions, or restricted spaces within aircraft structures. AMT reading levels in the USA average between undergraduate and graduate student levels, but having a much lower reading level on task cards helps ensure low error rates under real-world conditions.

Fonts. An often neglected, but important part of procedure writing is the text formatting. Use upper case and lower case throughout rather than all upper case to imply emphasis. Readers benefit from rapid perception of the shape of each word, which is much more salient in lower case or mixed case than in upper case. The poor lighting conditions encountered during maintenance tasks (night work, work in restricted spaces) make the ability to recognize word shapes a potent error reduction tool.

Where emphasis is needed, **bold**, *italics*, a larger font, or even a small number of words in UPPER CASE can help. Indentation also helps AMTs keep their place in the document. The font itself should be easily readable, either a serif font such as Times Roman or a sans-serif font such as Arial (used in this chapter). Make the text and diagram fonts large enough to be easily read, typically 12 point but certainly no smaller than 10 point. A “point” is 1/72 of an inch.

Handling feed-forward information

AMTs and inspectors share their expert knowledge widely, even with those in other companies where the matter concerns safety. This knowledge, known as feed-forward information, helps all to do a better job, e.g., by alerting inspectors to new places where cracks have been found or warning AMTs of hidden hazards within a task. This type of information should be formalized into the task cards and other documents so that it is captured and its lessons can be learned. One airline has a computer-based task card system for its NDI shops where best practices are shared by inspectors, allowing those new to each specific inspected part to benefit from accumulated information.

One concern regarding feed-forward information is that alerting an inspector to specific types of defects and specific locations may cause them to go straight to those points and inadvertently skimp on the rest of the inspection task. Controlled studies have shown just the opposite to be true. One study, at Sandia National Laboratories, tested this concern with airline inspectors on a B-737 where there were known defects in known locations. The overall result was that inspectors found more defects that were alerted, but also did better rather than worse on non-alerted defects.

Determining how many sign-offs are best

AMTs and inspectors must certify their work for legal and production control purposes, typically by signing off each part of a procedure. Most procedures involve several steps, so an issue is how to assign sign-offs to steps? At one extreme, we have encountered a one-line procedure for replacing a wiring harness on a jet fighter that merely stated "Accomplish Task 33-649 per manual". This procedure took several days, often handing off the work across shifts. How the steps were supposed to be accomplished without error is beyond the understanding of human factors engineers!

At the other extreme are tasks where past errors have resulted in the insertion of more and more sign-offs to "make sure they don't get omitted again". The danger here is that the AMT does not interrupt their work frequently to perform the sign-offs but waits until a convenient point in the procedure before signing off many steps already accomplished. Neither extreme appears sensible as both task AMTs' memory for where they are in the sequence.

A direct test of number of sign-offs on a simulated overnight check of over 100 steps showed that signing off logical groups of steps was just as safe in terms of correctly executed procedures and was both slightly faster and preferred by participants. The concept is to use AMTs' knowledge to find sensible related groups of task steps that are amenable to a single sign-off. This also related back to the Ordering the Activities section. on how steps are ordered: if the steps are not sequenced in the order the AMT finds logical, then sensibly related groups will be impossible to find. The illustration of Functional vs. Spatial layout in that section illustrates the use of sensible grouping of sign-offs.

Validating the document

Until a task card or manual has been tested under realistic conditions it is only a theory not a valid procedure. The draft procedure (i.e., before validation) needs to be tested by real AMTs on the real aircraft, or for new aircraft on the virtual mock-up. Often the validation is skipped entirely as engineers are convinced they "know the 'plane", when in fact they know the OEM documentation much better than the plane itself. Or there is too little time to validate, or (your favorite excuse here). Any excuse for not validating is equivalent to selling airplanes to customers without a test flight. Everything should be OK, but there are so many instances where errors have occurred that we know we are setting ourselves up for error if validation is omitted.

Overview

Table 6-3, below, presents a condensed set of the guidelines described above. These are presented in the same order as in this section to demonstrate internal consistency. Many of the guidelines can be incorporated into standard templates as noted above. These guidelines plus Simplified Technical English (STE) have been codified into a Documentation Design Aid (DDA), available at http://hfskyway.faa.gov. This computer program operates in a window, illustrating each good practice by an example, and detailing why the practice should be followed. The DDA also includes an STE checker to determine whether a word is allowed in STE, or has a synonym in STE.

The DDA was tested using six technical writers, who were able to make significant improvements to test documents within one hour of first trying the program. In a direct test of the effectiveness of documents designed using the DDA, researchers found substantial and statistically significant improvements in comprehension errors when the DDA was used. The error rates on a comprehension test for the two carriers' versions were 51% and 35%, but only 4% for the DDA version.

Table 6-3.Guidelines for Procedeures and Technical Documentation
Collect information
Get all documentation users involved in the design procedure.
Use the existing documentation and AMTs' knowledge as the basis for a task analysis
Find an agreed terminology
Ensure effectivity is specific to each tail number
Use participative design
Order information
Use a fixed logical sequence for multiple activities that require this sequence
Use a spatial rather than a functional sequence for multiple activities that have many logical sequences
Layout the Document
Use a flowchart at the start of the procedure
Use IF…THEN…ELSE Where there are choice points or branches in the sequence
Do not try to minimize page count in the document
Use short rather than long steps for instructions
Put Warnings and Cautions in text boxes
Do not put instructions in Warning or Caution boxes
Paginate the document
Use document users to help find best pagination
Check that each diagram is on the same page as its accompanying text
Do not try to minimize page count in the document
Use Illustrations
Use illustrations freely to minimize text/spatial errors
Use an overall aircraft diagram to locate the specific area of the task
Show the main illustration from the same viewpoint as the AMT performing the task
Indicate forward, up and right on each diagram
Change all text on the diagram, such as part names, to match that in the main text
Use separate diagrams for each side of the aircraft, not just "Left Side Similar" with a Right Side diagram
Write Instructions
Use Simplified Technical English for all instructions
Check the readability score of each document to ensure that it is Grade 6
Format text in easily readable font such as Calibri, Ariel or Times Roman
Keep text in 12 point. 10 point is an absolute minimum.
Use Upper Case and Lower Case letters throughout
Add emphasis with **bold**, *italic*, larger font
Use separate diagrams for each side of the aircraft, not just "Left Side Similar" with a Right Side diagram

Provide feedforward information	
	Give specific up-to-date information to keep AMTs safe and help inspectors locate defects
	Alerting inspectors to specific defects / locations will not harm performance on non-alerted items
Sign-off Logical groups of task steps	
	Provide sign-off boxes for logical groups of task steps
	Use AMTs to help determine these logical groups
	Too few sign-offs risk missed steps: too many risk working from memory rather than the task card
Validate the Document	
	Validate all documents on actual task with actual AMTs, even if AMTs have participated in the design
	Validate by having the AMT perform the task literally from the task card, noting any implicit steps or missing knowledge

WHERE TO GET HELP

Simplified Technical English

Simplified Technical English (STE) is available to qualified applicants via its website at: www.asd-ste100.org

Federal Aviation Administration (FAA)

The FAA has a database of papers and design aids, including the Documentation Design Aid (DDA) available through: www.hfskyway.faa.goc

Embry-Riddle Aeronautical University

A very good source of information related to aviation maintenance human factors, including the original version of this Guide, is the Embry-Riddle website at: http://amelia.db.erau.edu/hfami/index.html

Human Factors and Ergonomics Society

For general questions on Human Factors, including documentation design, the Human Factors and Ergonomics Society is the primary professional organization in the USA: www.hfes.org

EXAMPLE SCENARIO

Here we provide an example of a task card as found at a major maintenance facility, and how it was redesigned as the prototype for all paperwork at the facility. Some words and numbers have been changed to preserve the anonymity of the facility.

Here is the part of the original task card, with changes noted above.

VOLUME 8 OF 10 TASK NO. - X999-9XX9
DATE: 01-06-97 REV. - G

OPERATION INSTRUCTIONS

SEQ	CMD	RESP	DESCRIPTION	VERIF
999-000			FUEL DRAIN WITH LIQID IN SKID - CONTINGENCY (WITH PPE)	

NOTE

PERFORM THIS SEQUENCE IF TANK MUST BE DRAINED TO GAS BREAK WITH LIQUID IN SKID

ENTIRE SEQUENCE NOT PERFORMED _______

WARNING

THIS SEQUENCE IS HAZARDOUS DUE TO FUEL FLOW. CONTROLLING MANUAL CONTAINS STEPS TO CLEAR AREA AND VERIFY PERSONNEL ATTIRED IN PPE. THIS SEQUENCE SHALL BE PERFORMED ONLY WHILE AREA IS CLEARED FOR FUEL LOADING (X999-9XX9) UNDER CONTROL OF S9999.

NOTE

NOTED REQUIREMENT IS SATISFIED BY COMPLETION OF THIS SEQUENCE.

MANUAL X999-9XX9.010-A

SEQ	CMD	RESP	DESCRIPTION	VERIF
999-001	AMT	TEAM	PERFORMS FUEL TANK DRAIN AND REPORT COMPLETION.	

WARNING

THIS SEQUENCE INVOLVES HAZARDOUS FUEL OPERATIONS. AREA CLEAR, AIRCRAFT CONFIGURED FOR REMOTE OPERATION AND

PERSONNEL IF ON STATION, ATTIRED IN PPE SHALL BE VERIFIED BEFORE PROCEEDING. S9999 CONTROLS THE FOLLOWING REQUIREMENTS:

1. CLEAR AREA TO PERIMETER SPACE

2. VERIFY ESSENTIAL PERSONNEL ATTIRED IN PPE

3. INITIATE RECORDING AFTER PERSONNEL ARE ON STATION.

CAUTION

IF THE CROSSFEED AND ENGINE FEEDLINES ARE SOFTFILLED AND THE PRESSURES ARE GREATER THAN 70 PSIA, THIS SEQUENCE CAN NOT BE RUN IN PARALLEL WITH THE FLOW INITIATION SEQUENCER.

NOTE

OPERATIONS INVOLVING CRITICAL, 1R AND/OR 1S ITEMS ARE CONTAINED IN THE FOLLOWING SEQUENCE/STEPS.

While this task card fragment certainly has plenty of "white space" it shows a number of deviations from the Guidelines.

1. There are no instruction steps and action sign-offs in this fraction of the document, although much has to be performed. The one place for a sign-off is if the whole operation is not preformed, and even this is a line embedded in the text rather than a separate box.
2. Action steps occur in the Warning
3. The Caution has a complex conditional branch but this is not clearly shown and there is in fact no specified action for one branch.
4. The document has much of its content on the right side with narrow column width for no apparent reason.
5. The writing is all in UPPER CASE, using a fixed-width font (Courier) rather than a more readable font.

The illustration below shows how the document fragment can be re-written to make it clearer and less error prone.

VOLUME 8 OF 10 TASK NO. – X999-9XX9
DATE: 01-06-97 REV. - G

Operation Instructions

Seq #	Task Description	Verification
999-000	Fuel drain with liquid in skid- contingency (with PPE)	
	NOTE Perform this sequence if tank must be drained to gas break with liquid in skid	
	IF Entire sequence not performed **THEN** Sign-off here **AND** Go to step 999-007 **ELSE** continue	
	WARNING This sequence is hazardous due to fuel flow. Follow this procedure for safety.	
	NOTE REQUIREMENT IS SATISFIED BY COMPLETION OF THIS SEQUENCE according to MANUAL X999-9XX9.010-A	
999-001	Amt team performs fuel tank drain and report completion	
	Clear area to perimeter space following X999-9XX9 under S9999	
	Make Sure essential personnel are attired in PPE	
	Start recording when personnel are on station	
	CAUTION **IF** the crossfeed and engine feedlines are softfilled **AND** the pressures are greater than 70 psia, **THEN** do not run this sequence in parallel with the flow initiation sequencer **ELSE** ????????	
	NOTE Operations involving Critical, 1R and/or 1S items are contained in the following sequence/steps.	

REFERENCES

There are many books on writing technical documentation but few give any evidence for their recommended practices. The following are useful in a general way:

Dillon, A. (1994). Designing Usable Electronic Text.
Taylor and Francis, London

Inaba, K., Parsons, S. O. and Smillie, R. (2005). Guidelines for developing Instructions. CRC Press, Boca Raton FL.

Simpson, H. and Casey, S. M. (1988). Developing Effective User Documentation. McGraw Hill, New York

More useful papers on design include:

Drury, C. G. (1998). Case study: error rates and paperwork design, Applied Ergonomics, 29(3), 213-216

Drury, C. G., Patel, S. C. and Prabhu, P. V. (2000). Relative advantage of portable computer-based workcards for aircraft inspection. International Journal of Industrial Ergonomics. 26(2), 163-176

Patel, S., Drury, C.G. and Lofgren, J. (1994). Design of workcards for aircraft inspection. Applied Ergonomics 1994, 25(5), 283-293

CHAPTER 7:
ERROR AND ERROR REPORTING SYSTEMS

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LANDING PAGE

"When you get it right mighty beasts fly up into the sky.
When you get it wrong people die."

—Roger Bacon, c. (1384) [www.skygod.com]

The words of Roger Bacon quoted over six centuries ago seem fitting even today as real man-made beasts (i.e., aircraft) fly in virtually every corner of the world. However, just as the first line rings true, so too does the second. Aviation can be very unforgiving. Certainly, the aviation system is not so fragile that every error leads to an accident. Without a doubt, advances over the years have made aircraft technologically reliable and remarkably safe.

As in other domains, most (60-80%) aviation accidents involve some type of human error. Many accidents and incidents involve aircrew errors. Some accidents, however, occur as a result of human errors committed during maintenance.

The most commonly-used tool (worldwide) for analyzing events caused by maintenance errors is the Boeing Maintenance Error Decision Aid (MEDA), which was developed in the early 1990s . Boeing estimates that over 700 aviation maintenance organizations now use some form of the MEDA process. MEDA began as a maintenance error investigation process. However, in the early 2000s Boeing added the concept of violations of company policies, processes, and procedures as also being a cause (along with errors) of maintenance-related events. Now MEDA is best characterized as a maintenance event investigation process.

Also in the early 1990s, Wiegmann and Shappell were developing the Human Factors Analysis and Classification System (HFACS). HFACS was originally designed to analyze the causes of pilot error, but has since been modified for use across a variety of contexts and industries, including maintenance errors. Some airlines find it useful to classify all of their event investigation data (e.g., flight operations, maintenance and engineering, and ramp services) using the HFACS classification system, regardless of how the data are originally collected. This allows them to have a single classification system across airline functions.

INTRODUCTION

Aviation is statistically the safest means of transportation, safer than traveling by roads, rail, or even water. The aviation industry has gotten progressively safer over the latter half of the century to a point where accidents today are rare events, indeed (Figure 7-1). A Boeing analysis of the fatal accident rate for large jets showed that the fatal accident rate for the U.S. and Canada went from an average of approximately 0.5 fatal accidents per year per million departures in the 1990s to an average of approximately 0.2 fatal accidents per year per million departures from 2000 through 2006.

But as air traffic continues to increase, simple math tells us that the number of accidents will also increase unless the accident rate is reduced still further. Thus, various tools and models have been implemented and evaluated to find and eliminate the source of human errors in aviation. Traditionally, they have helped identify various causes of the accidents such as operation, assembly, design, inspection, installation and maintenance errors (Dillion and Lui, 2006).

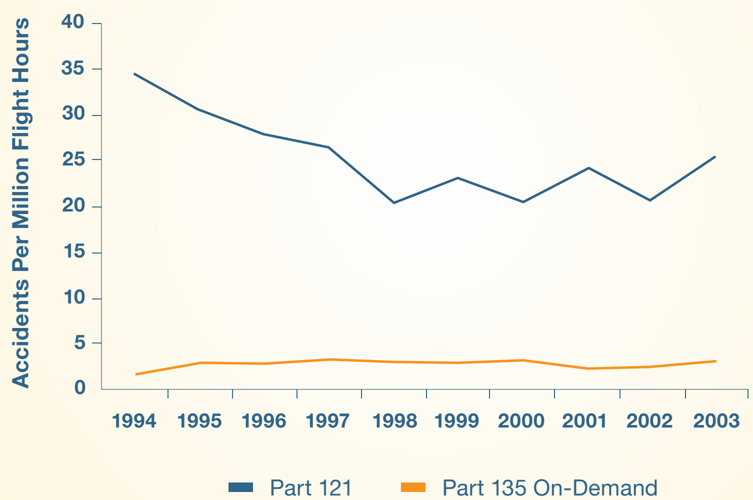


Figure 7-1: *U.S. Air Carrier Accident Rate by 14 Code of Federal Aviation Regulation Part 121 (Air Carrier) and Part 135 (Commuter)*

Maintenance and inspection errors and/or violations, can affect aircraft safety in two different ways:

- Primary Cause—The accident is due to the maintenance system failure. The accident is not in any way due to flight crew action.

- Contributing Factor—The accident chain begins with a component or system failure caused by a maintenance error. The failure is incorrectly handled by the flight crew, which ultimately leads to an accident. Flight crew error is the primary cause of such accidents.

A recent European Aviation Safety Agency (EASA) analysis found that maintenance was a primary cause in 8% of the accidents during the time period 1970-2006. An International Air Transport Association (IATA) analysis of aviation accidents in 2003 found that in 26% the accident chain began with a maintenance-caused event. IATA did not distinguish between maintenance as a primary cause or contributing factor, and, of course, these results differ from year to year. Taking the EASA and IATA data together, it appears that an average of 8% of the accidents per year have maintenance as a primary cause and that an additional 15%-20% have a maintenance failure as a contributing factor.

While the overall accident rate has gotten progressively lower over the last several decades, the rate of maintenance errors has increased by almost 200 errors per million flights (Figure 7-2). There is one estimate that 48,800 un-airworthy aircraft are dispatched each year as a consequence of maintenance errors.

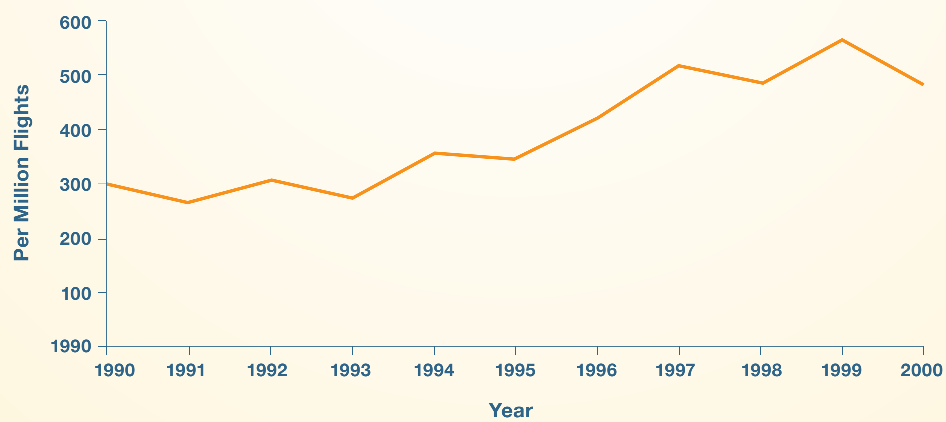


Figure 7-2: *Maintenance error mandatory occurence reports per million flights*

(Source: Federal Aviation Administration, Annual Review of Aircraft Accident Data: U.S. Air Carrier Operations, Calendar Year 2003)

REGULATORY REQUIREMENTS

Parts 121 and 135 of the Federal Aviation Regulations (FAR's) contain general requirements related to maintaining aircraft that come under their scope of applicability. However, there are no specific requirements in these parts of the FAR's that relate directly to human error. In fact, the FAR's do not define human (nor any other type of) error. Instead of errors, the FAR's rely on identifying regulatory violations, for which various types of proceedings and potential penalties are prescribed in Part 13.

The major differences in how violations are treated lie in the type of investigative process that is undertaken. The FAA has some discretion as far as this decision, but the main distinction seems to lie in the use of an informal investigation or administrative action versus a formal investigation. Formal investigations are predicated on the FAA's initial evaluation of the response to an "order of investigation." Formal fact-finding investigations are described in Subpart F. Formal hearings are defined in Subpart D and can include witnesses, depositions, lawyers, etc. Most maintenance errors do not result in violations of the FAR's. Therefore, it is not appropriate to use the terms "error" and "violation" synonymously.

EASA and Transport Canada (TC) have regulations requiring the investigation of maintenance-caused events. The U.S. Federal Aviation Administration (FAA) highly recommends such investigations in its Operator's Manual: Human Factors in Aviation Maintenance. The need for such investigations will likely soon be required by all national airline regulatory bodies due to anticipated requirements for for all airlines and maintenance organizations to implement a Safety Management System (SMS).

The International Civil Aviation Organization (ICAO) made requirements for an SMS a recommended practice on 23 November 2006 and wants it to be a standard by 1 January 2009. An SMS will require maintenance-caused event investigations as a reactive hazard identification process. These existing and impending regulatory requirements clearly demonstrate a need for maintenance-caused event investigation processes, such as MEDA and HFACS.

CONCEPTS

Active Error

An active error is one that has immediate consequences. For example, suppose an AMT actuates a control surface, e.g., a flap, while another AMT is working on some component of that surface. This error stands a good chance of immediately injuring the second AMT.

Decision Error

Decision errors represent intentional behavior that proceeds as planned even though the outcome did not. These so-called "thinking" errors generally arise from a lack of knowledge, information, or experience.

Error

In the broadest sense, an error is an action that has an unintended (and usually "bad") consequence.

Latent Error

A latent error is one that has delayed consequences. Latent errors can be associated with either technical tasks, e.g., forgetting to lock wire a fastener, or management tasks, such as instituting a poorly-conceived overtime policy. Latent errors are often referred to as “accidents waiting to happen”.

Mistake

A mistake is very similar to a decision-based error. It is essentially a bad or wrong decision. Regardless of how well the work is executed after the bad decision, the outcome will be bad.

Perceptual Error

Not surprising, when one’s perception of the world differs from reality, errors can, and often do, occur. Perceptual errors typically occur when sensory input is degraded or altered by physical surroundings.

Skill-Based Error

Skill-based behavior is best described as “automatic” behavior that we engage in with little or no conscious thought. For example, most people do not have to think about typing on a keyboard, turning a key in the ignition of their car, or riding a bike—they just do it. These “skills” are highly practiced and over time become quite routine and seemingly automatic.

Slip

A slip is similar, but not necessarily identical to, a skill-based error. In the slip scenario, the AMT decides on the correct course of action, but something prevents that action from being carried out properly.

The Swiss Cheese Model

One of most accepted models of accident causation is James Reason’s “Swiss Cheese” model of human error (Reason, 1990; Figure 7-3). According to the Swiss cheese model, accident investigators must analyze all facets and levels of the system to fully understand the causes of an accident. For example, working backwards in time from the accident, the first level to be examined would be the unsafe acts of operators (i.e., maintainers) that ultimately lead to the event. Not surprising, this level is where most accident investigations typically focus their efforts and consequently, where the majority of causal factors are uncovered. After all, it is these active failures, or actions of maintenance personnel, that can be directly linked to the event. For instance, improperly tightening a fitting, or worse yet, failing to lock out or tag out an energized piece of equipment, may yield relatively immediate, and potentially grave, consequences. Represented as failed defenses or “holes” in the cheese, these active failures are typically the last unsafe acts committed by maintainer.

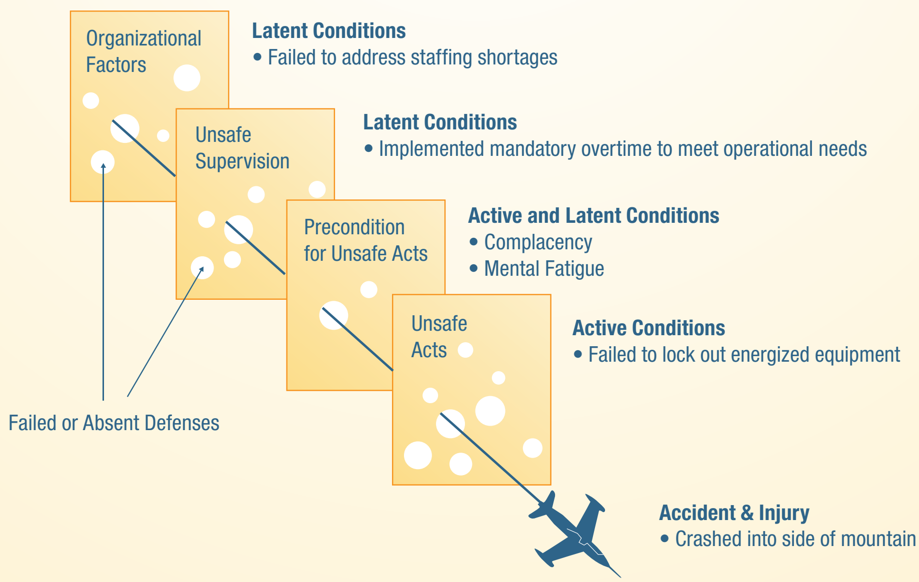


Figure 7-3. *Reason's (1990) "Swiss Cheese" model of organizational accidents.*

What makes the Swiss cheese model particularly useful in accident investigation is that it forces investigators to address latent failures within the causal sequence of events, as well. As their name suggests, latent failures, unlike their active counterparts, may lie dormant or undetected for hours, days, weeks, or even longer, until one day they adversely affect the unsuspecting technician. Consequently, investigators with even the best intentions may overlook them.

Violation

Errors are, by definition, unintentional. Violations, on the other hand, are intentional departures from the rules. Typically, the violator intends only to ignore the rule, but does not intend any harmful result. Violations often occur with the full knowledge and implicit approval of management. Often, violations occur because the "legal" way of doing things doesn't work or is inefficient.

METHODS

Maintenance Error Decision Aid (MEDA)

The scientific study of human error began with a study of pilot error in the late 1940s. Major interest in human error surfaced after the Three Mile Island nuclear power plant accident in the spring of 1979. Work in the area of human reliability began in the late 1970s and focused on situational factors that led to errors. Two major researchers (Swain and Guttman) called these situational factors Performance Shaping Factors (PSFs).

The concept of PSFs lends itself to incident investigations and determining what actions need to be taken to reduce the likelihood of future, similar errors. The PSF concept was used as the basis of the development of the MEDA process (in which they are called “contributing factors”).

The development of MEDA was a joint collaboration between Boeing and representatives from United Airlines, British Airways, Continental Airlines, the International Association of Machinists, and the FAA. This collaboration resulted in two products, a MEDA Results Form and a User’s Guide. The MEDA User’s Guide is a “how to” manual; the Results Form is used during the investigation, which is an interview with the technician/inspector whose performance led to the event.

As noted, MEDA started out as an error investigation process. The concept of violations of company policies, processes, and procedures was added to the MEDA philosophy in the early 2000s. Therefore, MEDA is now better characterized as an event investigation process. The MEDA philosophy is based on the event model and states:

- A maintenance-related event can be caused by errors, violations, or a combination of errors and violations.
- Maintenance errors are not committed intentionally.
- Errors result from a specific combination of contributing factors in the workplace.
- Although violations are intentional, they are also caused by contributing factors in the workplace.
- Most of the contributing factors to errors and/or violations are under management control.
- Therefore, improvements can be made to these contributing factors so that they do not combine to cause future events.

Figure 7-4 is a hierarchical model of the contributing factors than can lead to maintenance system failures. The individual AMT or Engineer works within an immediate work environment, which is, in turn, embedded in a supervisory framework and then an organizational culture. Each major factor at one level tends to be influenced by higher-level factors. Thus, the immediate work environment is influenced by both supervision and organizational factors.

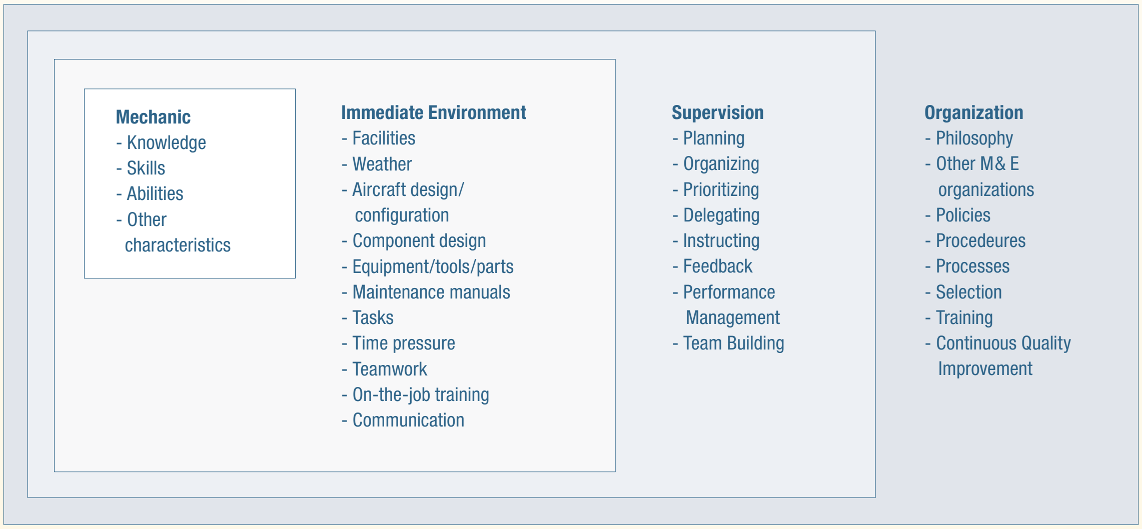


Figure 7-4. *Contributing factors to maintenance performance.*

During the MEDA development phase, Boeing found that an average of about four contributing factors were associated with each error that led to an event. This finding illustrates that the mechanic is only one part of the overall system. Focusing solely on the individual mechanic will have little impact on improving system safety. Rather, the analysis should consider all of the contributing factors to errors and violations.

Figure 7-5 illustrates the original MEDA error model. In the model, contributing factors cause errors and errors cause events. In the present MEDA model, since the philosophy is that errors and violations are causal, the word "error" is replaced by the words "system failure." Note that the MEDA model is based on the probabilistic relationship between the contributing factors, errors (system failures) and events. In other words, two mechanics could be carrying out the exact same maintenance task on two aircraft using the same tools, technical documentation, etc., and one may make an error and the other may not. Put simply, errors/violations occur as a result of a dynamic combination of contributing factors.

The MEDA Results Form was developed to assist the MEDA investigator in carrying out the interview with the mechanic and/or inspector who carried out the work that lead to the system failure(s) that lead to the event that started the MEDA investigation. An overview of the Results Form is given in the Applying MEDA hyperlink, and a copy of the Results Form is available here.

Boeing encourages users to make changes to the Results Form to make it as useful as possible to their operation. Many users make changes to Section I-General Information, but typically leave the remainder of the form as is. The general process for carrying out a MEDA investigation is also provided in the Applying MEDA hyperlink, as is the suggested process for carrying out the MEDA investigation interview. All of these sub processes are explained in detail in the MEDA User's Guide.

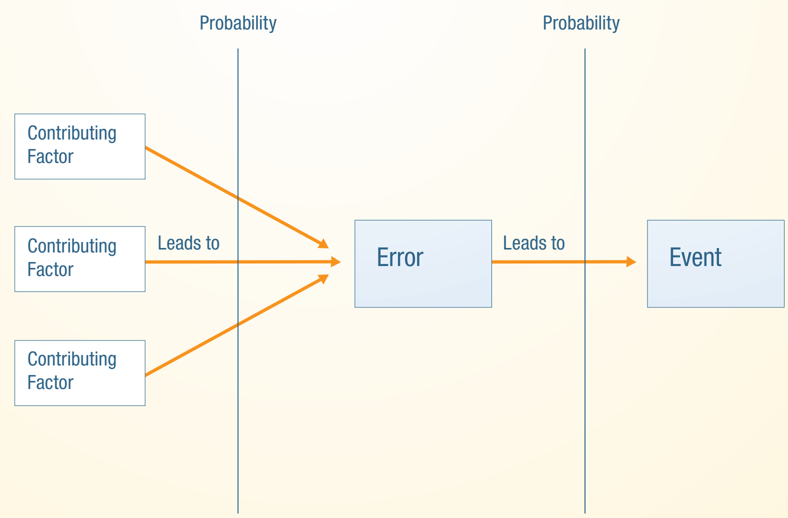


Figure 7-5: *Initial MEDA error model.*

The MEDA process offers maintenance organizations an event investigation process. MEDA can serve as the reactive hazard identification process that will be necessary when a Safety Management System is required by regulation. Experience in the MEDA users' community has shown that MEDA is a simple process that is easy to learn and implement.

In addition to the MEDA process, Boeing has developed the Ramp Error Decision Aid (REDA) process. REDA is designed specifically for ramp/apron events, especially aircraft damage, equipment damage, and personal injuries. A REDA Results Form and User's Guide are available in a digital format upon request. Finally, Boeing recently developed the MEDA—Workshops Results Form, which is also available in digital format upon request.

The Human Factors Analysis and Classification System (HFACS)

While MEDA has become the industry standard for investigating aircraft maintenance error, other types of errors (e.g., aircrew errors) have used other investigative and analysis tools – albeit there is significant overlap. The FAA and various airlines have used one such system, the Human Factors Analysis and Classification System (HFACS), for classifying accident/incident causal factors associated with aircrew error.

HFACS describes error at each of four levels: 1) unsafe acts of operators (e.g., maintainers); 2) preconditions for those unsafe acts; 3) unsafe supervision from middle management; and 4) organizational influences (Figure 7-6).

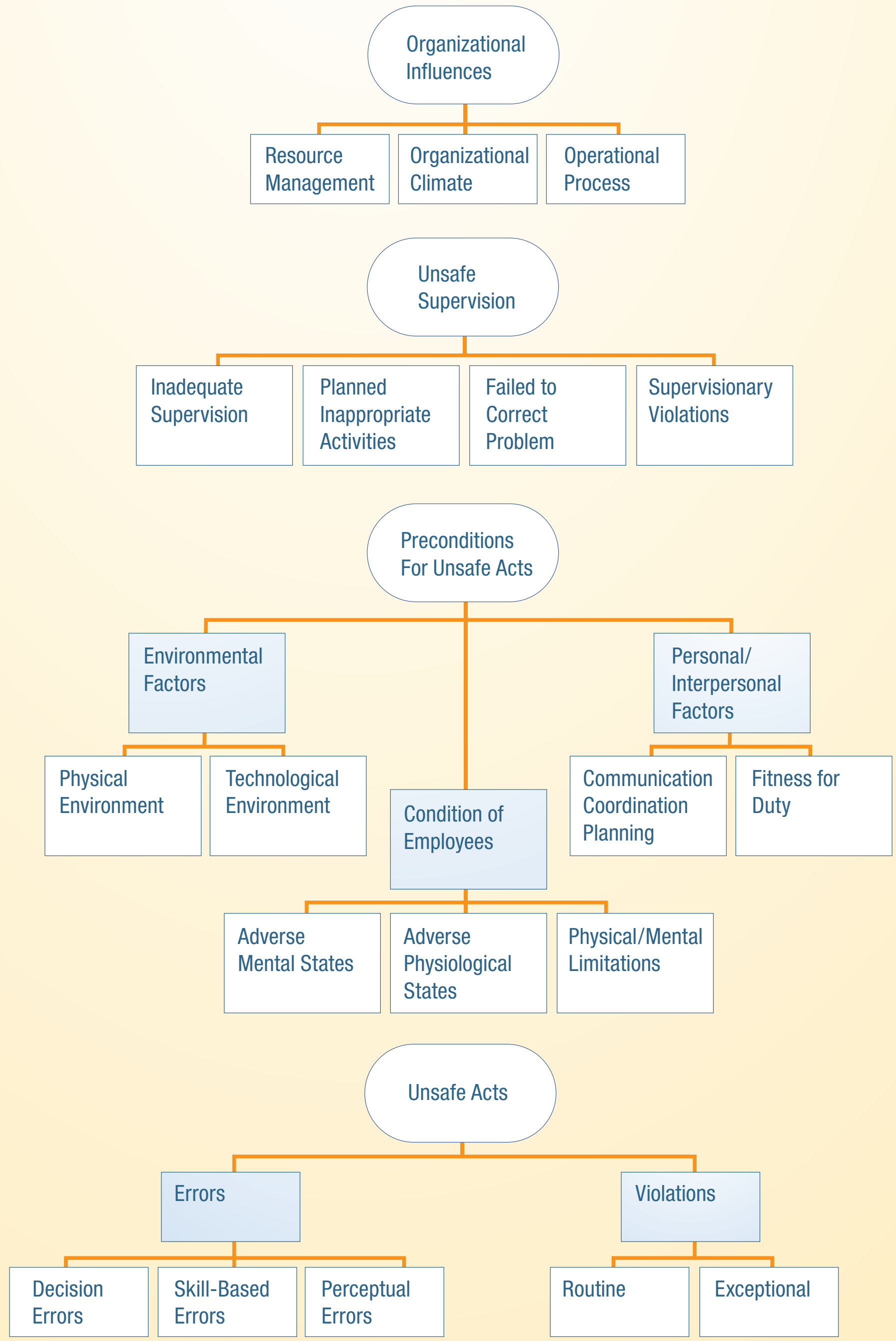


Figure 7-6: *The Human Factors Analysis and Classification System.*

While a detailed description of HFACS is beyond the scope of this chapter, we will describe briefly the HFACS framework and show how it has been modified for use with maintenance error by incorporating MEDA causal factors.

GUIDELINES

In this section, we provide a discussion of how the MEDA and HFACS methods can be used in combination to classify maintenance errors in a broad and deep framework. Many examples that relate to this discussion can be found in Table 1. Note that examples extracted from MEDA are presented in italics while those unique to HFACS are presented in normal font.

Unsafe Acts

Within HFACS, the unsafe acts of operators (e.g., mechanics) can be loosely classified into two categories: errors and violations (Figure 7-7). In general, errors represent the honest, unintentional mistakes that we, as humans, make all the time. Indeed, we commit errors every day. Violations, on the other hand, refer to the willful disregard for the rules and regulations that govern safe maintenance operations.

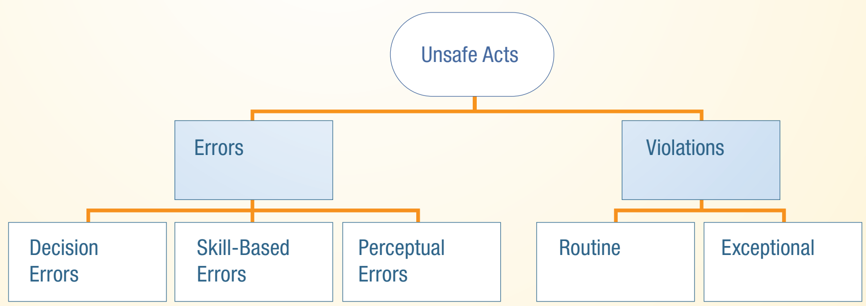
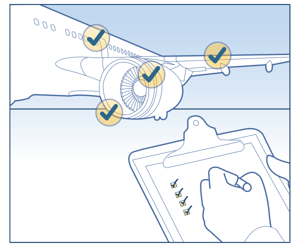


Figure 7-7: *Unsafe Acts of AMTs*

Errors. *Decision errors* represent intentional behavior that proceeds as planned even though the outcome did not. These so-called "thinking" errors generally arise from a lack of knowledge, information, and/or experience. It turns out that most decisions are procedural by nature and typically occur during highly structured tasks of the sorts, if X, then do Y, then do Z. Proceeding in any other way, or modifying the process on the fly, can lead to poor outcomes or accidents. On the other hand, changes associated with work plans are sometimes unavoidable as are the many choices mechanics make during even the most mundane maintenance task. Unfortunately, even the best maintenance mechanics can occasionally make bad choices.

In contrast, *skill-based errors* occur when we engage in what many refer to as automatized behavior with little or no conscious thought. For example, most people do not have to think about typing on a keyboard, turning a key in the ignition of their car, or riding a bike—they just do it. Unfortunately, it is the auto-



matic nature of these behaviors that make them particularly vulnerable to failures of attention, memory lapses, and simply technique errors. For instance, it is not difficult to imagine a mechanic becoming so involved in troubleshooting a new problem that they neglect or forget their original task. Indeed, the failure to prioritize one's attention or simply failing to pay attention can often lead to mistakes. Likewise, forgetting items in a checklist or losing one's place in a multi-step task has happened to even the most well intentioned mechanic. Alternatively, skill-based errors can simply be the result of adopting poor techniques.

Not surprising, when one's perception of the world differs from reality, errors can, and often do, occur. *Perceptual errors* typically occur when sensory input is degraded or altered by the work environment. Specifically, when mechanics are faced with incomplete sensory information due to poor lighting, excessive noise, or other adverse environmental conditions the brain will often "fill in the gaps" with what it feels belongs. As a result, it is not unusual for mechanics to misunderstand verbal orders in noisy workplaces. Likewise, many accidents have occurred simply because a mechanic misjudged their height, distance, or other important factors.

Table 7-1. HFACS-MEDA Unsafe Acts of Operators (Maintenance Personnel)

ERRORS

Skill-based Errors

- *Equipment/tool incorrectly used*
- *Slow reaction time*
- *Memory lapse*
  - *Not completing a task (e.g., forgot where one left off)*
  - *Reversed/omitted steps in multi-step task*
  - Aircraft systems not restored following maintenance
  - Maintenance item not secured (e.g. access panels, fairings, cowlings, oil/fuel caps, etc)
- Task overload
- Failed to prioritize attention (e.g., became involved in troubleshooting new problem and neglected original problem)
- Negative habit
- Improper position for task, (i.e. used arm as fulcrum on concrete)
- Work or motion at improper speed
- Improper lifting
- Working in awkward posture
- Excessive physical force exertion
- Failure to maintain eyes on surroundings or path
- Insecure footing
- Failure to recognize self in line of fire, (e.g., swinging door)

Perceptual Errors

- Failure to hear communications (e.g. due to noise)
- Misinterpreted warning (i.e., auditory or visual)
- Misinterpreted/misread equipment
- Misjudged distance
- Misjudged speed of object
- Misjudged depth/height
- Misjudged the texture of the object (i.e., slippery vs. coarse)
- Underestimated weight of object
- Failure to see small items (e.g. objects, cracks, etc.)

Decision Errors

- *Information not used*
- *Procedure available but the technician did not have enough time to get it*
- *Technician thought that he did not need the procedure because he had done the task many times before*
- *Excessive time spent on one task*
- *Failure to acquire parts on time*
- Misinterpretation of information
- Exceeded ability
- Inadequate work planning
  - Failure to prioritize task
  - Inadequate risk assessment
  - Wrong tool for the job
- Improper procedure/maneuver utilized
- Improper placement of tools, equipment, materials (e.g.
- placing ladder under flaps)
- Use of defective tool/equipment
- Operation/servicing of equipment at improper speed
- Improper attempt to save time
- Necessary action rushed/delayed
- Wrong response to abnormal situation

VIOLATIONS

- *Required protective equipment (guards, PPE, or other safety devices) not used/disabled*
  - *Failure to wear corrective lenses*
  - *Failure to use hearing aids or ear plugs*
- *Safety equipment not appropriate for the hazard*
  - *Personal protective equipment not properly worn*
  - Intentional use of defective or contaminated PPE
- *Proper equipment/tool available but not used*
- Knowingly used tools/material improperly (e.g. incorrect tool for job, etc.)
- Inadequate energy control (lock-out/tag-out)
- Loose objects (tools, etc.) left in work area
- Knowingly entered into unauthorized area
- Caution/warning ignored
- Exceeded duty times
- Under/over-serviced equipment

Table 7-1. HFACS-MEDA Unsafe Acts of Operators (Maintenance Personnel)

- ☐ Not current, qualified, or authorized for task/ equipment
- ☐ Horseplay
- ☐ Accepted unnecessary hazard
- ☐ Work group practice outside expected norms
- ☐ Documented procedure—most people in the same situation do not follow the process or procedure
- ☐ Undocumented procedure—most people do the procedure like the technician did.
- ☐ Information not used
- ☐ Work process/procedure not followed.
- ☐ Skipped operational check
- ☐ Did not use ”parts removed” tag
- ☐ Information/manual/task card/instruction not used or followed
- ☐ Failed to follow technical/safety procedures
- ☐ Failed to comply with training guidelines/ operating guidelines by individual or group
- ☐ Knowingly installed/removed part improperly
- ☐ Failure to follow shift orders
- ☐ Taking shortcuts
- ☐ Failure to properly inspect
  - Failed to properly inspect or service equipment
  - Failure to inspect work following maintenance
  - Sign-off without inspection

*Causal factors as described in the MEDA Guide are presented in italics. Those previously existing with HFACS are presented in normal font.

Violations. As previously noted, violations represent the willful departure from the rules and regulations that govern safe operations. Using definitions provided by James Reason, we typically distinguish between types of violations. The first, routine violations, tend to be habitual by nature and are often tolerated by management. For example, consider an AMT who routinely works on aircraft engines without utilizing proper personal protective equipment (PPE). While this is certainly against the rules, other people may do the same thing.

To make matters worse, routine violations (commonly referred to as “bending the rules”) are often tolerated and, in effect, sanctioned by supervisory authority. If supervisors disciplined AMTs for not wearing PPE, then it is less likely that workers would violate this rule. Therefore, by definition, if a routine violation is identified, one must look further up the supervisory chain to identify those individuals in authority who are not enforcing the rules.

Unlike routine violations, exceptional violations appear as isolated departures from authority and are neither indicative of an individual’s typical behavior nor condoned by management. For example, signing off a maintenance sheet without performing the maintenance or inspecting the work would typically be considered an exceptional violation. However, it is important to note that, while most exceptional violations are appalling, they are not considered “exceptional” because of their extreme nature. Rather, they are considered exceptional because they are neither typical of the individual nor condoned by authority.

Preconditions for Unsafe Acts

Arguably, the unsafe acts of maintainers can be directly linked to a significant percentage of aviation accidents. However, simply focusing on unsafe acts is like focusing on an ill patient without understanding the underlying disease causing it. Thus, investigators must dig deeper into the preconditions for those unsafe acts (Figure 7-8). For this purpose, HFACS and MEDA identify three major subdivisions of preconditions: the condition of the employee, environmental factors, and personal/interpersonal factors.

Table 7-2 provides a number of examples that relate to the discussion of preconditions. As with Table 7-1, the factors in italics are drawn from MEDA and the other factors from HFACS.

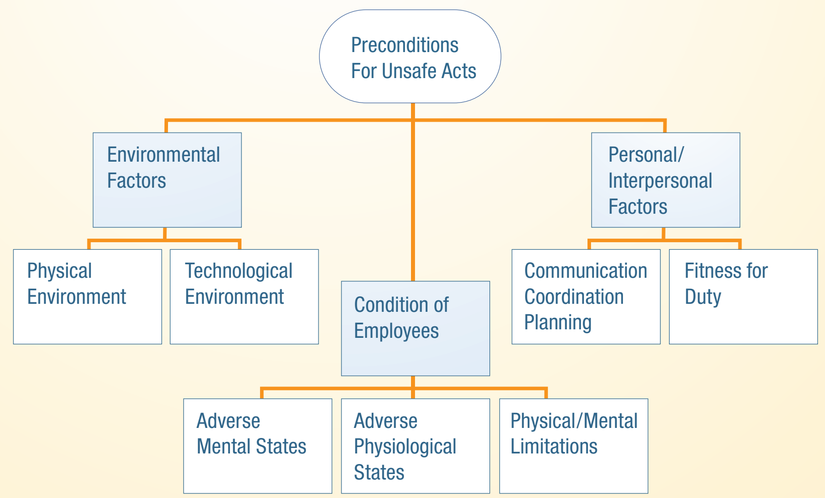
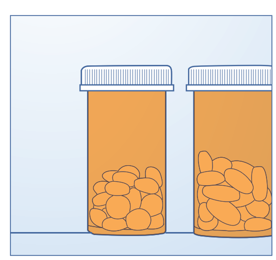


Figure 7-8: *Preconditions For Unsafe Acts*

Conditions of Employees (Maintenance Technicians). Being prepared mentally is critical for aircraft maintainers. As such, the category of *adverse mental states* accounts for those mental conditions that adversely affect performance. Principal among these are peer pressure, emotional stress, task saturation, distraction, and mental fatigue due to sleep loss or other stressors. This category also contains personality traits and pernicious attitudes, such as overconfidence, complacency, and misplaced motivation. Predictably, if an individual is mentally tired the likelihood that an error will occur will increase markedly. In a similar fashion, overconfidence and other hazardous attitudes, such as arrogance and impulsivity will increase the likelihood of committing a violation.



The second category, *adverse physiological states*, refers to those medical or physiological conditions that preclude safe operations. Particularly important to aircraft maintenance are such conditions as intoxication, physical fatigue, and simply being ill. Surely, many of us have gone to work while taking over-the-counter medications for a cold or flue. However, most of us would agree that our performance on the job suffered. While relatively innocuous in some occupations, the adverse effects of illness can be quite serious when an aircraft that may not be completely airworthy is released for flight.

The category of *physical/mental limitations* is reserved for those instances when operational requirements exceed the capabilities of the individual. While similar to adverse mental and physiological states described above, physical/mental limitations are chronic and/or permanent disabilities that impair the mechanic's ability to perform their duties. For instance, as people age their eyesight and hearing often degrade. Likewise, lower back pain can adversely impact one's ability to perform even the most routine task. The physical/mental aptitude of the mechanic is also included in this category. Just as everyone cannot play major league baseball or be the next country music star, not everyone has the aptitude to maintain aircraft.

Table 7-2. HFACS-MEDA Preconditions for Unsafe Acts

Environmental Factors

Physical Environment

- ☐ *High noise levels*
- ☐ *Hot*
- ☐ *Cold*
- ☐ *Humidity*
- ☐ *Rain*
- ☐ *Snow*
- ☐ *Insufficient or excessive lighting*
- ☐ *Wind*
- ☐ *Vibrations*
- ☐ *Workplace cleanliness*
- ☐ *Hazardous/toxic substances*
- ☐ *Inadequate ventilation*
- ☐ *Area(s) not organized efficiently (difficult to find parts, etc.)*
- ☐ *Working environment is too dynamic/crowded*

Technological Environment

Task

- ☐ *Repetitive/monotonous*
  - *Similar steps are performed over and over*
  - *The same task performed many times in multiple locations*
- ☐ *Complex/confusing work/task*
  - *Multiple other tasks are required during this task*
  - *Multiple steps required at the same time by different maintenance technicians*
  - *Long procedure with critical step sequences*
  - *System interacts with other systems during testing or fault isolation*
  - *Task requires exceptional mental or physical effort*
- ☐ *New task or task change*
  - *New maintenance requirement or component*
  - *Revision to a procedure*
  - *Engineering modification to existing fleet*
- ☐ *Different from other similar tasks*
  - *Same procedure on different models is slightly different*
  - *Recent change to aircraft configuration has slightly changed task*
  - *Same job at different worksites is performed slightly different*

Technology

- ☐ *Power sources*
  - *Not labeled with caution or warning*
  - *Guarding devices missing or damaged*
  - *Circuit protection devices not utilized or damaged*
  - *Cords chafed, split, or frayed*
- ☐ *Unsafe Equipment/Tools*
  - *Platform moves and is unstable*
  - *Brakes or safety devices inoperative*
  - *Non-skid material worn or missing*
  - *A lock-out mechanism is missing or faulty*
  - *Placards (warnings or cautions) are missing or faded*
  - *Sharp edges are exposed or personal protective devices are missing*
  - *Power sources are not labeled or protected*
- ☐ *Unreliable Equipment/Tools*
  - *Intermittent or fluctuating readings on dials or indicators*
  - *Damaged or worn out*
  - *Expired use limits*
  - *History of defects*
- *Layout of Controls and Displays*
  - *Easy to read wrong display or use wrong control*
  - *Awkward locations, hard to reach*
  - *Too small to read or control*
  - *Directional control of knobs or dials is not clear*
- *Mis-calibrated Equipment/Tools*
  - *Tool out of calibration from the start of use*
  - *Wrong specifications used during calibration procedure*
- *Inappropriate equipment/tools for the task*
  - *Standard hand tools used for leverage*
  - *Not capable of handling weights, forces, or pressures required for the task*
  - *Connections or grips not the right size*
- *No instructions for tool/equipment*
  - *Instructional placards missing or faded*
  - *Directional markings missing*
  - *Tool usage instructions not available*

Table 7-2. HFACS-MEDA Preconditions for Unsafe Acts

- ☐ *Tool/Equipment too complicated*
  - *Tool usage requires too many simultaneous movements/ readings*
  - *Fault isolation or testing is too complex*

  Tool/Equipment incorrectly labeled
  - *Hand marked labeling or operating instructions are incorrect*
  - *Tool has incorrect scale readings*
- ☐ *Complex design/configuration/parts*
  - *Fault isolation on the system or component is difficult*
  - *Installation of components is confusing, long, or error prone*
  - *Multiple similar connections exist on the system or component*
  - *Installation tests for the component are extensive and confusing*
  - *Different sized fasteners can be installed in multiple locations*
- ☐ *Inaccessible design/configuration/parts*
  - *Components or area to be maintained is surrounded by structure*
  - *No access doors exist in the maintenance area*
  - *Area lacks footing space or hand-holds*
  - *Small or odd-shaped area*
- ☐ *Aircraft configuration variability*
  - *Similar parts on different models are installed differently*
  - *Aircraft modifications have changed installation or other maintenance procedures between aircraft*
- ☐ Parts incorrectly labeled
- ☐ Parts easy to install incorrectly
  - Can be easily installed with wrong orientation
  - No orientation indicators (e.g., arrow, colors)
  - Connections identical in size, color or length
  - Components are too heavy for easy removal/ installation
- ☐ Lack of feedback provided by component or system
- ☐ Equipment/controls design
- ☐ System protection devices on tools/equipment
- ☐ not available
- ☐ Checklist layout
- ☐ Display/interface characteristics

Condition of the Employee

- ☐ **Adverse Mental States**

  Mental fatigue

  Emotional stress (e.g., tension, anxiety, depression)

  Inadequate vigilance, attention span, alertness

  Inability to concentrate

  Task saturation

  Perceived pressure to finish a task more quickly than needed in order to release the aircraft from the gate
- ☐ *Risk-taking behavior*
- ☐ *Peer pressure*
  - *Unwillingness to use written information because it is seen as a lack of technical skills/knowledge*
  - *Lack of individual confidence*
  - *Not questioning other's processes*
  - *Not following safe operating procedures because others don't follow them*
- ☐ *Complacency*
- ☐ *Confusion about where one is in a task*
- ☐ Distraction
- ☐ Overconfidence

Adverse Physiological States

- ☐ *Physical health*
- ☐ *Personal injury*
- ☐ *Adverse effects of medication*
- ☐ Physical fatigue
- ☐ Intoxication

Physical/Mental Limitations

- ☐ *Inadequate knowledge of systems, procedures*
- ☐ *Demonstrated lack of technical skills*
  - *Safety wiring*
  - *Rigging of controls*
  - *Using calibrated equipment*
  - *Carrying out a fault isolation task*
- ☐ *Inadequate Task knowledge*
  - *Slow task completion*
  - *Technician change of maintenance responsibilities*
  - *Task performed by maintenance technician for the first time*
  - *Task performed in wrong sequence*

Table 7-2. HFACS-MEDA Preconditions for Unsafe Acts

- ☐ *Lack of airline process knowledge*
  - *Technician new to airline or to type of work (from line to hangar, etc.)*
- ☐ *Sensory acuity (e.g. vision loss, hearing loss, touch)*
- ☐ *Restricted field of vision due to protective eye equipment*
- ☐ *Pre-existing chronic disease*
- ☐ *Chronic pain limiting range of movement*
- ☐ *Drug or alcohol use*
- ☐ *Complaints of frequent muscle/soft tissue injury*
- ☐ *Body size/strength*
  - *Abnormal reach, unusual fit, or unusual strength required for the task*
  - *Inability to access confined spaces*
- ☐ *Inadequate experience for complexity of situation*

Personnel Factors

- ☐ *Communication/Coordination/Planning*
- ☐ *Not understandable information*
  - *Unfamiliar words or acronyms*
  - *Unusual or non-standard format*
  - *Poor or insufficient illustrations*
  - *Not enough detail or missing steps*
  - *Poorly written procedures*
- ☐ *Unavailable/inaccessible information*
  - *Procedure does not exist*
  - *Not located in correct or usual place*
  - *Not located near worksite*
- ☐ *Incorrect information*
  - *Missing pages or revisions*
  - *Does not match aircraft configuration*
  - *Transferred from source document incorrectly*
  - *Steps out of sequence*
  - *Not the most current revision*
  - *Procedure does not work*
- ☐ *Too much/conflicting information*
  - *Similar procedures in different resources do not agree (e.g. MM versus task card)*
  - *Too many references to other documents*
  - *Configurations shown in different resources do not agree*
- ☐ *Update process is too long/complicated*
  - *Requested revisions have not been incorporated yet*
  - *Configurations changed by Service Bulletins or Engineering Orders have not been updated in applicable maintenance procedures*
  - *Document change requests are not submitted, lost, or incorrectly filled out*
- ☐ *Incorrectly modified manufacturer's MM/SB*
  - *Intent of manufacturer's procedure is not met*
  - *Non-standard practices or steps are added*
  - *Format does not match rest of procedure or other procedures*
- ☐ *Operator cannot use digital information*
- ☐ Poor communication/coordination among technicians,
- ☐ managers, FAA, etc.
- ☐ Lack of teamwork
- ☐ Lack of assertiveness
- ☐ Inadequate shift turnover/meetings (failure to pass needed information regarding status of aircraft, special problems)

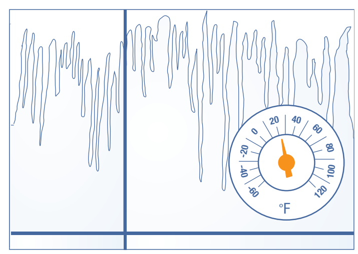
- ☐ *Personal Readiness*
- ☐ *Nutritional factors (missed meals, poor diet)*
- ☐ *Absenteeism*
- ☐ *Medical leave*
- ☐ *Vacations*
- ☐ *Personal event*
  - *Death of a family member*
  - *Marital difficulties*
  - *Change in living conditions*
- ☐ Inadequate rest
- ☐ Self-medicating
- ☐ Overexertion while off duty

*Causal factors as described in the MEDA Guide are presented in italics. Those previously existing with HFACS are presented in normal font.

Personal/Interpersonal Factors. Good communication skills and team coordination have been the mantra of industrial/organizational and personnel psychology for decades. Not surprising then, *communication, coordination, and planning* form the cornerstone of any successful maintenance program. Within the context of aviation maintenance, this includes coordination within maintenance control and with other aviation operations. It's not uncommon for miscommunications and misunderstandings to take place between supervisors and mechanics. Likewise, communication among mechanics working on an aircraft and between shifts is critical particularly on larger jobs. (See the Communication chapter.)

Fitness for duty is a concern in any organization, but especially so in an aviation maintenance setting. Nevertheless, people occasionally show up for work not ready to perform their job. For instance, lack of sleep, hangovers, and self-medicating can all affect performance on the job and are particularly detrimental during maintenance that requires concentration and considerable thought. (See the Fatigue and Fitness for Duty chapter.)

Environmental Factors. It is well known that the physical environment (e.g., weather, heat, vibration, and lighting) can have an impact on human performance. For instance, imagine having a flat tire on a quiet country road with temperatures in the low 70s. Although an inconvenience, you would simply pull the car to the side of the road and change the tire making certain that you had all the lug nuts on tight. Now let's change the conditions a bit. Let's make it 35 degrees and drizzling, or maybe 105 degrees in sweltering heat. Understandably, many people would not take as much care changing the tire and might not check, and re-check the security of the lug nuts. During which situation do you think it is more likely that an error will occur resulting in an avoidable accident? (See the discussion of the PEAR model in the Human Factors chapter.)



Likewise, the *technological environment* (e.g., design of equipment and controls, display/interface characteristics, checklist layouts, task factors and automation) can also have a tremendous impact on AMT performance. We are all familiar with the poor design of certain tools and pieces of test equipment. What we often don't consider are the procedures, checklists, and instructions that can be equally flawed. As a result, mechanics are often left with little choice but to work around procedures that are poorly written or outdated. While in some cases this "work-around" might be successful, the problem is the lack of standardization among mechanics that are left to their own devices to complete the task. (See the Procedures and Technical Documentation chapter.)

Unsafe Supervision

The cause of many (not all) accidents/incidents can be traced back to middle management (Figure 7-9). As such, we have identified four categories of unsafe supervision: inadequate supervision, planned inappropriate operations, failure to correct a known problem, and supervisory violations. The list of combined MEDA-HFACS factors associated with unsafe supervision is shown in Table 7-3.

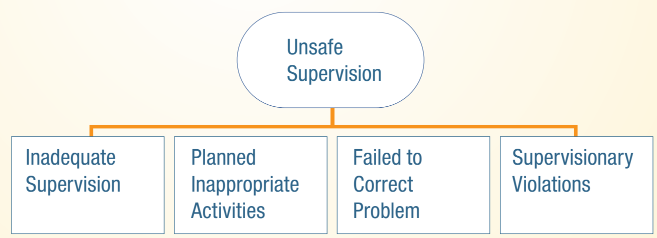


Figure 7-9: *Unsafe Supervision*

Table 7-3: HFACS-MEDA Unsafe Supervision

Inadequate Supervision

- ☐ *Supervisor does not have confidence in group's abilities*
- ☐ *Management doesn't "walk the talk" and thereby sets poor*
- ☐ *work standards for maintenance staff*
- ☐ *Unrealistic attitude/expectations*
  - *Pressure on maintenance technicians to finish tasks sooner than possible or reasonable*
  - *No overall performance expectations of maintenance staff based on management vision*
- ☐ *Amount of supervision*
  - *"Look over the shoulder" management style*
  - *Frequent questioning of decisions made*
  - *Failure to involve employees in decision-making*
- ☐ Failed to provide adequate training
  - *Airline processes not documented or stressed in training*
- ☐ Failed to provide professional guidance/oversight
  - *Technician performance/skills not accurately tracked/measured*
- ☐ Failed to provide adequate protective equipment
- ☐ Failed to provide adequate/proper tools
- ☐ Failed to provide current publications/adequate technical data and/or procedures

Planned Inappropriate Operations

- ☐ *The workgroup performs the task differently than specified in the source data (or written information)*
- ☐ *Time constraints*
  - *Constant fast-paced environment*
  - *Multiple tasks to be performed by one person in a limited time*
  - *Increase in workload without an increase in staff*
  - *Too much emphasis on schedule without proper planning*
- ☐ *Excessive length of work day*
- ☐ *Significant change in work hours or change in conditions*
- ☐ *Planning/organization of tasks*
  - *Excessive downtime between tasks*
  - *Not enough time between tasks*
  - *Paperwork is disorganized*
  - *Tasks are not in a logical sequence*
- ☐ *Prioritization of work*
  - *Technicians not told which tasks to carry out first*
  - *Important or safety related tasks are scheduled last*
  - *Fault isolation is not performed with the most likely causes checked first*
- ☐ *Delegation/assignment of tasks*
  - *Assigning the wrong person to carry out a task*
  - *Inconsistency or lack of processes for delegating tasks*
  - *Giving the same task to the same person consistently*
  - *Wide variance in workload among maintenance technicians or departments*
- ☐ *Meetings do not have purpose or agendas*
- ☐ Failed to allow for adequate rest
- ☐ Excessive tasking/workload
- ☐ Poor shift turnover

Failed to Correct Problem

- ☐ Failed to correct inappropriate behavior/ identify risky
- ☐ behavior
- ☐ Failed to correct a safety hazard
- ☐ Failed to initiate corrective action
- ☐ Failed to report unsafe tendencies
- ☐ Failed to provide and demand adherence to technical doctrine
- ☐ Lack of accountability

Supervisory Violations

Violated procedures
Risk outweighs benefit
Authorized unqualified personnel to perform task
Failed to enforce rules and regulations
Authorized unnecessary hazard
Willful disregard for authority by supervisors
Inadequate inspection
Fraudulent documentation
Inadequate documentation

The role of any supervisor is to provide the opportunity to succeed. To do this, supervisors must provide guidance, training opportunities, leadership, and motivation, as well as the proper role model. Unfortunately, instances of *inadequate supervision* can occur. For example, suppose a supervisor either does not provide adequate training or does not allow a mechanic to attend training. This could easily result in a poor decision-making or an erosion of skills on the part of the mechanic. Likewise, the lack of sound professional guidance and oversight has proven to be the breeding ground for many of the violations that have crept into the workplace.

Occasionally, the operational tempo and/or the scheduling of employees are such that individuals are put at unacceptable risk, their rest is jeopardized, and their ultimate performance is degraded. These *planned inappropriate operations,* although arguably unavoidable during emergencies, are unacceptable during normal operations. Tasks that present essentially no risk during routine operations can cause lethal consequences with AMTs are overworked, underrested, or otherwise strained by a continuously high operational tempo.

The third category of known unsafe supervision, *failed to correct a known problem*, refers to those instances when deficiencies among individuals, equipment, training or other related safety areas are “known” to the supervisor, yet are allowed to continue unabated. For example, it is not uncommon for accident investigators to interview the friends, colleagues, and supervisors of maintainers that have been killed in a fatal accident. Nothing bothers an investigator more than to hear someone say that they “knew it would happen to him some day.” If the supervisor knew that a mechanic was incapable of performing safely, and allowed them to work anyway, he or she clearly did the mechanic no favors. The failure to correct improper behavior, either through remedial training or discipline, essentially signed the employees death warrant - not to mention that of others who may have been involved.

Supervisory violations, on the other hand, are reserved for those instances when supervisors willfully disregard existing rules and regulations. Although arguably rare, supervisors have been known occasionally to violate the rules. For instance, there have been occasions when individuals were permitted to work on an aircraft without current qualifications or licenses. Likewise, it can be argued that failing to enforce existing rules and regulations or flaunting authority are also violations at the supervisory level. While rare and possibly difficult to separate, such practices are a flagrant violation of the rules, and invariably set the stage for the tragic and predictable consequences.

Organizational Influences

Just as some accidents/incidents have roots within middle-management/supervision, still others have roots at the highest level of the organization (i.e. CEOs, presidents, vice-presidents, admirals, generals, etc.). Unfortunately, these organizational errors often go unnoticed by safety professionals, due in large part to the lack of a clear framework from which to investigate them. Generally speaking, the most elusive of latent failures revolve around issues related to resource management, organizational climate, and operational processes (Figure 7-10). Table 7-4 shows examples of the combined MEDA—HFACS errors associated with organizational influences.

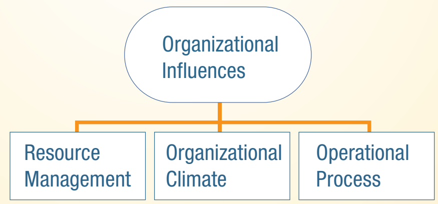


Figure 7-10: *Organizational Influences*

Resource management refers to corporate-level decision-making that deals with the allocation and maintenance of organizational assets, such as human resources (personnel), budgets, and equipment/facilities. Generally, corporate decisions about how such resources should be managed center around two distinct objectives—the goal of safety and the goal of on-time, cost-effective operations. In times of prosperity, both objectives can be easily balanced and satisfied in full. However, as mentioned earlier, there may also be times of fiscal austerity that demand some give and take between the two.

Unfortunately, history shows us that safety is often the loser in such battles. Safety and training are often the first “costs” to be cut in organizations having financial difficulties. Excessive cost cutting could also result in reduced funding for new equipment or may lead to the purchase of equipment that is inadequately designed for the type of maintenance performed in the organization. Other trickle-down effects include poorly maintained equipment and workspaces, and the failure to correct known design flaws in existing equipment.

Table 7-4. HFACS-MEDA Organizational Influences

Resource Management

Human Resources

- ☐ *Not enough staff*
  - *Not enough trained personnel at the time*
  - *Overall inadequate staffing levels*
- ☐ *Corporate change/restructuring*
  - *Layoffs are occurring*
  - *Early retirement programs drain experience*
  - *Reorganizations, consolidations and transfers cause more people to be in new jobs*
  - *Demotions and pay cuts*
  - *Frequent management changes*
  - *Work previously accomplished in-house is contracted out*
- ☐ Selection
- ☐ Training
- ☐ Inadequate or missing background checks
- ☐ Inconsistent promotional opportunities

Monetary/Budget Resources

- ☐ Excessive cost cutting
- ☐ Lack of funding
- ☐ Unfunded mandates

Equipment/Facility Resources

- ☐ *Proper equipment/tools/parts unavailable*
  - *Is not owned or in stock*
  - *Not available for procurement*
- ☐ *Tools/Equipment cannot be used in the intended environment*
  - *Not enough space to operate tool*
  - *Requires level surface where one is not available*
- ☐ *Workspace/equipment conditions*
  - *Confined, obstructed, or inaccessible workspaces*
  - *Purchasing of unsuitable equipment*

Organizational Climate

Structure

- ☐ Chain-of-command
- ☐ Communication
- ☐ Accessibility/visibility of supervisor
- ☐ Delegation of authority
- ☐ Formal accountability for actions

Policies

- ☐ *Company policies*
  - *Unfair or inconsistent application of company policies*
  - *Standard policies do not exist or are not emphasized*
  - *Standard error prevention strategies don't exist or are not applied*
  - *Inflexibility in considering special circumstances*
  - *Lack of ability to change or update policies*
- ☐ Drug and alcohol policies

Culture

- ☐ *Union action*
  - *Contract negotiations create distractions*
  - *Historical management/labor relations are poor*
  - *Positive or negative communication from union leadership*
  - *Strike, work slowdown, or other labor action creates a disruption*

Norms and rules

Organizational customs

Values, beliefs, attitudes

Operational Process

Operations

- ☐ *Quality of support from technical organizations*
  - *Inconsistent quality of support information*
  - *Late or missing support information*
  - *Poor or unrealistic maintenance plans*
  - *Lack of feedback on change requests*
  - *Reluctance to make technical decisions*
  - *Frequent changes in company procedures and maintenance programs*

Table 7-4. HFACS-MEDA Organizational Influences

- ☐ **Operational tempo**
    - Incentives
    - Quotas
    - Time pressure
    - Schedules

Procedures

- ☐ *Work process/procedure (If the work process or procedure is followed but does not bring about the desired result)*
    - *Standard operating procedures (SOPs) incorrect*
    - *General maintenance manuals outdated*
    - *Inadequate inspection allowed*
    - *Process/procedure does not obtain the desired outcome*
- ☐ *Work process/procedure not documented*
    - *No procedure for radio check before towing operation*
    - *No inspection criteria*
    - *No procedure for proper use of safety equipment*
- ☐ Performance standards
- ☐ Clearly defined objectives

Oversight

- ☐ Established safety programs/risk management programs
- ☐ Management's monitoring and checking of resources, climate, and processes to ensure a safe work environment

*Causal factors as described in the MEDA Guide are presented in italics. Those previously existing with HFACS are presented in normal font.

Organizational climate refers to a broad class of organizational variables that influence worker performance. It can be viewed as the working atmosphere within the organization. Primary indicators of an organization's climate is its established chain-of-command, delegation of authority and responsibility, communication channels, and formal accountability for actions. An organization's policies and culture are also good indicators of its climate.

Policies are official guidelines that direct managers' decisions about such things as hiring and firing, promotion, retention, raises, sick leave, drugs and alcohol, overtime, accident investigations, and the use of safety equipment. Culture, on the other hand, refers to the unofficial or unspoken rules, values, attitudes, beliefs, and customs of an organization. Culture is "the way things really get done around here."

Finally, *operational process* refers to corporate decisions and rules that govern the everyday activities within an organization. These include the establishment and use of standardized operating procedures and formal methods for maintaining checks and balances (oversight) between the workforce and management. For example, process factors such as operational tempo, time pressures, incentive systems, and work schedules are all factors that can adversely affect safety.

As noted earlier, there may be instances when upper management determine that it is necessary to increase the operational tempo to a point beyond a supervisor's staffing capabilities. Therefore, a supervisor may resort to the use of inadequate scheduling procedures that put mechanics at an increased risk of error. Organizations should have official procedures in place to address such contingencies as well as oversight programs to monitor the attendant risks.

Summary

We believe that integrating MEDA with HFACS improves the outcome of maintenance incident investigations. Because HFACS is currently being used to classify aircrew errors, its combination with MEDA, a proven maintenance error investigation method, offers a single, common system can be used for both aircrew and maintenance errors. The largest benefit of the HFACS-MEDA framework is that we now have an accident investigation process that is based on sound human error theory and two tools that have been validated in the aviation industry.

WHERE TO GET HELP

Boeing (MEDA)
The MEDA system was developed by the Boeing Company and is provided by Boeing to any airline or maintenance organization that requests it. Dr. Bill Rankin is the main human factors contact point at Boeing.

William L. (Bill) Rankin, PhD
Technical Fellow
Lead, Maintenance Human Factors
William.L.Rankin@boeing.com

Federal Aviation Administration (FAA)
There are a number of human factors resources within the Federal Aviation Administration.
www.hf.faa.gov
www.faasafety.gov

A direct link for aviation maintenance is the Senior Scientific and Technical Advisor for Human Factors in Aviation Maintenance.

Dr. William B. (Bill) Johnson, PhD
Senior Scientific and Technical Advisor for
Human Factors in Aviation Maintenance
bill.johnson-dr@faa.gov

HFACS
The HFACS taxonomy was developed by Drs. Scott Shappell and Doug Wiegmann. The main contact for questions related to HFACS is Scott Shappell at Clemson University.

Scott A. Shappell, PhD
Professor
Department of Industrial Engineering
Clemson University
HFEng@clemson.edu

Human Factors and Ergonomics Society

The HFES is the only organization in the United Stated dedicated specifically to the Human Factors profession. The HFES was formed in 1957 and typically maintains about 5,000 members. It includes a Technical Interest Group on Training. The organization headquarters is in California.

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EXAMPLE SCENARIOS

Combining Error Sources

You are the Director of Maintenance Safety in your organization's Safety Management System (SMS). As such, you are responsible for investigating all maintenance errors that lead to either property damage of injuries to the staff or the public. The Director of Safety for the entire organization has asked you to coordinate your incident investigations, findings, and corrective actions with the Director of Operations Safety. The idea is that all incidents and corrective actions related to either maintenance or operational errors should be embedded in a common, searchable database.

You and your operations counterpart have discussed how you might be able to do this. You keep running into the same issue, namely, the way maintenance errors are classified (using MEDA) is different than the way operational errors are classified. Conceptually, both you and operations director are on the same page. However, you need a practical way to combine the error classifications for maintenance and operations.

Issues

1. Is there anything fundamentally different between operational errors and maintenance errors. That is, can errors from the two different sources be combined, at least in theory?
2. Are the general error categories used in MEDA unique to the maintenance domain?
3. Is there a candidate error classification system that will work for both maintenance and operational errors?
4. Do you lose any value by embedding maintenance errors in a larger error category framework?

Responses

1. No, there really isn't any fundamental difference between maintenance and operational errors. The discussion of human error and of the various causes of human errors in this chapter reveals no disconnect between errors committed by maintainers and those committed by flight crew members.

2. No, MEDA does a very good job of covering the most common classes of errors in the maintenance world, but many of those same types of errors routinely occur in the operational world. To be sure, the precise nature of the errors will differ between maintenance and operations. For example, flight crew members will not likely fail to re-connect a flight control system so it is in an operational configuration. After all, flight crews don't work on the guts of their flight control system. However, flight crews routinely change the settings of various flight control surfaces, e.g., flaps, so they are properly set for a particular flight regime, such as take-off. One operational equivalent of leaving the flight control system in an improper configuration (a maintenance error) is to leave their trim or flaps in an incorrect operational configuration.

3. The combined MEDA/HFACS error classification scheme, as represented by Tables 7-1 through 7-4 is a good candidate for an error classification system that will work for both maintenance and operations.

4. No, you don't lose any value by embedding maintenance errors in the combined MEDA/HFACS system. In fact, you stand to gain a great deal by allowing analysts to work from a common error database that combines both maintenance and operations. The greater coverage of a combined system works in favor of finding error patterns and proactively changing things to prevent future errors.

Applying MEDA

The MEDA investigation process is shown in Figure 7-11. Once an event occurs, an initial investigation must be conducted to determine if mechanic or inspector performance was the cause of the event. If an event can be attributed to mechanic or inspector performance, an interview is held with the person who did the work that lead to the event. The purpose of the interview is to identify the contributing factors to the maintenance system failure and to get ideas from the interviewee regarding improvements that can be made to prevent future, similar system failures. Follow-up interviews may need to be carried out if other staff in the maintenance organization contributed to the system failure, for example, by failing to have ground support equipment available to assist in the task. The data from the Results form can then be added to a database in order to analyze and identify trends in contributing factors, maintenance system failures, and events. Final decisions about which corrective actions will be implemented are typically made by management because the corrective actions can cost money. Any changes that are made need to be communicated to the maintenance techni-

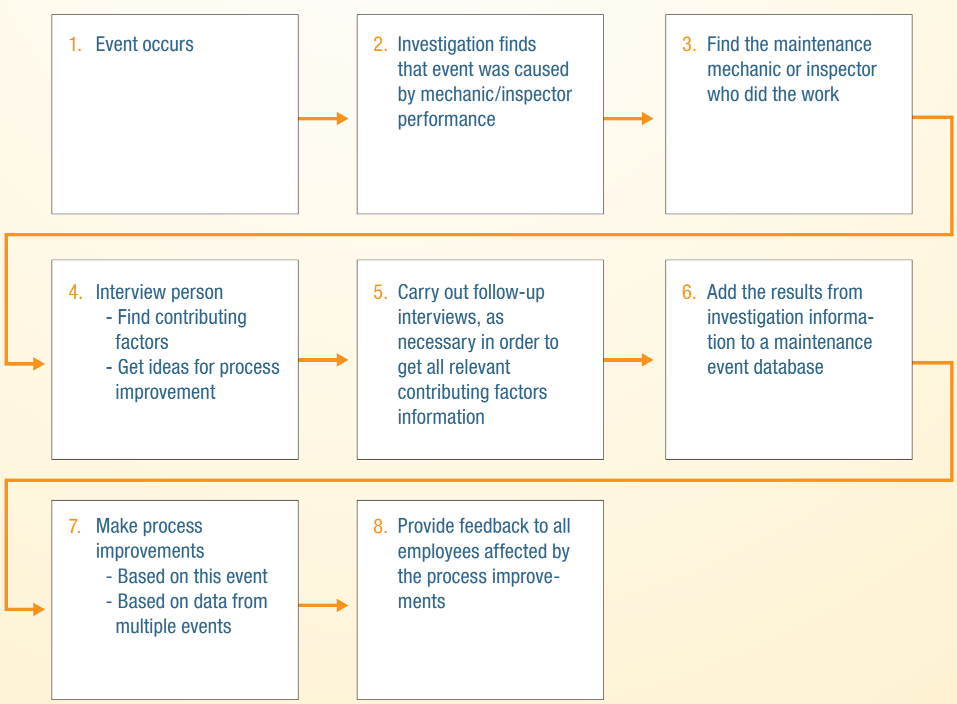

Figure 7-11: *The MEDA Investigation Process*

cians to ensure that the technicians see that the MEDA process is being used to improve the work environment and not two punish the staff.
The MEDA Results Form is divided into six sections:

- I. General Information
- II. Event
- III. Maintenance System Failure
- IV. Contributing Factors Checklist
- V. Error Prevention Strategies
- VI. Summary of Contributing Factors, System Failures, and Event

These six sections are briefly summarized below.

Section I

The General Information section gives the specific details about where and when the event occurred that started the investigation. Boeing provides a digital copy of the Results Form to anyone who requests it. Boeing recommends that the form be modified to best suit the company's needs. This section is the one that is most often modified by the organization..

Section II

Section II of the Results Form can be used to record the event that started the investigation. There are four main categories of events:

1. Operations Process Event—These are events that interrupt the normal process of flying from point A to Point B, like flight delays, gate returns, cancellations, etc.
2. Aircraft damage events
3. Personal injury events
4. Rework—Finding that a task was not done correctly (e.g., through an inspection or functional test), which requires having to do the task a second time.

Section III

In section III, the investigator identifies the maintenance system failure that directly caused the event. This section was previously called the Maintenance Error section. When the concept of violations was added to the MEDA event philosophy, the section name was changed to reflect this. There are seven major categories of maintenance system failures:

1. Installation failure
2. Servicing failure
3. Repair failure
4. Fault isolation, test, or inspection failure
5. Foreign object damage
6. Airplane/equipment damage
7. Personal injury

Within most of these categories, very specific failures are provided—e.g., wrong equipment/part installed. The investigator puts a check mark next to the specific system failure that caused the event, and then writes a brief description of the failure on the form.

Section IV

There are ten categories of Contributing Factors in the Results Form checklist. These categories were used because they are easily understood by maintenance personnel. They include:

A. Information
B. Equipment, tools and safety equipment
C. Aircraft design, configuration, and parts
D. The job or task
E. Technical knowledge and skills
F. Individual factors
G. Environment and facilities
H. Organizational factors
I. Leadership and supervision
J. Communication.

Each of these categories has finer breakdowns of contributing factors. During the MEDA interview, the investigator puts a check mark by a specific contributing factor (or "other" if it is not listed). Then the investigator is asked to describe specifically how the contributing factor contributed to the system failure. If the contributing factor category is not causal to the system failure, then the investigator is to check the "N/A" space next to the category. More information on each category of contributing factor can be found in the User's Guide.

Section V

This section is divided into two parts. Part A is used to identify organizational barriers that failed to prevent the event. The second part of this section asks the investigator to recommend strategies to improve the contributing factors. This list is developed by the MEDA investigator and interviewee during the MEDA investigation/interview.

Section VI

The final section of the Results Form is used to summarize the contributing factors, system failures, and the event. This section was not on the original MEDA Results Form, and was added at the request of MEDA users.

MEDA Interview Process

Listed below is an outline of how to carry out the interview to collect the contributing factors information. A more in-depth discussion is provided in the MEDA User's Guide.

1. Team leader introduce the interview team.

2. Ask the interviewee if they know anything about the MEDA process.

    a. If the interviewee says "no," then give a somewhat in-depth explanation of MEDA.

    b. If the interviewee says "yes," still give a brief explanation of MEDA.

3. Then the team leader should begin the interview by asking the interviewee to tell their story about what happened. Say something like, "Would you please tell me what was happening before and during the time you were doing the maintenance task."

    a. Do not interrupt the person while they are telling this story, unless they get off the topic. Then gently guide them back to telling their story.

    b. Encourage them to keep talking by saying something like, "Can you think of anything else?" or "Anything that you can add to your story?"

    c. While they are talking, listen for them to mention contributing factors, and write this information down in the appropriate contributing factors category on the MEDA Results Form.

4. After they have told their general story, then ask specific questions about the contributing factors that they mentioned. Use the para phrase to do this. A paraphrase begins with "I think that I heard you say that (such and such was a contributing factor), please tell me more about this."

5. Respond to their statements in a positive manner. Say such things as,

    a. "I know what you mean."
    b. "I have done that myself"
    c. "Sometimes those procedures are hard to understand and follow."
    d. "I agree with you, that is an error-prone task."

6. Do NOT asking "leading" questions like

    a. "At that point you probably asked for help, didn't you?"
    b. "Then you probably did…"

7. Do NOT say things that would put the interviewee on the defensive, such as:

    a. "You did WHAT?!?"
    b. "I can't believe that you did that."

c. "You didn't use the calibrated tool for that task?"
d. "A good mechanic would not have done that."

8. TRY not to ask questions that can be answered with a simple "yes" or "no" response. However, this is hard to do, especially when you go through the MEDA contributing factors categories toward the end of the interview.

9. Go through the remaining contributing factors categories that have not yet been discussed during the interview.

10. Then get the interviewee's input on how to improve the contributing factors that were uncovered during the interview. Write them down in Section V.B.

11. Thank the interviewee and promise to get back to them with feed back on the improvements that will be made.

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CHAPTER 8:
HUMAN FACTORS TRAINING

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LANDING PAGE

Aviation maintenance programs are built on a foundation of extensive training for AMTs and Engineers. Licensed Aviation maintenance technicians (in the U.S.) and Certifying Engineers (in other countries) undergo in-depth training related to the tasks they perform as part of their jobs. For the past 15 years, or so, there has been an increasing emphasis on the human factors aspects of aviation maintenance. The primary human factors topics, which are discussed in other parts of this Guide, include general knowledge of human factors, human error, fatigue, facility design, procedures, shiftwork, ethics, and the programmatic aspects of human factors.

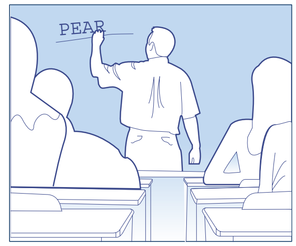
As regulatory and maintenance organizations have become more aware of the human factors aspects of aircraft maintenance tasks, the concepts, methods, and empirical knowledge of human factors have made their way into the AMT training curriculum. Non-U.S. regulatory agencies have taken the lead in this regard, but the FAA will eventually incorporate human factors into the training curriculum required for AMT certification. These training components will become more relevant and critical as airlines and maintenance organizations implement safety management systems (SMS) in compliance with International Civil Aviation Organization (ICAO) requirements.

This section of the Human Factors Guide describes the basis for human factors training in the aviation maintenance domain. It also provides guidance regarding the most important factors associated with “good” human factors training.

INTRODUCTION

Human factors training programs are hardly new. It is generally agreed that Continental Airlines established the first training program in about 1990, known as Crew Coordination Concepts (CCC). As the concept evolved, US Airways (then US Air), with cooperation of FAA, adopted the CCC approach, restructuring and renaming it Maintenance Resource Management (MRM). The name, MRM, aligned the new maintenance training with the growing success of the flight operations Crew Resource Management. As the programs evolved, institutions quickly recognized that the human factors training initiatives would be successful only as they expanded throughout the organization.

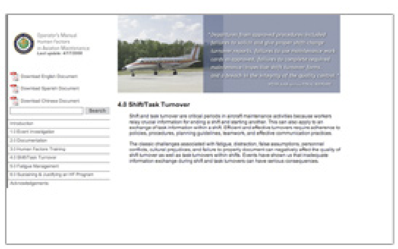
Since 1989, FAA has sponsored an extensive maintenance human factors research program, and has sponsored and co-sponsored 20 major industry conferences on human factors in maintenance and inspection, adding ramp safety in 2006. The majority of the research reports and conference proceedings are available at the FAA human factors website www.hf.faa.gov.

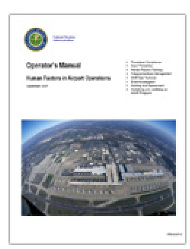


In general, maintenance organizations are determined to meet or exceed regulatory training requirements. However, their primary goal is to design and deliver cost effective training that will enhance human performance, increase quality, and reduce errors. In an attempt to satisfy these objectives organizations address the following questions (and others):

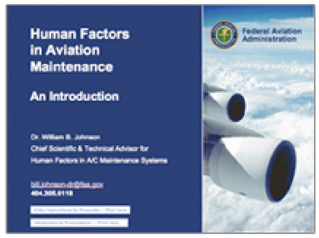
- How do I ensure that my training will be acceptable to my national regulatory authority?
- To whom must the training be delivered?
- What are the key topics that I must cover?
- How do we ensure that the training is matched to our company needs?
- How much is enough?
- What training techniques are most applicable?
- Who should deliver the training and how can we qualify the trainers?
- How do we select an outside provider if we choose to do so?
- How can we cost justify the training?

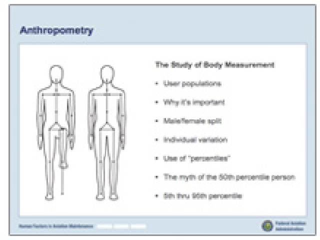
The FAA and the aviation maintenance industry have worked together to produce a number of guidance documents that include the topic of human factors training. In 2005, FAA teamed with industry to publish the *Operator's Manual for Human Factors in Maintenance*. In 2007, another FAA-industry team published the *Operator's Manual for Human Factors in Airport Operations*. Both of these short "how to' manuals address training and are available on the FAA website.





In 2007 – 2008, FAA created the Maintenance Human Factors Presentation System (MHFPS). Distributed via DVD, the MHFPS is a tool to deliver human factors training. It is comprised of 170 PowerPoint slides, 40 animations, and 11 short videos. An address to obtain the MHFPS is on the FAA human factors website, or simply contact the author.





This chapter is not a theoretical treatment of either the fundamentals of training development or maintenance human factors. Instead, it describes the most relevant issues related to initial and recurrent maintenance human factors training. We suggest the use of the instructional systems development (ISD) process. However, the chapter is based on many current time-tested human factors training programs and does not suggest that readers reinvent human factors in order to establish and continue an effective program.

REGULATORY REQUIREMENTS

The regulations of one's National Aviation Authority (NAA) are often the starting point to define the minimum human factors training requirements. After all, the organization must be in compliance, so this is a reasonable primary information source. With proper attention to accepted practices of instructional design and delivery, the NAA mandates are sufficient to ensure the existence of high value human factors training.

There is no doubt that the presence of regulations affects the implementation of human factors programs. A 2006 international survey showed that the most robust and extensive maintenance human factors programs were in the countries where it was a regulatory requirement.

The international regulations on maintenance human factors training vary. Some countries have requirements for teaching general human factors knowledge and specific training for initial mechanic/engineer certification; introductory training for all maintenance workers and managers; and recurrent training for everyone. That is the case with Transport Canada, the European Aviation Safety Authority (EASA), the Civil Aviation Safety Authority (CASA) in Australia, and other NAAs. Currently, the US FAA does not have mandates on initial or recurrent human factors training. Table 8-1 shows a listing of the human factors training requirements for some NAAs and their regulation references.

Table 8-1. Comparison of maintenance human factors training requirements

	FAA	EASA	Canada
Regulation	None	• Part 66 • Part 145 (Part 147) (only within approved basic training. All other HF trainings could be performed by 147, or 145, or own personnel, or contractors, or, or, or)	STD 566 CAR 573.06, STD 573.06
Required Hours	None	Not specified. Based on approval of the individual training course. (Within approved basic training usually 2—3 days.) *CAP716 recommends 3 days for initial training and 1 day for continuation training	16 Initial
Continuation Training	None	• Must undergo continuation training before 24 months elapse • Must be of sufficient duration and based on a program acceptable to Authority.	• Update training is performance based and determined by the organization in accordance with an approved cycle. Usually not to exceed 36 months. • Additional training as required determined by quality assurance program findings.
Guidance Documents	Ops Manuals HF Guide AC120-72 8300.10 HBAW 05-04	•CAP 716 • AMC 145.A.30(e) • GM 145.A.30(e) • ICAO HF Digests and Training Manual.	• HPIAM: TP 12863 Human Factors for Aviation **Basic Handbook**, Printed Publication • TP 12864 Human Factors for Aviation **Advanced Handbook**, Printed Publication • TP 12865 Human Factors for Aviation **Instructor's Guide**, Printed Publication • FRMS: TP 14572, TP 14273, TP 14574, TP 14575, TP 14576 & TP 14578

In this global aviation environment, organizations typically follow the strictest of the applicable regulations. This means that a large portion of the world, including about 30% of US maintenance organizations, usually comply with the rules of EASA. As a result, the large organizations throughout the world are essentially working under the EASA regulations. Of course, the same regulations may evolve to international harmonization over time.

In 2000, FAA published Advisory Circular (AC) 120-72 Maintenance Resource Management Training. This document remains relevant today. While some of the terminology has changed, the fundamentals of maintenance human factors training programs have not. The FAA Advisory Circular is complemented by an extensive document published by the Civil Aviation Authority (CAA) of the United Kingdom in 2003, entitled CAP 716. This UK document offers guidance on training programs as well as all aspects of human factors programs for maintenance. Both documents are "required reading" for those working in maintenance human factors.

CONCEPTS

The following concepts are but a small subset of those related to training program development. However, we are not attempting to provide a detailed "how to" guide for training development. These concepts will help readers understand the discussion in this chapter.

Curriculum

A curriculum is simply a list of topics that will be covered in a training course or even an entire training program. For example, there is an established curriculum for training people to become AMTs.

Dirty Dozen

In the 1990s, Transport Canada introduced a list of the most common sources of errors in aviation maintenance. This list is known as "The Dirty Dozen" and it has been widely distributed in the aviation maintenance community. Table 8-2 is a list of the Dirty Dozen, and includes a brief explanation of each cause for error.

Table 8-2. The Dirty Dozen

1. Lack of communication	**7. Lack of resources**
The exchange of information that conveys meaning between two or more people. Lack of communication often leads to misunderstandings and the results could be catastrophic.	Failing to use or acquire the appropriate tools, equipment, information, and procedures for the task-at-hand. Lack of resources or misusing resources has been linked to many accidents or incidents.
2. Complacency	**8. Pressure**
Self-satisfaction accompanied by a loss of awareness of the dangers. This often happens when doing familiar, repetitive work.	Pushing for something, in spite of opposing odds, or creating a sense of urgency or haste. This factor is most prevalent when deadlines approach or when trying to meet a tight schedule.
3. Lack of knowledge	**9. Lack of assertiveness**
Insufficient experience or training in the task-at-hand. It is easy to see how lack of knowledge could lead to an error or an accident. Often lack of assertiveness plays a part because people do not like to admit they do not know something.	Failing to behave in a self-confident manner. Lack of assertiveness has been identified as a link in the chain of events for many accidents.
4. Distraction	**10. Stress**
One's attention is drawn away; mental or emotional confusion or disturbance occurs. When working among many people, with frequent work interruptions, or when coping with stress, it is easy to become distracted.	Mental, emotional, or physical tension, strain, or distress. Stress is not inherently good or bad; how one handles it determines its impact on the individual. Stress is very difficult to measure objectively.
5. Lack of teamwork	**11. Lack of awareness**
Failing to work together to achieve a common goal. Lack of teamwork creates an unhealthy environment in terms of personal dissatisfaction and group disconnect.	Failing to be alert or vigilant in observing. Lack of awareness of the work situation or your surroundings often results in error or injury to yourself or others.
6. Fatigue	**12. Norms**
Weariness from labor or exertion, nervous exhaustion, temporary loss of power to respond. Shift work can have an enormous physical impact, but there are ways to combat fatigue. For example, sleeping and exercising regularly, avoiding complex tasks at the bottom of the circadian rhythm, and asking others to check the work.	Unwritten and, often, unspoken rules about how work is done. Always work according to the instructions. If norm are actually a better way to do things, change the instructions so norms become part of the approved procedures.

Initial Training

Initial training is provided for students who have had no previous training on the particular topic. Often, initial training consists of an introduction to the fundamental concepts and methods of human factors.

Learning Objectives

In a top-down training development process, such as Instructional System Development (link to ISD, below), the starting point for deciding what material goes into the training course is identifying what students should know or be able to do when they complete the course. These elements are called learning objectives, i.e., the objectives of taking the course is to be able to know or do them at the end.

Recurrent Training

As its name implies, recurrent training, is given after the initial training is completed. It can be "refresher" training, which is a condensed version of initial training, or it can expand the initial training to cover a broader range of material or to delve deeper into specific subject matter. The term "recurrent" implies that this type of training is taken on a periodic basis, not just one time. Recurrent training is sometimes called "continuation" training, since it can be viewed as a continuation of the initial training.

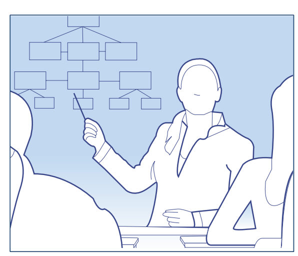
Train the Trainer

This is a common term in the training world. It simply means bringing an individual up to a level of knowledge and skill that permits him or her to teach others the subject matter of a course. For human factors training in aviation maintenance, the "trainer" who is being trained to teach the course(s) is often, but not always, an instructor who has experience teaching non-HF material.

METHODS

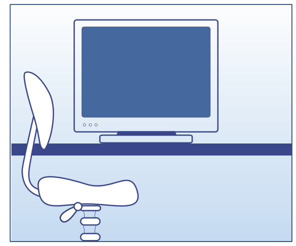
Classroom Instruction

Classroom instruction is what most people envision when they think of training. Typically, classroom instruction involves one, or more, instructor standing in front of the students. The majority of human factors training is delivered in the classroom. In many cases, the human factors training classroom is arranged in a circle or around conference tables. Such seating arrangement promotes discussion. Most classrooms also need some way to break into small groups.



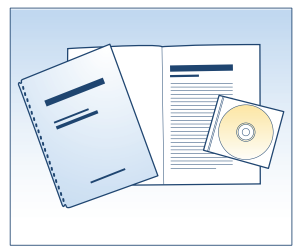
Computer-Based Training (CBT)

Computer-based training can take many forms, but always involves students interacting with either an instructor or pre-programmed training modules via a computer. There are a few international computer-based training offerings. In most cases, the CBT is used for the initial delivery of declarative knowledge and initial fundamental proficiency testing. It is usually accompanied with a day or more of group interaction with the human factors trainer.



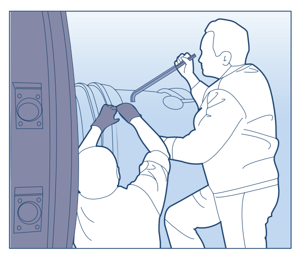
Instructional System Development (ISD)

ISD is a top-down process that systematically identifies learning objectives, supporting knowledge and skills, and instructional methods. The end product of ISD is typically a course syllabus, lesson plans, and supporting materials, such as handouts, videos, etc. A good source of information on structured training program development can be found in Advisory Circular 145-10.



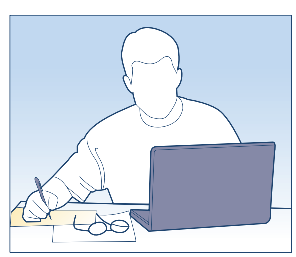
On-the-job Training (OJT)

As the name implies, on-the-job training, or OJT, is accomplished while the student is working on real maintenance tasks. Typically, OJT consists of assigning a student to a mentor, i.e., an experienced AMT/Engineer. The mentor (trainer) demonstrates how to perform specific tasks and monitors the student's progress until they reach the required level of proficiency. The usefulness and efficiency of OJT depends almost entirely on the ability of the mentor to teach the student the required knowledge and skills.



Remote Learning

The simplest definition of "remote learning" is any type of instruction that does not occur in a classroom or on the job. Usually, remote learning involves using computers and video links to build a virtual classroom. Remote learning typically allows participants to engage an instructor via a voice or video chat link, to see and hear an instructor giving lecture presentations (complete with white board and PowerPoint presentations), and to take part in class discussions. This training method is not (currently) used extensively in the aviation domain.



GUIDELINES

The information in this section of the chapter is meant to be practical, not theoretical. The individual guidelines have been derived from long experience in the aviation maintenance-training domain.

Teach the Sources of Human Error

There is general agreement that human error is the primary or a contributing factor in 80% (or more) of major accidents. People routinely commit errors that result in injuries, damage to equipment, regulatory non-compliance, breaches of flight safety, and more. The goal of human factors training is to help workers recognize the situations that can lead to error, see them as contributing factors, and identify the corrective actions that reduce the likelihood of error.

Some human factors trainers have used the PEAR model to show the major categories of factors that contribute to human error. Regardless of whether the PEAR model is used explicitly, the factors contained in the PEAR categories must be addressed in training. The PEAR model is more fully described in Chapter 1. Figure 8-1 shows an overview of the PEAR categories.

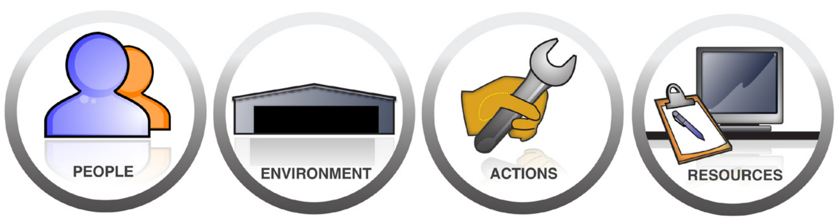


Figure 8-1: *The PEAR model*

P stands for People. It includes factors such as fitness for duty, physical characteristics, certification, and the mental and skill requirements necessary to complete the task. E stands for the work Environment, which includes both physical social, and organizational factors. The A represents all of the Actions necessary to complete a maintenance task, and R indicates the resources necessary to complete the job.

A lot of fundamental science related to human error underlies models like PEAR or concepts like the Dirty Dozen. However, aviation maintenance human factors training is best when delivered in plain language with straightforward concepts that can be applied at work.

Necessary Elements for Successful Human Factors Training

Each organization designs and implements a slightly different human factors training program matched to their specific challenges and corporate culture. However, there are common elements of successful human factors training across the industry. Examples of these common elements include:

- Senior management support
- Training for everyone
- Reporting and managing error
- Continuous communication and feedback

Senior management support. The foundation of any successful organizational program is senior management support. Senior managers must have the vision and commitment to reduce maintenance errors and increase safety with sustained attention to maintenance human factors issues. When top decision makers clearly support the mission and purpose of human factors programs, a positive organizational culture change is more likely. Without such a commitment, a pervasive organizational change is unlikely.

Training for everyone. Human factors training must extend across all the levels of an organization. It cannot be limited to certificated or return-to-service personnel. It must extend from the cleaning crew to the responsible executive of the organization. In fact, this is a requirement in the EASA and Transport Canada regulations (See EASA GM AMC 145.A.35 (e) 6).

Experience has shown that it is the middle managers and supervisors—often evaluated by their ability to control costs and on-time performance—who often become the weak links in the application of human factors programs. For that reason, their training requirement is equal to that of all other workers. These individuals interact daily with the workers who are ultimately responsible for carrying out the new strategies. Mid-level managers also need the support of upper-level management in applying the new human factors approaches in the field. With proper training, middle managers are more likely to use their understanding of human factors to push and manage a cultural change.

Reporting and managing error. If human factors training is going to be effective at reducing errors, workers must be able to transfer the concepts and language of the training directly into the workplace. Chapter 7 (need link here) discusses event investigation tools like Boeing's Maintenance Error Decision Aid (MEDA), the importance of voluntary reporting, and a "just culture." The industry acceptance of the FAA's Aviation Safety Action program (ASAP) is another excellent source of information. Note: Need link to ASAP here http://www.faa.gov/safety/programs_initiatives/aircraft_aviation/asap/. Peer observations/audits of normal performance are another high value means to identify opportunities to identify not only positive actions but also actions that can be improved.
Maintenance human factors training is successful when workers are able to recognize the challenges associated with PEAR or the Dirty Dozen and report these in a proactive manner. The total human factors program is successful only when management makes and tracks changes based on workers' reports.

Continuous feedback. Incorporating human factors into the fabric of an aviation maintenance organization is usually a cultural change. Continuous communication and feedback must occur in order to sustain the change process. Several communication channels exist to distribute the results of human factors training programs. These include newsletters, group meetings, person-to-person discussions, public bulletin boards, e-mail, etc. The idea is to provide managers and workers with information on the type of actions occurring in the workplace and their effect on the company's overall performance (i.e., quality, safety, dependability). (Link here to the Communication chapter.)

The Human Factors Trainer

Who should deliver human factors training? That is a question without a set answer. The primary concerns regarding human factors trainers center on the professional, academic, and maintenance experience of the potential instructor. For example, should the instructor have a college degree in psychology or human factors, an A+P (engineering) certificate, a minimum number of years of maintenance experience, extensive teaching experience, or some combination of these qualifications? There is no precise answer. In lieu of listing prerequisites for a human factors instructor it is better to describe what the instructor must be able to do.

Instructors should understand the aspects of human factors by embedding them into all the training curricula. To accomplish this, instructors must—

- Be able to garner attention and respect based on their ability to communicate human factors topics clearly and effectively.
- Demonstrate and communicate an applied understanding of fundamental human factors principles as they apply to aviation maintenance work environments.
- Demonstrate credibility as a human factors instructor based on academic credentials, maintenance certification, working experience, teaching experience or a combination thereof.
- Have excellent communication and motivational skills; be able to effect attitude changes; and impart knowledge.
- Follow instructional plans and procedures and adapt the plans based on audience requirements.
- Be able to promote and lead interactive classes using industry "lessons learned" relative to the subject matter, including associated costs and personnel injuries.
- Debrief students after practical examinations. Openly discuss mistakes and potential ramifications along with how to avoid these traps on-the-job.
- Advocate the training department's knowledge, experience, and lessons learned to other departments throughout the organization.

Training the Trainer

Maintenance human factors trainers should have taken formal courses in the art and practice of being a teacher. They should also have taken one or more formal maintenance human factors courses. Any aircraft systems instructor is prepared to discuss far more about an aircraft than the information in the course syllabus. This should also be true for the human factors instructor. The trainer must be able to add value to the prepared script and be able to answer unexpected inquiries.

There are many human factors courses offered by training companies, colleges, and universities worldwide. There are also many human factors symposia that help prepare attendees to develop a broad understanding of human factors programs and procedures. It is unlikely that a trainer can be fully prepared without the benefit of such outside resources. The company must make the commitment to ensure that the external training happens.

Instructors should be strongly competent as trainers and as human factors practitioners. They should also know (or learn) something about the actual operations in maintenance organizations. Instructors learn a lot about aviation maintenance as human factors trainers. However, they should also learn as much as possible about maintenance prior to the first class.

An effective way to prepare human factors trainers is to permit them to co-teach a number of classes in advance of teaching the class alone. For human factors training programs, co-facilitation is a luxury that provides the opportunity for two representative workers to actively present and facilitate the instructional process.

Experience using two instructors has shown it is best when mechanic/engineers co-facilitate with human factors experts. Together, they can be a dynamic team representing a valid combination of knowledge and work experience. Additionally, they can respond to course participants with examples and scenarios that demonstrate the human factors concepts being presented. After a few classes, the respective parties are able to enhance their strengths in both human factors and maintenance.

While a two-instructor class is ideal to qualify instructors, it is also expensive. Some training companies insist on “co-facilitation” of human factors classes. Each company or training system provider must decide what arrangement of instructors works best for their situation. In most cases, one qualified instructor is sufficient.

Human Factors Training Curriculum

Educators and professional instructional designers rightfully argue that a company should conduct job and task analyses to determine the contents on a human factors course. With respect to maintenance human factors that may have been true in the early 1990s. Since then, there has been significant research, development, evaluation, and evolution regarding content and training design for maintenance human factors. In fact, many regulations and guidance materials list the general areas that an initial class must include.

Before deciding what the training curriculum should include, a company must differentiate between initial and recurrent training. Initial training, as described in EASA Part 66.9.1 (Human Factors) and Transport Canada Part V, Standard 573.05, is typically required for certification as an AMT or Certifying Engineer. The curriculum for initial training tends to be much broader than that for recurrent training. In recurrent training, it is possible to assume that the participants will already have a general working knowledge of human factors concepts, methods, and data.

Maintenance human factors experts and regulatory agencies, including the FAA and EASA, have identified the following key topics that are likely to be included in a training program. The FAA Operator's Manual for Human Factors in Maintenance (Note: Put in a link to the Ops Manual) also includes this list and a discussion of these topics.

- General/introduction to human factors
- Safety culture/organizational factors
- Human error—error principles, event investigation and case studies
- Human performance and limitations
- Fatigue management and general fitness for duty
- Environment—physical and social
- Procedures, information, tools, and task sign-off practices
- Planning of tasks, equipment, and spares
- Communication
- Teamwork and leadership
- Professionalism and integrity
- Shift and task turnover
- Undocumented maintenance
- The 12 common human errors (Required by Transport Canada Part V, Standard 573.05)

An organization should select topics from the list above based on its requirements. The Safety Management System (SMS) and data from various event-reporting systems define the needs. The essence of a human factors training program is as much about how to select the content as it is about the delivery methods. Defensible training program design will help ensure compliance with the NAA and other appropriate regulators.

Cost Justification of Training

The FAA Operator's Manual for Human Factors in Maintenance offers a chapter on cost justification of human factors programs. The chapter recognizes that it is very difficult to match a specific intervention to a specific prevention. It offers a plan to show how one small intervention at a time contributes to a significant safety impact and cost reduction.

WHERE TO GET HELP

Aeronautical Repair Station Association
www.arsa.org

Embry-Riddle Aeronautical University
http://amelia.db.erau/hfami/index.html

European Aviation Safety Agency (EASA)
www.easa.eu.int

Federal Aviation Administration (FAA)
There are a number of human factors resources within the Federal Aviation Administration.

www.hf.faa.gov
www.faasafety.gov

A direct link for aviation maintenance is the Senior Scientific and Technical Advisor for Human Factors in Aviation Maintenance.

Dr. William B. (Bill) Johnson
Senior Scientific and Technical Advisor
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Human Factors and Ergonomics Society
The HFES is the only organization in the United Stated dedicated specifically to the Human Factors profession. The HFES was formed in 1957 and typically maintains about 5,000 members. It includes a Technical Interest Group on Training. The organization headquarters is in California.

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EXAMPLE SCENARIO

You are the Training Manager for the maintenance division of a European airline. The Technical Operations Quality Manager of an organization that holds an EASA 145 certificate tells you that it is about time to develop new recurrent training related to Human Factors for the up-coming EASA audit, which will occur in a few months. You ask two of your most experienced trainers to look over the current course offerings, suggest a new recurrent training course, and then develop it. You give them two weeks to do the needs analysis and then make recommendations for the new course.

The two trainers come back to you with the following observations and recommendations:

- The initial 2-day HF training course seems to be adequate. End-of-course evaluations have been positive and the trainers have received e-mail from mechanics relating human factors stories from the hangar floor. The trainers have incorporated some of these stories into each class. They want to broaden the scope of the curriculum for the new recurrent training class.

- Their search of the regulations brought them to EASA Part 145.A.35 (d), which covered continuation training. The continuation training has to take place every two years and has to cover, at a minimum, a) relevant technology, b) organizational procedures, and c) human factors. They found that there are no specific minimum time requirements for delivery as long as it is within the 24-month period. The training has to be delivered to all personnel within the maintenance organization, from sweepers to the Accountable Executive.

- This "relevant technology" and "new procedures" sections of the EASA regulations are already being adequately addressed by existing training. There is no continuation training for human factors, so the recommendation is to concentrate on human factors in the new course. They recommend that the continuation training should review human factors fundamentals, give the students human factors memory joggers, and review the lessons learned from recent events in the company or the industry

- They recommend that the new continuation course be a total of 4 hours long, delivered in two 2-hour segments over a two-week period.

The remaining issues relate to how the new training program can be efficiently developed.

While searching Google the trainers find the FAA's new (2008) Maintenance Human Factors Presentation System (MHFPS) and send an e-mail requesting the DVD. The MHFPS gives the trainers a pre-developed human factors training presentation. It contains 170 PowerPoint Slides that can be modified to show their company name and image. The system also has 40 animation files and 11 FAA videos that can be used for discussion.

They use the MHFPS to talk about human error, fatigue, and a unique way to look at maintenance human factors at work and at home. The MHFPS introduces the class to the PEAR model. PEAR is an acronym that encompasses people, the environment in which they work, the actions they perform, and resources necessary to perform the work. The PEAR categories are then integrated into the event discussions.

The end result is a success. The students like the class. Management likes the content and the scheduling flexibility. The FAA-EASA audit team really appreciates that the company chose the FAA software and modified it to meet their specific training requirements. Your trainers have made you look very good.

The trainers continue to work diligently at their current aviation employer. However based on their recent success as instructional designers and human factors trainers they are now checking Monster.com to find safety jobs in a more economically secure industry.

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CHAPTER 9: WORKPLACE SAFETY

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LANDING PAGE

Aviation maintenance workers are keenly aware that their jobs revolve around the necessity for keeping the flying public safe. They devote their lives to ensuring the airworthiness of the aircraft in their care. Because of the constant emphasis on public safety, it is easy to lose sight of the requirement for personal safety.

Statistics maintained by the U.S. Department of Labor and the National Safety Council (NSC) indicate that workplaces can be very dangerous. While aviation maintenance workplaces do not seem to be significantly more dangerous than many other types of work environments, all of the elements are present to cause or permit serious injuries. These include working with heavy parts, working at heights, using toxic chemicals, working in all kinds of weather, working at night, working around turbine engines, propellers, etc.

In this chapter, we discuss the major human factors issues related to aviation workplace safety. Our focus here is the safety of the workers themselves, not equipment airworthiness, although these two issues are directly related.

INTRODUCTION

Supporting and enhancing the continued safety of the flying public underlies nearly all training, regulation, and working procedures in the aviation industry. Most of this emphasis, however, is placed on the airworthiness of equipment and crews. Safety is also relevant to the maintenance workplace. The aviation maintenance system is not safe until the maintenance workers are safe.

Workplace injuries have both human and monetary costs. We sometimes tend to lose sight of the pain and suffering, psychological and family stress, lifestyle and quality-of-life adjustments, and career-shortening implications of workplace injuries. These points are brought into sharp focus whenever those injured in workplace accidents recount their experiences

Workplace injuries also increase operating costs and reduce efficiency and effectiveness. Additional costs may arise from Workers' Compensation or health insurance claims or premiums, from regulatory fines, from lawsuits, from labor grievances, and from increased investigative or training requirements.

In this chapter, we discuss the major human factors issues related to aviation workplace safety. Our focus here is the safety of the workers themselves, not equipment airworthiness, although these two issues are directly related.

REGULATORY REQUIREMENTS

Workplace safety traditionally has not been a primary concern of the FAA, except where unsafe working conditions might also affect the safety of aircraft or crews. The Federal Aviation Regulations (FARs) contain no rules related directly to workplace safety. In the FAR description of the certificate holder's Operations Manual [Part 121.135 (a)(1)], an ambiguous statement requires that the Manual "Include instructions and information necessary to allow the personnel concerned to perform their duties and responsibilities with a high degree of safety…". It is not clear whether this requirement refers to the safety of the maintenance workers, the safety of aircrews and the flying public, or is inclusive.

The locus of responsibility for the safety of aircraft maintainers is not clear-cut. OSHA ordinarily would be the federal agency responsible for such safety matters. However, OSHA generally defers to other federal agencies that oversee groups of workers. When Congress created OSHA in 1970, they excluded, without direct reference, any group under the jurisdiction of another federal government agency, including the aviation industry under the FAA. Many of these otherwise excluded organizations have worked with OSHA anyway, especially in the area of workplace safety.

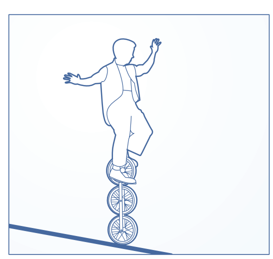
CONCEPTS

Accident Proneness

Accident proneness suggests that certain individuals are involved in more accidents than others because of some innate predisposition. This concept has been generally discredited in the safety community. It is attractive to many people in positions of responsibility because it implies that people involved in accidents are completely culpable for their own injuries. In fact, accidents occur because of inadequate design, poor preparation, or personal limitations, not because of individual predisposition.

Compliance

To be "in compliance" means that one acts in accordance with all applicable rules and standards. This is necessary, but not sufficient in all cases, to prevent accidents and injuries. Rules and standards often represent minimum requirements or may be restricted to a narrow scope. Advances in technology or changes in working procedures may outdate them



Consensus Standards

All the major groups that would be affected by a “consensus” standard must agree to the standard’s content. In fact, many of the people who write the standards are typically employed by organizations that will be affected by the standards. Organizations may not want to allow standardized requirements that jeopardize their business practices. Thus, consensus standards are likely to represent the lowest common denominator among its developers and may or may not be technically adequate.

Criterion-Based Standards

Criterion-based standards require that certain strict, rigid, and objective criteria be met in order to be in compliance. Certain OSHA standards, such as those that specify Threshold Limit Values for certain toxins, are criterion-based. Contrast these standards with performance-based standards.

Dangerous

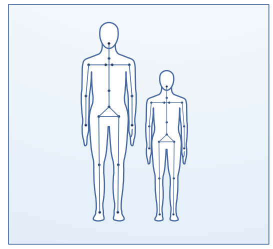
Dangerous means risky, hazardous, or unsafe. In the safety profession, situations, tools, or other elements can be either of the following:

- Imminently dangerous—impending or immediate risk of harm, such as a bare electrical cord
- Inherently dangerous—dangerous by their nature, such as poi sons or explosives, but might not pose an immediate risk of harm.

“di minis” Violation

Regulatory agencies do not treat all rule violations equally. A “de minis” violation occurs when there is non-compliance with a rule or standard, but that violation doesn’t immediately or directly affect a person’s safety or health.

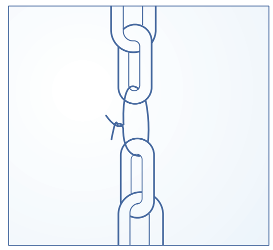
Design for the Individual



While we are used to thinking in terms of "averages," there really are no average people. Each person has different body dimensions, strength, abilities, and limitations. The human factors design and evaluation processes consider these individual requirements. A safe work environment necessarily considers the safety of each individual worker.

Failure

Failure is a general term that means the inability to perform an intended task or function. Any system component—human, procedural, or automated—can fail. In the systems view of aviation maintenance, the maintenance process is only as reliable as its weakest component. Even the failure of a seemingly unimportant element can cause the overall system failure.



Failure Management

To paraphrase a bit of commonly accepted wisdom, "Stuff happens!" Over the life of a system, certain failures are likely to occur. Failure management is the process of planning, setting policies, and making decisions that identify and eliminate (or control) potential failures and implementing corrective or control procedures after actual failures.

General Duty Clause

General Duty Clause refers to a comprehensive requirement in the OSHA regulations for every employer to provide work and a workplace free from recognized hazards. This is meant to put employers on notice that they have a general duty regarding their workers' safety.

Hazard

A hazard is a dangerous condition that can interrupt or interfere with the expected, orderly progress of an activity. The Department of Defense recognizes four classes of hazards.

- Negligible—will not result in injury to people or serious damage to equipment
- Marginal—can be controlled to prevent injury or damage
- Critical—will cause injury or serious damage (or both)
- Catastrophic—will cause death to workers.

Human Reliability

The essence of the concept of reliability is repeatability. If something is reliable, it can be counted on to do the same thing over and over in the same manner. The opposite of reliability is variability. Humans are notoriously variable. We tend not to do the same thing twice in the same manner or like another person. While we prize our individuality, the major cause of human error is human variability.

Job Safety/Hazard Analysis

Job Safety Analysis (JSA), or Job Hazard Analysis (JHA), is a technique used to determine the hazards connected with a job or task. It is used to develop controls for these hazards and to devise the requirements or qualifications of those workers who will perform the job or task. JSA/JHA reduces the job or task into subtasks or activities for analysis.

Loss Control

Loss Control is the name given to a range of programs designed to minimize accident-based financial losses. Insurance companies often mandate loss control programs, which are usually some combination of on-site, checklist inspections and an analysis of "near misses" (see Critical Incident Technique).

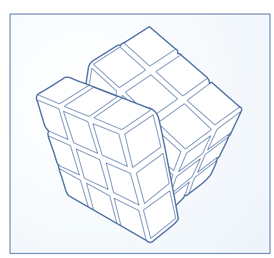
National Institute for Occupational Safety and Health (NIOSH)

NIOSH is the sister agency to OSHA located in the Department of Health and Human Services. Both NIOSH and OSHA were created at the same time. NIOSH does not directly develop rules or regulations but is responsible for research into the causes of and cures for occupationally caused injuries and illnesses. OSHA may require extensive technical assistance from NIOSH in the form of Health Hazard Evaluations when the causes of health or safety problems are unknown or complex.

Occupational Safety and Health Administration (OSHA)

OSHA is the federal agency created by the Occupational Safety and Health Act of 1970. Located in the Department of Labor, OSHA is responsible for establishing and enforcing federal workplace safety and health standards. Many states administer their own occupational safety and health programs. This is allowed under the Occupational Safety and Health Act, so long as these state-run programs meet or exceed federal standards. OSHA standards are published in the Code of Federal Regulations (CFR), Section 29, Subsections 1910-1926.

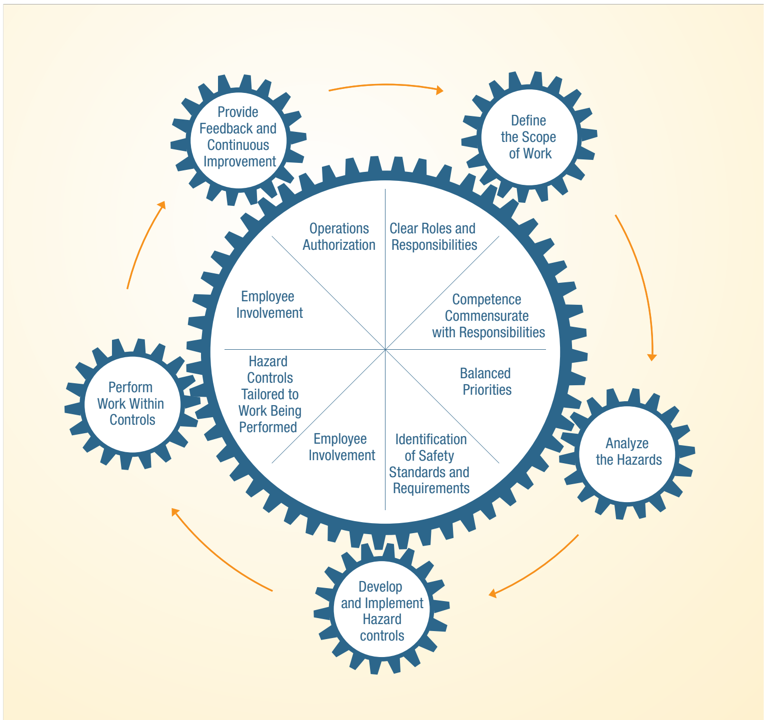
Performance-Based Standards



Performance-based standards identify important, broadly-defined goals that must result from applying a standard, rather than specific technical requirements. For example, the standard for completing a Rubik's Cube is to arrange the cube so that each side of the cube is one and only one color. Recent OSHA regulations, such as the confined space entry standard, are performance-based standards. Contrast these with criterion-based standards.

Safety Culture

"Safety Culture" is a term coined to define a set of organizational values that promote worker and public safety as an overriding priority. In organizations with a safety culture, everyone is trained, provided with policies and procedures, and rewarded for identifying safety hazards before they result in injuries to workers or the public.



Surveillance

Surveillance refers to a number of techniques for analyzing and monitoring the workplace to identify safety-related problems. There are two types of surveillance:

- *Passive*—using existing records, including medical, insurance, OSHA, and production logs, to detect developing health or safety problems

- *Active*—investigating the work, workplace, tools and equipment, materials, or environment to learn the causes of and solutions to problems uncovered during passive surveillance.

Systems Approach

The systems approach considers humans to be part of an integrated system, not external to or isolated from the total environment.

System Safety

System safety should result when a systems approach is used to address safety. It requires applying design, operating, technical, and management techniques and principles throughout the life of a system to reduce hazards to their lowest practical levels.

Worker's Compensation

Workers' Compensation is a system of insurance required by state law. It is usually financed by employers and provides payments to employees or their dependents for occupational illness, injuries, or fatalities, regardless of fault. As part of the state laws mandating workers' compensation insurance, employers are generally protected from individual personal injury litigation. The scope of such protection varies from state to state.

METHODS

There are many methods that can be applied to workplace safety. In fact, most of the general human factors methods described in the Human Factors chapter are applicable, one way or another, to workplace safety. Certain methods are routinely associated with safety. The primary safety methods are described in this section.

Critical Incident Technique

The Critical Incident Technique is a general human factors method. It asks (and allows) workers to report equipment, practices, or other people that cause, or almost cause, accidents. The Critical Incident Technique can be implemented as either a written or oral process i.e., we can ask people to supply their reports in writing or in face-to-face interviews.

Most people are reluctant to report even grossly unsafe acts if they have to implicate their co-workers or, especially, themselves. Because of people's reluctance to report unsafe behavior, successful critical incident reporting systems allow reporters to maintain their anonymity. One of the oldest and most successful programs of this nature is the Aviation Safety Reporting System (ASRS). The ASRS allows aircrew members and aircraft maintainers to report incidents or near-incidents completely confidentially.

The Critical Incident Technique is based on the assumption that the people who spend every working day in a particular work environment know about the unsafe elements in that workplace. This information is quite useful for improving safety. If we can identify which elements contribute to near-accidents, we can correct those elements before an accident occurs. In contrast, surveillance techniques require us to wait until after an accident occurs to identify it.

Direct Measurement

The most common, and in many ways the most useful, safety-related method is direct measurement and observation. Although many safety hazards result from subtle combinations of workplace elements, a great number of safety hazards are easy to identify and eliminate. We have a large and ever-expanding base of data related to unsafe actions, conditions, and designs.

A major frustration of safety professionals is that the same types of accidents happen over and over, even though we know what causes these accidents and how to prevent them. By going into the workplace and making fairly simple measurements and observations, we can identify and eliminate conditions known to cause accidents and injuries.

While the concepts of direct measurement and observation are simple, actually going into the workplace and performing measurements and observations can be daunting. As with other safety-related techniques, there must be some framework to organize the effort. One way to structure such measurements is with audit checklists similar to those described in Establishing a Human Factors Program. Such checklists can organize your measurement efforts and provide a screen to prevent you from inadvertently omitting important measurements.

Direct observation can be performed either at the workplace or remotely, for example with videotape or digital video. In either case, analyzing the dynamic movements of workers requires a level of expertise and experience likely to be found only among professional human factors practitioners.

The biggest drawback of direct measurement is that it is extremely intrusive; the act of making the measurement can affect the factor being measured.

Job Hazard Analysis (JHA)

Job Hazard Analysis (JHA) is the most fundamental technique associated with identifying and mitigating workplace hazards. JHA isn't just one technique, but a category of methods used, first, to identify, then, to evaluate, and, finally, to eliminate or minimize safety hazards.

The identification phase of JHA usually involves a records analysis technique, such as surveillance; a reporting method, such as the Critical Incident Technique; or both. JHA sometimes uses an observation technique, such as video analysis. Regardless of the methods, its intent is to identify actual or potential safety hazards for later analysis.

After hazards are identified, JHA uses one of a number of evaluation methods to assess the safety risk of each potential hazard. These methods can range from analyzing worker motions using videotape to directly measuring weights, angles, temperatures, etc. The NIOSH lifting equation is a common evaluation tool for lifting hazards.

Since very few entirely new hazards appear suddenly in the workplace, once a hazard is identified and evaluated, there are usually several strategies to eliminate the hazard or to minimize its effects. Risk control strategies include eliminating the source of the risk, building physical barriers between the hazard and the workers, and establishing different qualifications for those who perform the hazardous task.

NIOSH Lifting Equation

One of the most common hazardous tasks industrial workers undertake is lifting. Back injuries traditionally constitute the single largest category of work-related injuries, both in terms of numbers of occurrences and cost. Various studies over the past 30 years have identified the factors that contribute most to the high rate of back injuries.

The National Institute of Occupational Safety and Health (NIOSH) has periodically assembled the relevant research findings regarding back injuries. In turn, NIOSH has distilled this empirical information into a mathematical equation that establishes a “safe” envelope for lifting tasks. This equation, shown in Figure 9-2, is known as the “lifting equation.” The latest version of the NIOSH Lifting Equation was devised in 1994.

Surveillance

As noted in the CONCEPTS section, surveillance refers to more than one technique. This concept is recognized in the FARs (Part 121.373) insofar as it pertains to the effectiveness of a certificate holder’s maintenance program. That is, aviation maintenance organizations are required to monitor their repairs and inspections to ensure that they are done properly. This is conceptually similar to surveillance related to workplace safety. However, the emphasis in the FARs is on the airworthiness of aircraft, while this section of the Guide is concerned with the health and safety of those who work in the aviation maintenance organization.

The most common type of surveillance, termed passive surveillance, involves monitoring and analyzing accident and injury records to identify patterns of recurring incidents. A passive surveillance analysis might identify a “cluster” of forklift accidents in a particular department or workshop.

After passive surveillance identifies a potential safety hazard or a cluster of accidents, investigators take an active role in trying to verify the hazard and learn its causes and solutions. This is known as active surveillance, although its methods are akin to direct observation, interviews, critical incident reporting, etc.

GUIDELINES

Evaluating an Existing Safety Program

In the Human Factors section of this Guide contains several checklists related to specific areas of workplace safety. The following four indexes provide information about the overall effectiveness of an existing safety program. An effective program demonstrates a decline in any or all of these measures. It will also compare well with comparable measures from other organizations in the same industry group.

Disabling Injury Index (DII). The DII combines frequency and severity measures into a single index. The Frequency Rate and Severity Rate are defined below.

DII = Frequency Rate x Severity Rate

Frequency Rate (FR). The FR represents the number of events (accidents or illnesses) per 500 employees in a given year. It is based on the ANSI Z16.1 (1967) formula, which predates the formation of OSHA.

$$FR = \frac{\text{Number of events X 1,000,000}}{\text{Total number of hours worked}}$$

Incidence Rate (IR). OSHA does not recognize the Frequency Rate, but instead uses a multiplier of 200,000, which represents the approximate working hours of 100 full-time employees. The IR is based on a formula OSHA developed to allow comparison with other organizations.

$$IR = \frac{\text{Number of events x 200,000}}{\text{Total number of hours worked}}$$

Severity Rate (SR). The SR tracks the number of lost days associated with a particular type of event. This calculation can help determine if a certain type of problem, such as cumulative trauma disorders (CTDs), is responding to intervention, even if there is an increase in the number (frequency) of cases. It is not unusual for there to be an increased number of people reporting CTD symptoms following training on the topic. If the training and other solutions are successful, there will be fewer days lost for each new case. As with other indices, the mulitplier (1,000,000 in this case) is arbitrary, but must be held constant to compare different types of lost-time events.

$$SR = \frac{\text{Total of days lost x 1,000,000}}{\text{Total number of hours worked}}$$

Other possible measures of severity include the following:

- Average number of days lost per employee per year
- Average Workers' Compensation costs paid per employee per year
- Total days lost for each type of disorder or injury
- Total Workers' Compensation costs paid for each type of disorder or injury.

Evaluating Potential Safety Hazards

It is difficult to consider workplace safety as a single issue. There are so many workplace elements that can be the source of safety hazards that one is quickly overwhelmed by a glance at the big picture. It is much more effective to divide the workplace into small topical areas that each can be examined for potential hazards.

Just as it is difficult to view workplace safety as a single issue, it is inefficient to use a single technique to identify and evaluate safety hazards. While the process of hazard evaluation is collectively known as Job Hazard Analysis (JHA), it is really a number of separate techniques. A general rule that applies to safety, as well as other workplace topics, is that the probability of finding something increases in direct proportion to the number of ways one looks for it. An addendum to this rule is that the probability of finding something also increases with the number of times one looks for it. The most effective JHA (1) combines a variety of safety analysis methods to look for safety hazards and (2) repeats the analysis regularly.

We recommend that a workplace safety program include a function to identify and evaluate potential safety hazards. This function should be built around a JHA process that uses at least the following methods:

- *Surveillance*—Accident and injury statistics should be routinely reviewed and analyzed to identify trends and the causes or loci of various types of injuries and equipment damage.

- *Direct observation and measurement*—Safety committees composed of workers, management, and, occasionally, professional consultants should periodically observe maintenance operations to identify unsafe equipment or practices.

- *Analytical evaluation*—Maintenance tasks that are amenable to analytical evaluation, e.g., manual lifting, should periodically be subjected to the appropriate calculations. For manual lifting, the NIOSH Lifting Equation is an appropriate analytical tool.

- *Critical incident reporting*—A mechanism should be put into place to allow workers anonymously to report unsafe equipment or activities that resulted, or nearly resulted, in injury or equipment damage.

Effective workplace safety programs need to have a focus within the maintenance organization. This focus is traditionally provided by a safety committee composed of managers, workers, and, if necessary, professional consultants. Committee membership usually rotates among various members of the organization.

If potential safety hazards are identified, but the safety committee lacks the knowledge or experience to fully evaluate their risk, then an outside safety consultant should be retained to help make a risk determination.

Minimizing Safety Risks

The overall goal of any safety program is to prevent personal injuries and equipment damage. It makes moral and economic sense to avoid problems, rather than to deal with their consequences. The following guidelines are aimed at reducing the risk of safety problems by taking proactive steps to minimize workplace risks.

Individual Issues. As noted earlier, there are a number of safety issues related mainly to individual workers. We address the following individual safety issues:

- Behavior/Motivation
- Clothing/Personal Protective Equipment
- Fitness/Wellness
- Training/Skill Level
- Alienation
- Violence.

Behavior/Motivation. There are several behavioral theories addressing why workers injure themselves or otherwise fail as a system component. Workers may not care about the consequences; they could misperceive the risks or the consequences; or they might intentionally sabotage the system. All of these theories agree about the positive contribution of the following:

- Individual participation in goal setting
- adequate and appropriate feedback about workers' actions
- an understanding of cause and effect relationships in the workplace
- sufficient training in recognizing and managing the potential hazards on the job.

Clothing/Personal Protective Equipment. People usually work best when unencumbered by heavy clothing or personal protective equipment (PPE) such as gloves or respirators. It is critical that workers have appropriate clothing and PPE, but improperly fitting PPE can create a new hazard. Proper training in the correct way to wear and use PPE is also important. PPE can protect workers' eyes, ears, feet, hands, head, and respiratory processes. An example of eye and respiratory PPE is shown in Photo 1. A more radical example of PPE is shown in Photo 2.

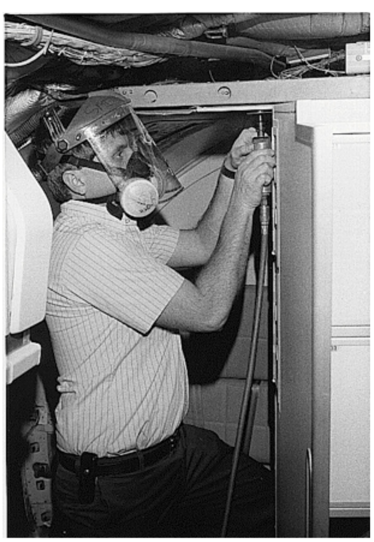


Photo 1. Example of eye and respiratory PPE. (Courtesy of Delta Air Lines)

Photo 2. Complete suit of PPE. (Courtesy of Northwest Airlines)

Unfortunately, no PPE has been proven effective for Cumulative Trauma Disorders, including most lower back problems. The only exception is hearing protection such as ear plugs and ear muffs.

Wrist splints or braces are considered therapeutic devices for treatment, not for prevention, and should be used under the super-vision of a medical professional. There is no compelling evidence of reduced risk of back injury while wearing back belts.

Fitness/Wellness. Evidence shows a high return on investment for individual wellness programs. These financial benefits should increase the number of organizations with comprehensive wellness programs. It is important to provide employees with information about non-work activities that affect their health and safety while also respecting individuals' privacy.

Chronic conditions or diseases may increase the risk of workers developing work-related symptoms. For example, circulatory problems such as those from diabetes may lead to symptoms of Raynaud's Syndrome or Vibratory-Induced White Finger Syndrome. Though the primary cause of such diseases is not work-related, it would be prudent to modify the diabetic person's work to reduce the risk that he or she may develop symptoms.

Training/Skill level. The FAA specifies the training necessary for AMT certification. When training is coupled with job-specific safety information and ongoing feedback about performance, most workers will experience few safety problems during their careers. Carefully considering the implications of changing a work procedure or installing different equipment, for instance, further decreases the probability of safety problems.

Alienation. More and more people report feeling estranged from their work environment. The breakdown of previously close and supportive relationships between an individual and his or her organization can create dangerous situations such as sabotage or negligence. Alienation is implicated in stress complaints, fatigue reports, poor quality, and reduced productivity. Organizations may reduce alienation with an active suggestion system, an open-door policy, a formal grievance and appeals process, and other behavior motivation suggestions such as those we listed previously in this chapter.

Violence. Homocide is the second most frequent cause of occupational death in the United States. Almost two million people are injured by workplace violence each year. Though this problem is not widely recognized in aviation maintenance, violence is associated with increased employee turnover and layoffs, facility closings, increased job demands and other trends that are becoming increasingly common in the aviation industry.

Organizations can participate in Employee Assistance Programs to provide counseling and other services to reduce workers' unnecessary stress. Employees also benefit from conflict resolution training to help them deal with personal and interpersonal problems. Finally, an Employee Assistance Program should have an emergency action plan in effect to deal with hostage, terrorist, and other potentially violent situations.

Task Issues. Some safety hazards are the result of the inherent nature of certain maintenance tasks. In this section, we address the following task-related issues:

- Monotony/Variety
- Postures
- Cumulative Trauma Disorders
- Lifting/Manual Material Handling.

Monotony/Variety. Some people prefer a high percentage of routine tasks in their daily routine. Others need more varied activities to feel motivated and stimulated. Neither need is more correct or more natural, and most of us prefer a mix of routine and variety. It is more effective to accommodate an individual's needs and style than to attempt to change the individual's basic personality. For certain tasks such as repetitive inspection it is important to maintain at least some minimal level of stimulation to prevent drowsiness or inattention.

Posture. It is very risky to work at the extremes of our reach, especially if we are applying force. It is also risky to work in awkward or unbalanced postures. Figure 9-1 shows neutral postures for standing and sitting work positions. Sitting or standing still for long periods is troublesome, as is any posture that reduces local blood flow in the muscles. Training in proper postures is important, but not sufficient. It is more effective to be alert for opportunities to redesign the workplace and work tasks to eliminate the need for risky postures.

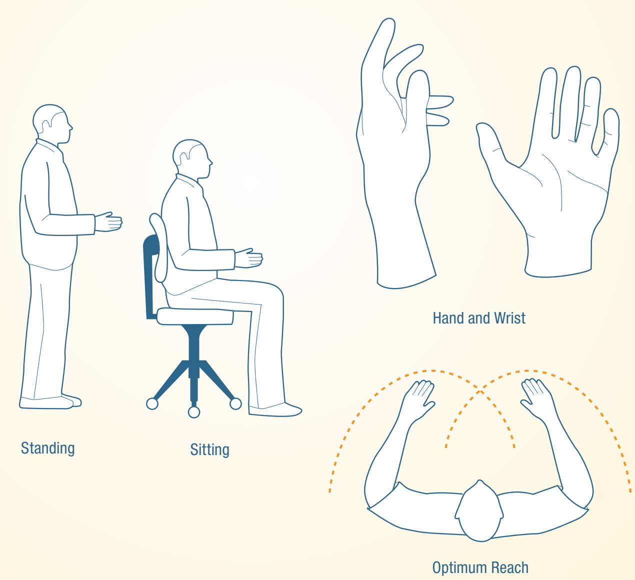


Figure 9-1. *Neutral Working Conditions*

Cumulative Trauma Disorders. CTDs arise from repeated stress, usually to only one or two joints. CTDs do not produce immediate symptoms, but manifest themselves over the long-term. Carpal Tunnel Syndrome, de Quervain's Syndrome, tendonitis, and ganglionic cysts are examples of CTDs resulting from repeated stress. Many lower back injuries, as well as noise-induced hearing loss, are common examples of the cumulative effects of everyday activities.

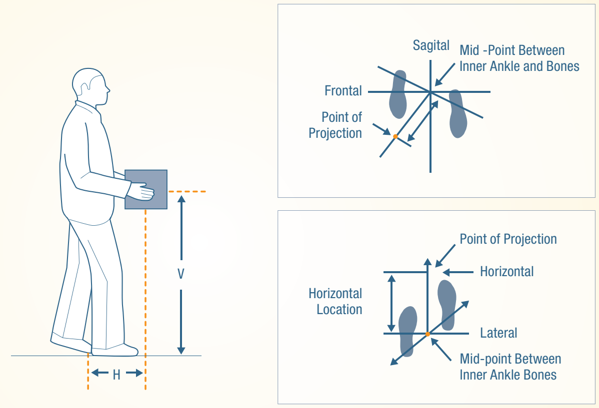
The most successful CTD prevention programs combine actions that include the following:

- Effective management commitment
- Work and workplace analysis to discover possible hazards
- Modifications to the work and workplace to reduce hazards and to manage any residual consequences
- Training for all affected employees in the causes, symptoms, process, treatment and (most importantly) the prevention of CTDs.

Lifting/Manual Material Handling. The latest (1994) National Institute for Occupational Safety and Health (NIOSH) guidelines for lifting activities reflect the current scientific findings on lifting limits. They also provide methods for evaluating asymmetrical lifting tasks i.e., when the object is not directly in front of the body, and the effects of various handles (coupling).

The physical components of the NIOSH lifting formula are shown in Figure 9-2. Note that the maximum recommended weight of lift is 51 pounds.

The Frequency Multiplier (FM) factor in the lifting equation is given in Table 9-1 for a range of work duration and beginning lifting heights.



Recommended Weight Limit (RWL) = LC x HM x VM x DM x AM x FM x CM

Where:

		Metric (cm)	U.S. Customary (inches)	Description
LC = Load Constant	=	23 kg	51 lb	Maximum Weight
HM = Horizontal Multiplier	=	(25/H)	(10/H)	H = Horizontal Location
VM = Vertical Multiplier	=	1-(.003 I V-75 I)	1-(.0075 I V-30 I)	V = Handgrip Height
DM = Distance Multiplier	=	.82+(4.5/D)	.82+ (1.8/D)	D = Vertical Distance of Lift
AM = Assymmetry Multiplier	=	1-(.0032A)	1-(.0032 A)	A = Angle of Assymmetry
FM = Frequency Multiplier	=	(See Table 9-1)	(See Table 9-1)	
CM = Coupling Multiplier	=	(See Below)	(See Below)	

Coupling Multipliers (CM) when:

V<30 in (76cm)	V≥30 in (76cm)	and the coupling type rating is:
1.0	**1.0**	Good = optimal container and handgrips/handles
.95	**1.0**	Fair = non-optimal container **OR** handgrips/handles
.90	**.90**	Poor = non-optimal contianer **AND** handgrips/handles

Figure 9-2. *NIOSH Lifting Formula—1994*

Table 9-1. Frequency Multiplier Table (FM).

Frequency‡	Work Duration					
	≤ 1 Hour		> 1 but ≤ 2 Hours		> 2 but ≤ 8 Hours	
Lifts/Min (F)	V† < 30	V ≥ 30	V < 30	V ≥ 30	V < 30	V ≥ 30
≤ 0.2	1.00	1.00	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.70	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
>15	.00	.00	.00	.00	.00	.00

The 1994 formula provides lifting guidance only for two-handed lifting activities. It is not applicable to, and might under- or over-estimate the recommended weight in, other situations like the following:

- When non-lifting situations, such as walking up stairs, are a large part of the job being evaluated
- If there are unusual working conditions, such as unexpectedly heavy loads or unfavorable environments
- When lifting in unusual postures, such as seated, kneeling, or constrained
- When lifting unusually hot, cold, or contaminated objects
- Wheel barrow or shoveling operations
- High-speed, jerky lifts lasting less than 2-4 seconds
- While standing on a floor with a coefficient of static friction less than 0.4 (approximately the same as a clean, dry leather work shoe on a smooth, dry floor)
- When lifting and lowering are different as when a person must lift an object, but then drops it rather than having to lower it.

Figure 9-3 provides an example of how the NIOSH Lifting Equation can be used in the aviation maintenance environment. In this example, a technician working an 8-hour shift must occasionally (3 or 4 times per shift) lift a cardboard box from a wooden pallet resting on the floor to a workbench top that is 34 inches above the floor. The box contains a subassembly and is smooth, i.e., has no handles.

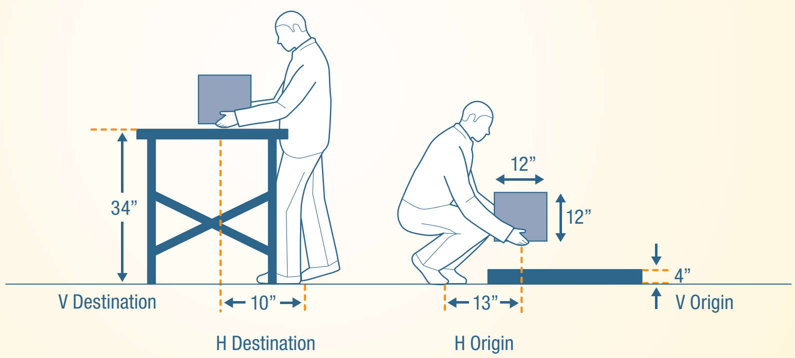


Figure 9-3. *Example of a Lifting Task*

The box and subassembly weigh a total of 38 pounds. The relative positions of the pallet and workbench require the technician to walk to the pallet and face the cardboard box while lifting it to waist level. The technician then carries the box to the workbench and places it on the top of the bench.

The basic question we're trying to answer is whether the box weighs too much for the technician to lift it safely. For simplicity, we'll assume that prior to lifting the box from the pallet, the technician slides it to the edge, avoiding a situation in which he or she has to lean over the edge of the pallet.

Using the Lifting Analysis Worksheet in Table 9-2 and the information in Figure 3-5 and Table 9-1, we will determine whether this is a safe lifting task. The Lifting Analysis Worksheet is adapted from the NIOSH Application Guide. After filling in the descriptive information in the top section of the Worksheet, we should enter the task variables in the section marked Step 1.

The average and maximum object weight is the same, i.e., 38 pounds. Vertical hand locations are the top surface of the pallet and the top surface of the work-bench since the technician must lift the box from its bottom surface. The vertical distance (D) is simply the difference between the origin and the destination vertical hand positions. This number is always positive, regardless of the relationship of the origin and destination vertical hand positions.

Because we've said that the technician is facing the load at both the origin and the destination, there is no asymmetry to the lift. There are only a few of these lifts per shift; therefore, the frequency (the left-hand column in Table 9-1) should be taken as "< .2". Likewise, the work duration of the task should be taken as "< 1 hour". Finally, the object coupling, listed in Figure 9-2, should be taken as "Fair" since the container is not particularly awkward, but has no hand grips.

Table 9-2: Lifting Analysis Worksheet, example

Job Title: Date:

Analyst: Job Description:

Step 1: Measure and Record Task Variables

Object Weight (lbs)		Hand Location (inches) Origin		Hand Location (inches) Destination		Vertical Distance (inches)	Assymetry Angle (degree) Origin	Assymetry Angle (degree) Destination	Lifting Frequency (lifts / minute)	Duration (hours)	Object Coupling
L avg	L max	H	V	H	V	D	A	A	F		C
38	38	13	4	10	34	30	0	0	≤ .2	≤ 1	Fair

Step 2: Determine the multipliers and compute the RWL's

		LC		HM		VM		DM		AM		FM		CM			
	RWL -	LC	x	HM	x	VM	x	DM	x	AM	x	FM	x	CM			
Origin	RWL -	51	x	.77	x	.81	x	.88	x	1.0	x	1.0	x	.95	=	26.59	pounds
Destination	RWL -	51	x	1.0	x	.97	x	.88	x	1.0	x	1.0	x	1.0	=	43.53	pounds

Step 3: Compute the Lifting Index (LI) for origin and destination

$$\text{Origin LI} = \frac{\text{Object Weight (L)}}{\text{RWL}} = \frac{36}{26.59} = 1.4 \qquad \text{Destination LI} = \frac{\text{Object Weight (L)}}{\text{RWL}} = \frac{36}{43.53} = 0.9$$

In Step 2 of the Worksheet, we can enter the factors in the Lifting Equation. Note that we calculate the Recommended Weight Limit (RWL) for both the lift's origin and its destination. Using the equations listed in Figure 3-5, we calculate the origin RWL as follows:

- LC is constant and equal to 51 pounds
- The origin "H" is listed in Figure 3-6 as 13". Therefore, HM is 10/13 = .77.
- The origin "V" is 4". Therefore, VM is 1-(.0075 |4-30|) = .81.
- The difference between the origin and destination vertical hand position is 34-4=30". Therefore, DM is .82+(1.8/30) = .88.
- There is no asymmetry, "A," so AM = 1.00.
- From Table 3-3, we take the factor at the intersection of F = <0.2 and Work Duration = < 1 hour, which is FM = 1.00.
- From Figure 9-2, we take the Coupling Multiplier for V < 30" (since the vertical hand position at the origin of the lift is only 4") and the coupling type of "Fair". Thus CM = .95.
- Carrying through the calculation for the origin RWL, we find that it is 26.59 pounds, which can be rounded to 26.6 pounds.

A similar calculation for the destination RWL yields 43.5 pounds. Moving to Step 3 of the Worksheet, we now calculate the Lifting Index for both the origin and the destination. The Lifting Index is merely an indication of how heavy the actual load is compared to the RWL. From these simple calculations, using an object weight of 38 pounds, we see that the Lifting Indices are 1.4 and 0.9 for the origin and destination, respectively.

Since the origin Lifting Index is greater than 1, this part of the task is likely to be hazardous for most technicians. To remedy this, begin by looking at the smallest modifiers in the origin calculation. In our example, these would be the horizontal multiplier (HM = .77) and the vertical multiplier (VM = .81). If we can raise the load and move the technician closer, our origin Lifting Index will come down closer to 1. This can be done easily by placing the pallet on a lift table.

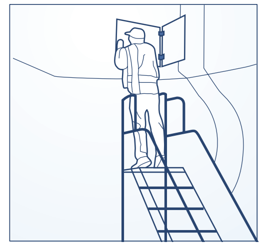
Everyone involved in lifting activities or supervising lifting activities needs to know the major risk factors associated with material handling injuries and how to quickly analyze the material handling activities. It is not necessary to undertake a complete lifting analysis using the NIOSH Lifting Equation until an evaluation shows a reason for concern.

Basically, any activity that can lead to possible overexertion is suspect. Personal issues such as inadequate strength, limited flexibility, reduced coordination, inappropriate mental state, or a history of musculoskeletal problems increase the risks associated with material handling. Handling an awkward or heavy object (especially if it weighs more than 50 pounds) may require excessive force. Environmental factors, including poor footing, annoying noise, whole body vibration, and extreme heat, humidity, or cold temperatures, can also increase risk.

Other activities that can increase material handling risks are repeating the lifting activity more than 15 times per shift; lifting and holding; lifting and carrying; jerking the material; skipping breaks; performing the same activities throughout the shift; and lifting while bent, twisted, or squatted. It is also risky to lift from or to extremely low or high locations. To reduce the risk of injuries, workers should keep their hands close to the spine, between the knees and shoulders, and directly in front of the body while they handle materials.

Tool and Equipment Issues. Maintenance tasks generally require the use of tools, fixtures, and test and support equipment. This is certainly true of aviation maintenance. Certain components are routinely removed from aircraft and taken to a shop for maintenance. Other aviation maintenance tasks involve the airframe itself. In either case, the tools and equipment often present safety risks. The following tool and equipment issues are addressed in this section of the Guide:

- Work support systems
- Electronics and radiation
- Vibration
- Guarding
- Motorized vehicles
- Workstation design
- Hand tool design



Work support systems. Work stands often require AMTs to assume fatiguing positions. Overhead work is especially troublesome. Working at height is common in aviation maintenance. A safety risk exists when outrigger supports are needed, but not used, on any mobile lift. Finally, it is difficult and potentially unsafe for a worker to apply large torsion forces, such as when using a large wrench, while standing on many of the existing support structures. The support may move or tip over during such an activity. It is useful to review accident data to detect incident patterns or unsafe equipment.

Electronics and radiation. There has been a gradual increase in the number of avionics components and electronic testing equipment in aviation maintenance. With this increase comes some concern about electromagnetic radiation effects. Radar calibration, for instance, could be risky when the AMT does not follow proper procedures. Because modern equipment meets radiated energy guidelines, probably the most frequent risk is damage to the avionics and test equipment, not to people. Effective training in the best way to use equipment is critical. It is equally important to ensure, through proper maintenance and testing, that the equipment stays within radiation guidelines.

Vibration. Typically, segmental vibration of a part of the body (especially the hand and arm) is more troublesome than whole-body vibration. Various body parts have resonant frequencies when they vibrate in unison with the source in the range of 4-150 Hz. The range between 50-150 Hz is most troublesome for the hand and is associated with Vibratory-Induced White Finger Syndrome (VWF). Pneumatic tools can produce troublesome vibrations in this range and are implicated in the reduced local blood flow and pain of VWF. It is necessary to reduce these vibrations in amplitude, to change their dominant frequency to one higher or lower, to provide dampening material, and to limit workers' exposure time. Typical usage for pneumatic tools in aviation maintenance is shown in Photo 3.

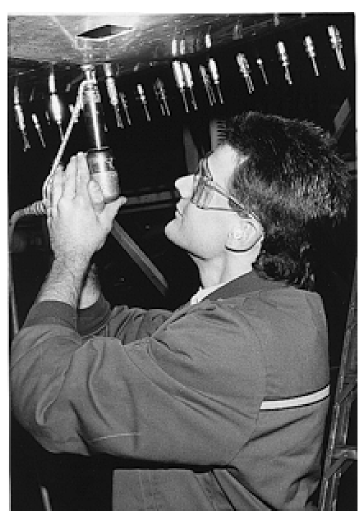


Photo 3. Usage of pneumatic tools in aviation maintenance. (Courtesy of Delta Air Lines)

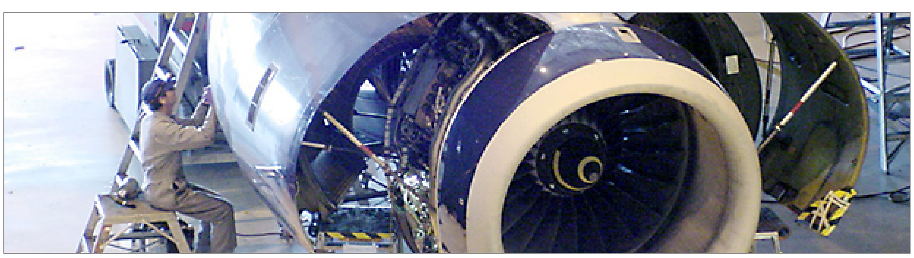
Guarding and tool use. A safe environment ensures the separation of people from rotating or moving equipment. Subpart O of the CFR 1910 OSHA standards describes specific guarding situations and solutions. Progressive discipline is necessary whenever anyone attempts to defeat these guards, although such behavior may indicate inadequate equipment design. Guards are more likely to be removed or defeated if they interfere with workers' job activities.

Motorized vehicles. Motorized vehicles include a range of vehicles from powered hand trucks and fork lifts to automobiles and trucks used in maintenance. Using motorized vehicles is the most dangerous activity most people undertake during their working lives.

Subpart N of CFR 1910 includes guidelines for powered industrial trucks and other heavier vehicles. Basically, it is necessary to ensure that no one runs a vehicle into another person or damages another object. It is also important to prevent the operator from falling from the vehicle. Falls from motorized vehicles can directly cause operator injuries and loss of vehicle control. Falls can be prevented with harnesses or other operator restraints. Periodic planned maintenance of the vehicles and recurring training (at least annually) of the operators reduces risk. Progressive discipline and safety incentives may have short-term positive effects.

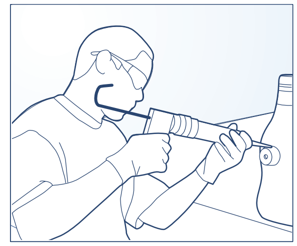
Workstation design. When there is a mismatch between the person doing the work and the workstation he or she uses, both productivity and safety can suffer. Major workstation design principles relate to seating, work surface, reach profiles, available space, and work item organization.

Adjustable seating and work surfaces improve the match between the person and the workstation. It may be necessary to provide several sizes of workstation seating due to the variability of body sizes. Reach profiles refer to the work surface (bench top or work table) area the hands cover during normal working activities. Most of the work should occur in the area a person can reach with his or her elbows hanging relaxed at his or her sides.



It is permissible for workers occasionally to extend their elbows to reach something, but this action should be minimized. Do not require workers to reach with their shoulders and backs. Workers must have enough space to move around and to reach and see into areas necessary for their work activities. Train them to organize their work items to reduce reaching and holding. Provide them with holders, shelves, articulating arms, cutting jigs, and other fixtures to reduce reaching and holding further.

Hand tool design. Users often modify tools to meet their needs. Such modifications do not ensure good tool design and does not guarantee that everyone can use the same tool. An ideal tool embodies the design elements listed below. Use these elements to evaluate hand tools you are considering using in your workplace:



- Keeping a straight wrist and relaxed elbow and shoulder during work
- Suitable surface characteristics, including durability; adequate friction; and protection from hazards, such as thermal or electrical energy
- Appropriate grip size for the person using the tool; this ranges from about 1-3 inches in diameter
- Comfortable hand grip area so that force is not concentrated on a small area of the palm or between the fingers
- Enough leverage to perform the task
- No frequent or constant one-finger pressing or trigger squeezing
- Minimized vibration
- Ambidextrous use, i.e., for either hand
- Low shock and torque transmission to the person
- Appropriate weight, light enough to reduce fatigue, but heavy enough to be stable
- Spring loaded operation to reduce finger/thumb activity
- No pinch points or sharp edges that might injure the user
- Easy to use and maintain.

Facilities and Environment Issues. Productivity-related facility issues are discussed in Facility Design. Many facility and environmental characteristics also present potential safety hazards. In this section, we discuss the following facility and environmental issues:

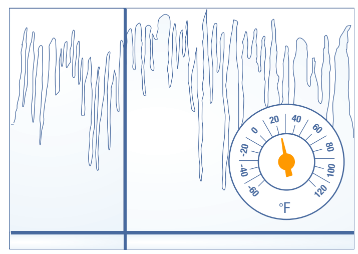
- Lighting
- Noise
- Temperature
- Air quality
- Housekeeping
- Ingress/Egress
- Walking and working surfaces

Lighting. There are two potential problems associated with lighting in the maintenance workplace: 1) too little light where it is needed and 2) glare.

A good recommendation for most aviation maintenance tasks is to provide 800 lx of illumination. Some very difficult, but critical, inspection situations may require a minimum of 1000 lx or special lighting, e.g., polarized or infrared. Individual light requirements may double with age. A 55-year-old may need nearly twice as much illumination to safely perform the same task as a 25-year-old worker.

Noise. It is appropriate to reduce noise levels whenever practical because noise is a fatiguing stimulus, even at levels as low as 65 dBA. It is also reasonable to assume that any factor that can create increased muscle tenseness, as noise can, contributes to the possible development of Cumulative Trauma Disorders and circulatory problems.

Temperature. Most aviation maintenance tasks take place in large hangars, frequently with open bay doors. Since it is difficult to precisely control the temperature in such a facility, it is important to understand the safety and performance effects of various temperatures. Table 9-3 summarizes the general effects of ambient temperature on performance (adapted from Woodson).



The best methods of controlling heat-stress effects include the following:

- Reduce the amount of heat produced and transmitted to the person through process modification and barriers
- Allow the worker to lose heat through convection and evaporation
- Do not force a worker to wear unnecessary clothing or equipment and keep his or her physical exertion level low
- Provide fans, air conditioning, or personal cooling garments, as appropriate
- Ensure that the individual is fit, suitable, and acclimatized to the heat
- Supply emergency treatment and sufficient rest time in a cooler environment.

Low temperatures can be as stressful and dangerous as high temperatures. The effects of cold can be more subtle and insidious than those of heat. Cold stress can usually be effectively handled by providing the following elements:

- Windbreaks
- Local heat sources
- Dry, windproof, layered clothing.

Table 9-3. Human performance at various temperatures	
Temperature (F)	Performance Effect
90˚	Upper limit for performance
80˚	Maximum acceptable upper limit
75˚	Optimum with minimal clothing
70˚	Optimum for typical clothing and tasks
65˚	Optimum for winter clothing
60˚	Hand and finger dexterity begins to deteriorate
55˚	Hand dexterity reduced by 50%

Air quality. Air quality can directly affect certain human performance levels. It is possible for some airborne toxins to increase the risk of Cumulative Trauma Disorders by impairing peripheral blood flow (to the hands, for instance). Increased carbon monoxide levels can reduce mental alertness, increasing the risk of an accident or error. It is necessary to keep oxygen levels around 20% to ensure optimum performance. An efficient heating ventilation and air conditioning system is critical for maintaining appropriate humidity, air content, and air movement levels.

Housekeeping. Accidents correlate to workplace cleanliness and order. A clean and well-ordered workplace demonstrates a professional attitude toward the work being performed. It also reduces the number of workplace hazards present. It is impossible to trip over something that is not left laying around. Tools and equipment stored correctly last longer, are easier to find, and work better. Clean walls, ceilings, and floors distribute available light more evenly and efficiently, with less glare. If everyone cleans up spills as soon as possible, there is less chance of material contamination, slips and falls, and burns of the eyes or skin.

Ingress/Egress. OSHA and most local fire-control authorities require at least two means of accessing a workspace. This access must be along unobstructed corridors and through doors wide enough to accommodate emergency traffic. To comply with the principles and requirements of the Americans with Disabilities Act (ADA), it is important to plan for quick egress by people in wheelchairs, or otherwise encumbered or impaired.

Make sure that doors located along escape routes open with the flow of escaping traffic, so they will not block the traffic flow during the initial opening. Do not lock these doors without providing an emergency disconnect. There must be adequate lighting to aid escape, and the escape door must usually be marked with a lighted sign so it can be located in dim ambient light. It is smart to label non-exits, especially if they might trap people during an emergency. Your emergency plan should include escape routes from all work positions.

Walking and working surfaces. People need good footing to prevent them from slipping and falling, especially if they are carrying, pushing, or pulling an object. Usually, this means a minimum coefficient of static friction of approximately 0.5 between the person's shoe soles and the floor.

Walking surfaces should be clean; appropriately sanitary; dry; and free of loose items or tripping hazards, such as protruding nails, splinters, holes greater than one inch in diameter, or loose boards. Floor load ratings must exceed the weight of the loads imposed on the floors. This is tricky because a single file cabinet often can exceed a typical load rating.

Materials Issues. Materials used in the aviation maintenance workplace include common components, raw metal and composite materials, and hazardous chemicals. Most aviation maintenance facilities need a written hazardous chemicals/materials program including the following elements:

- Hazard assessment/evaluation to determine which hazardous materials are present at the workplace
- Proper container labeling to identify materials and to warn anyone shipping, storing, or using them
- Material Safety Data Sheets (MSDS) on all hazardous materials
- Employee training and information programs and systems
- Emergency procedures, including prior notification and coordination with local authorities, to deal with leaks, spills, or other undesirable events.

Refer to 29 CFR 1910.1200 (Hazard Communication) for additional information on evaluating chemical hazards and informing everyone who may be affected. OSHA regulations, 29 CFR 1910 – Subparts 102-106, also give specific use and storage guidelines for acetylene, hydrogen, oxygen, nitrous oxide, and flammable or combustible liquids.

There are a number of safety issues related to materials used in the aviation maintenance workplace. In this section, we describe the safety implications of the following materials-related issues:

- Composites
- Degreasers and solvents
- Deicing fluids
- Fuels and flammables
- Storage.

Composites. There is increased use of composite materials like graphite and fiberglass in the aviation industry. Maintenance technicians and repairmen must understand hazards associated with these materials and with methods for managing any undesirable effects. As much as 20% of a workforce can develop dermatitis from working with plastic resins. Phenolformaldehyde materials can irritate the skin, eyes, and nose. It is necessary to identify such hazards and then inform everyone exposed to them. Good management techniques for working with composites include the following:

- No smoking or eating in the workplace
- Using appropriate skin and respiratory protection
- Providing good lighting and HVAC
- Placing hand and eye washing stations in convenient locations
- Providing limited test runs of new materials
- Communicating any problems to all affected
- Developing a team of "first responders" to address immediate problems or concerns.

Degreasers, solvents, and chemical strippers. The most common problems associated with degreasing and solvent compounds relate to how they are stored and disposed of. Degreasing or solvent baths are dangerous to people and to equipment when they are left open; the best designs include self-closing covers. Many baths have unsuitable (often temporary), unstable bases or stands. Replace these with appropriate stands. Dispose of these compounds correctly to reduce environmental impact and to protect people from accidental exposure.

The aviation industry is wisely finding replacements for many previously used troublesome chemicals. Other techniques to decrease environmental impact include reducing the amount of hazardous material used and recycling whenever possible.

Deicing compounds. Most deicing compounds used today are glycol and water mixes. Ethylene glycol may be lethal in relatively small amounts (less than 5 mg), if consumed by a human (or another animal). Capturing and recycling ethylene glycol is common in fixed-stand deicing situations; otherwise, it becomes a storm drain environmental problem.

Fuels and flammables. Although jet fuel is the most common fuel found in the aviation maintenance environment, tanks of compressed gaseous fuels [such as Liquefied Petroleum Gases (LPG)] are also present. It is appropriate to control access to these fuels and to protect storage tanks from moving equipment, static discharge, unauthorized use, and corrosion. Internal volume or pressure sensors, external leak detectors, or diligent daily volume measurements such as "sticking the tank" help detect leaks.

Minimize the areas where gases can collect, such as in small rooms or under walkways that cross fueling areas. Small quantities of flammable liquids—paints, solvents, or fuels—are best stored inside a building in double-walled metal or other suitable fire-resistant cabinets (OSHA 1910.106(d)(3)). Larger quantities should be stored outside in an appropriate shed away from other operations. Segregate compressed gases—such as oxygen, argon, hydrogen—to reduce problems with leaking, contamination, or misuse.

Storage. Even otherwise non-hazardous materials sometimes become hazards because of how they are stored. Storage areas can be inadequate when the hangar's floor plan is largely open. Scrap, parts to be modified, or incoming parts, components, and subassemblies might sit on the hangar floor in temporary storage. These create hazards for anyone moving work support platforms or material handling equipment around the hangar. They can also block emergency egress. It is better to create holding or staging areas segregated from other operations by secure personnel and equipment barriers such as fences and railings.
Racks used for storage must be stable and strong enough to hold their loads. It should be easy visually to check the contents and select what is needed. The highest shelf should be no higher than the eye height of the shortest person. Unmarked containers are especially dangerous and should not be used, even for temporary storage of non-hazardous materials.

Administration/Organization Issues. As with any work-related topic, workplace safety has a number of associated administrative or organizational issues. These issues can have as much effect on worker safety as any of the more direct elements we have described earlier in this section. In fact, administrative issues by their nature tend to have very broad effects, generally applying across the entire maintenance organization instead of to a specific group. We address the following issues in this section:

- Record keeping
- Shiftwork and scheduling
- Warnings/Signs
- Work breaks
- Monitoring/Work pace/Standards
- Incentives
- Overtime
- Committees
- Catastrophes/Emergencies
- Lockout/Tagout
- Bloodborne pathogens
- Smoking policy
- Confined space entry.

Record keeping. The most frequent OSHA citation involves inadequate recording of injuries and illnesses. Title 29 CFR (Chapter XVII, Part 1904) requires the following documentation:

- Log and summary of injuries and illnesses (OSHA Form 200)
- Supplementary record of each case (OSHA Form 101)

- An annual summary of all cases to be posted throughout February of the following year (OSHA 200-summarized).

Shiftwork and work schedules. Most aviation maintenance operations involve considerable night work with twenty-four-hour operations being typical. There is concern about the effects of both short- and long-term exposure to non-day work. The issues associated with shiftwork and scheduling are discussed in Shiftwork and Scheduling.

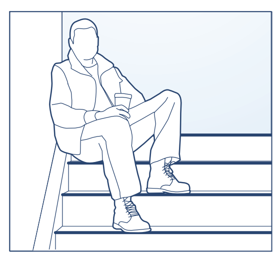
Warnings and signs. Provide warnings or instructions whenever there is a significant potential for personal injury or property damage, especially if the person affected may be unaware of the danger. To be effective, the warnings and instructions must contain the following elements:

- Clearly identify the hazard(s).
- Describe the possible consequences.
- Inform the person what to do or not do.

The sign must attract a person's attention (it must be conspicuous), it must be visible in available light (it must be legible), and it must be understandable to the person affected. Additionally, it must be durable enough to remain effective, often for years.

The underlying standard for warning signs is ANSI Z 535 (Parts 1-5), which was revised in 2002.

Work breaks. Many of the soft tissue problems associated with maintenance work arise from holding awkward postures for too long. Even standing or sitting still for several minutes can increase discomfort and potential problems. It is necessary to adjust one's position frequently to keep the blood flowing and to avoid cramping or strain. The best work breaks are self-paced, occurring regularly and as necessary, almost subconsciously, as workers monitor their localized blood flow and muscular fatigue.



Micro-breaks rarely last more than 20-30 seconds, if taken before serious fatigue or cramping occurs. Approximately three longer breaks, i.e., 10 minutes or longer, taken during the course of the day allow workers the opportunity to walk around and stretch in order to "plump up" the intervertebral discs. Longer breaks also provide rest for the eyes, especially if close-focus work is required. Workers should focus at a distance at least 30 feet away during the break to achieve the greatest rest benefit.

Monitoring, Work Pacing, and Job Standards. Significant planning and motivational benefits follow when workers know how much work is to be accomplished in a given period. However, there are two problems associated with this tendency when applied to industry. First, it is possible to over-motivate people, causing them to lose efficiency and to act in an unsafe manner. Many injuries—

strains and sprains or Cumulative Trauma Disorder—result from this "grin and bear it" attitude. Photo 4 shows an example of a sign intended to motivate technicians to work faster but which may only serve to increase stress.

Photo 4. Example of motivational technique that might increase stress.

The second problem arises from the enforced mediocrity associated with standardizing jobs and externally pacing the work activities. It is usually more effective to motivate workers properly and then to let them work at their own pace. The pace varies throughout the day and may also change seasonally.

Overtime. Fatigue, such as that from working occasional overtime, affects people differently. Typical problems associated with overtime are work errors, especially those due to mental mistakes, and disruption of social activities, including family time. Also, there is a decline in work output for each additional hour of overtime worked. It may be useful to view overtime as a symptom of system imbalance. If the overtime recurs frequently, the work system is seriously out of balance. Examine the system for permanent interventions that alleviate the need for overtime.

Committees. Most organizations have a current interest in increased worker participation. Since there are fewer managers than there were 10 years ago, the workforce is increasingly independent and transient. At the same time, the workplace is also more complex and time-sensitive.

One technique for dealing with these trends is implementing worker committees to evaluate working conditions and to recommend improvements. This usually requires someone with specialized training in group dynamics, but provides the organization with motivated employees and superior internal communications.

Catastrophes and Emergencies. There are numerous calamitous events that can disrupt operations, place people in jeopardy, and threaten equipment or facilities. These events include fires, explosions, floods, hurricanes and tornadoes, earthquakes, serious work accidents (and their resulting rumors), hazardous material spills, and terrorist acts or civil strife.

Advance planning is necessary to address these events and to reduce their consequences. Such planning involves command and communication procedures, selection and training of response teams, emergency equipment, sheltered areas, alarm systems, evacuation and transportation, on-site security, and coordination with groups outside the organization.

Lockout/Tagout. When a worker is servicing a piece of equipment or a system, it is important to control against undesirable release of hazardous energy that could injure someone or damage equipment. The general procedure to control this energy includes the following steps:

- Train all workers involved in the maintenance process so that they understand the equipment or system to be maintained and the lockout/tagout process
- Notify everyone who may be affected
- Shut off all power sources
- Put a tag on the controls to explain why they are to be left off
- Disconnect all primary energy sources such as electrical, hydraulic, or pneumatic lines
- Lock out these energy sources, using multiple locks with unique keys if the work is done by a team
- Control or release all energy from secondary sources such as capacitors, counterweights, or pressure tanks
- Verify the lockouts
- Remove the tag(s) and lock(s) after completing the work
- Notify everyone affected when the work is completed.

First Responders/Bloodborne pathogens. During an emergency there is little time to consider how to protect the first responder team members (or other employees), especially from bloodborne diseases such as Human Immunodeficiency Virus (HIV) or hepatitis. Prior to having an emergency, an organization should develop a written plan to control exposure to these organisms and to minimize any residual effects. The plan should include the following details:

- Training for the first responders
- Engineering and work practice controls
- Required personal protective equipment
- Warning signs and labels
- A case management program subsequent to an exposure event, including vaccines, record keeping, and follow-up.

Smoking policy. Many organizations have smoking policies, but these are usually meant to protect workers only from the effects of second-hand smoke. There are other important health and safety smoking effects. As many smokers have noticed, one's hands become cooler after smoking a cigarette as a result of decreased blood flow to the extremities. This could increase the risk of soft tissue injuries, such as Carpal Tunnel Syndrome.

Another potential problem with smoking in the workplace is the concentration and heat-activation of volatile toxins present in the air. Coupled with the increased risk of fires and the general health consequences associated with smoking, these risks weigh heavily on the side of all organizations implementing a smoking cessation program.

Confined spaces. Bodily entry into any space with limited means of entry or exit not designed for continuous occupancy requires written procedures, prior training, and safety equipment. Some confined spaces have other hazards present, such as toxic gases or fumes, electricity, machinery, etc. An example of a common confined-space entry task in aviation maintenance is fuel cell repair. Confined spaces are considered inherently hazardous even without being associated with other hazards.

The written confined-space entry plan must address the following for anyone entering such a space:

- Receives appropriate training in entering such spaces and in using any safety equipment
- Secures a written entry permit before entering the space if it contains any hazards that could cause death or serious physical harm
- Tests the space for sufficient oxygen and for dangerous gases or vapors
- Ventilates the space before and during entry
- Locks out any connecting lines
- Has the appropriate safety equipment and trained assistance present during entry.

WHERE TO GET HELP

The American Conference of Governmental Industrial Hygienists publishes a catalog of documents, books, and reports useful to industrial hygienists and others involved in industrial hygiene activities. They also publish the list of Threshold Limit Values for many chemicals used in the United States.

American Conference of Governmental Industrial Hygienists (ACGIH)
1330 Kemper Meadow Drive
Cincinnati, OH 45240
Phone: 513.742.2020
http://www.acgih.org

The American Association of Occupational Health Nurses coordinates professional activities for nurses throughout the United States involved in occupational medicine.

American Association of Occupational Health Nurses (AAOHN)
2920 Brandywine Rd.
Suite 100
Atlanta, GA 30341
Phone: 770.455.7757
http://www.aaohn.org

The largest association of safety engineers in the United States is the American Society of Safety Engineers. They publish a catalog of information available to safety specialists and hold Professional Development Conferences.

American Society of Safety Engineers (ASSE)
1800 East Oakton Street
Des Plaines, IL 60018
Phone: 847.699.2929
http://www.asse.org

The professional association of industrial hygienists is the American Industrial Hygiene Association. They provide continuing education for industrial hygienists and a list of industrial hygiene publications. They also conduct public affairs activities and become involved in regulatory issues affecting the profession.

American Industrial Hygiene Association (AIHA)
2700 Prosperity Avenue, Suite 250
Fairfax, VA 22031
Phone: 703.849.8888
http://www.aiha.org

The federal government agency charged with general responsibility for environmental issues is the Environmental Protection Agency.

U.S. Environmental Protection Agency (EPA)
Ariel Rios Building

1200 Pennsylvania Avenue, N.W.
Washington, DC 20460
Phone: 202.272.0167
http://www.epa.gov

The Human Factors and Ergonomics Society is the professional organization representing human factors/ergonomics specialists in the United States. They coordinate intersociety affairs, continuing education, annual meetings, publications, and regulatory or legislative activities that affect the profession.

Human Factors and Ergonomics Society (HFES)
Post Office Box 1369
1124 Montana Avenue, Suite B
Santa Monica, CA 90403
Phone: 310.394.1811
http://www.hfes.org

The largest fire protection and prevention association in the United States is the National Fire Protection Association. This non-profit organization has over 80,000 members. It publishes numerous authoritative documents, including the "National Fire Code."

National Fire Protection Association (NFPA)
1 Batterymarch Park
Quincy, MA 02169
Phone: 617.770.3000
http://www.nfpa.org

The National Safety Council is the largest organization in the world devoted entirely to safety. This non-profit organization was chartered by congress, but is not an agency of the federal government. It has an extensive safety-related database and holds frequent seminars, conferences, and meetings.

National Safety Council (NSC)
1121 Spring Lake Drive
Itasca, IL 60143-3201
Phone: 630.285.1121
http://www.nsc.org

Much of the research done by the National Institute for Occupational Safety and Health (NIOSH), serves as a basis for the standards enforced by the Occupational Safety and Health Administration. NIOSH is part of the Department of Health and Human Services (DHHS) Centers for Disease Control & Prevention (CDC)

National Institute for Occupational Safety and Health (NIOSH)
Education and Information Division
4676 Columbia Parkway
Cincinnati, OH 45226
Phone: 513.533.8302
http://www.cdc.gov/niosh

The safety consulting, training, and enforcement branch of the federal government is the Occupational Safety and Health Administration. OSHA is part of the Department of Labor.

Occupational Safety and Health Administration (OSHA)
200 Constitution Avenue, NW
Washington, DC 20210
Phone: 800.321.6742
http://www.osha.gov

The largest wellness organization in the United States is the Wellness Councils of America. WELCOA was founded as a national non-profit organization in 1987. They hold meetings throughout the year, publish information about wellness, and help coordinate and produce local wellness council activities.

Wellness Councils of America (WELCOA)
9802 Nicholas St.
Suite 315
Omaha, NE 68114
Phone: 402.827.3590
http://www.welcoa.org

EXAMPLE SCENARIO

A new airframe component weighs 62 pounds. It is approximately cubicle, about two feet long on each side, and in smooth packaging. The AMT must position it at waist level during installation.

Issues

1. What is the best way for an AMT to lift this item?

2. How do you measure the Horizontal Location variable, "H", for the NIOSH lifting equation in this situation?

3. What is the difference between the two vertical variables: "V" and "D"?

4. Would this be an example of a "Good" coupling?

5. If the AMT must hold the component to one side during installation, would this be better, or worse?

Responses

1. The information required to address the issues in this scenario is found in the Lifting/Manual Material Handling subsection. The NIOSH lifting equation, shown in Figure ??, and the discussion and worksheet related to it indicate that the maximum weight that can be lifted by an individual is 51 pounds. Technically, there is no safe way for an individual to lift more than 51 pounds, unassisted. The best way for an AMT to lift this 62-pound component is to get someone else to help.

2. Measure the Horizontal Location variable from the midpoint of a line connecting the inside of the protruding ankle bones to the midpoint of a line connecting the hand grip locations.

3. "V" refers to the vertical height of the hand-grip locations, measured at both the origin, or beginning, of the lift and at the destination, or end. "D" refers to the distance traveled by the lifted object during the lift. It is the absolute value of the difference between beginning and ending height of the hand-grip locations.

4. This would probably get a poor grip rating, because the component is large and the packaging is smooth, i.e., has no handles or hand-grips.

5. This would be an example of asymmetrical lifting. In the lifting equation, the Recommended Weight Limit is reduced when there is an asymmetric lifting component. Therefore, this type of lift will significantly reduce the amount of weight that can be lifted safety.

REFERENCES

Code of Federal Regulations (CFR) Title 29, Labor.
http://www.access.gpo.gov/cgi-bin/cfrassemble.cgi?title=200329
[These are the OSHA regulations.]

Geller, E.S. (1996). The Psychology of Safety, Chilton Book Company, Radnor, PA.

Waters, T.R., Putz-Anderson, V., and Garg, A. (1994). Applications manual for the revised NIOSH lifting equation. National Institute for Occupational Safety and Health, Division of Biomedical and Behavioral Science, Cincinnati, OH.

CHAPTER 10: COMMUNICATION

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LANDING PAGE

"What we have here is a failure to communicate."
—Strother Martin in the movie "Cool Hand Luke"

Most of our activities in work and in life involve some form of communication—a term that is likely overused. To the extent that we transmit or receive information, we have communicated. In the aviation maintenance world, much of the information we use takes the form of written procedures, which are a type of non-verbal communication. Guidelines related to written procedures are provided in the "Procedures and Technical Documentation" chapter.

As much as we use written procedures, we acquire a lot of the information we need to do our jobs from verbal interchanges with other AMTs or Engineers, technical support representatives, regulators, pilots and other flightcrew members, supervisors, and others. Verbal communication can take place through various channels, such as face-to-face, telephone, radio, etc. Non-verbal communication, such as instant messaging, phone texting, and e-mail, typically requires an electronic communication link. One common form of non-verbal communication, body language, requires that all parties to the communication can see one another.

In this section of the Guide, we will examine the fundamental aspects of interpersonal communication and provide guidance for making sure the intended message is sent and received.

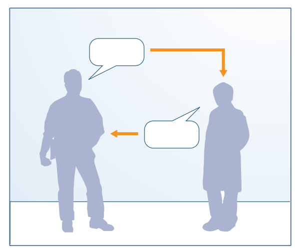
INTRODUCTION

The concept of communication can become very complicated. However, in its simplest form, communication between two people (interpersonal communication) consists of exchanging information. We often think of one person as giving or sending information and the other person receiving it, but this is an oversimplified view of communication. In fact, the receiver is also giving information to the sender through questions, comments, gestures, etc.

Think of a common communication "event" in the aviation domain, such as shift turnover. The outgoing AMT or engineer must convey to the incoming AMT the status of overall work and, especially, unfinished job cards. This verbal exchange can include pointing to a particular step on a job card, questions related to parts availability, a facial expression indicating the AMTs doubt that a supervisor understands what's going on, a shared anecdote involving similar tasks done on other aircraft, etc. This is definitely NOT a situation in which the outgoing AMT talks and the incoming AMT passively listens.

Communication is such a diffuse and pervasive concept that it is easy to lose sight of its primary purpose, which is to convey information. Nido Qubein, a noted educator and President of High Point (North Carolina) University, is a prominent and vocal proponent of effective communication. He lists four basic requirements for communication:

- A message must be conveyed.
- The message must be received.
- There must be a response.
- Each message must be understood.



Other communication researchers have provided more abstract principles related to communication. Donnell King (2000) has published what he calls the four principles of interpersonal communication, as follows:

Interpersonal communication is

- Inescapable—It is not possible to get through life without communicating.
- Irreversible—Once something is said, it cannot be "unsaid".
- Complicated—Even seemingly simple statements can be, and often are, misinterpreted. See Wiio's Laws.
- Contextual—Communication does not occur in a vacuum. It is subject to the situation, environment, culture, and personality context in which it is embedded.

One of the obvious factors affecting interpersonal communication is language. In particular, if the spoken language of the sender and that of the receiver differ, the chances of misinterpreting the message are fairly high. Unlike the verbal communication that occurs among flight crews and air traffic controllers, which always takes place in English, there is no international agreement regarding a common language for maintainers. Even among people conversing in the same language there is ample opportunity for ambiguity, confusion, and misinterpretation. Imagine the magnitude of these problems for AMTs trying to communicate when their native languages differ.

Messages are often interpreted, at least in part, on what is NOT included. During a shift turnover discussion, for example, if the outgoing AMT does not mention any problem with the undone task he or she is handing off to the incoming AMT, is it reasonable to assume that no problem exists? This is just one of the considerations that makes interpreting messages so difficult. It also illustrates why interpersonal communication is so complex.

This section of the HF Guide examines various aspects of interpersonal communication as it relates to aviation maintenance.

REGULATORY REQUIREMENTS

"If we don't talk, people die."

—Bill O'Brien (FAA) writing in a 1992 issue of Aircraft Maintenance Technology

The overwhelming majority of FAA rules and regulations related to maintenance pertain to maintaining written manuals, procedures, and repair records. Many deal with information that must be transmitted from either the FAA or manufacturers to technicians in the field. These include airworthiness directives (AD's), notices to airmen (NOTAM's), etc. The applicable human factors elements for written procedures are addressed in the Procedures and Technical Documentation section of this Guide.

There are no explicit regulatory requirements related to the exchange of non-written information among maintenance technicians and inspectors. For that matter, there are no regulatory requirements governing non-written communication among any of the typical aviation maintenance groups. There is an implicit requirement that important, i.e., safety-related, information will be passed between shifts and that verbal instructions will be unambiguous.

The aviation maintenance community is just now beginning to transfer some of the Crew Resource Management (CRM) training, experience, and methods from the operational domain. Much of the information in such aviation maintenance settings is exchanged in non-written form, so good communication skills and practices are of primary importance. FAA Advisory Circular (AC)120-72 describes the training curriculum required to support Maintenance Resource Management (MRM).

The European Aviation Safety Agency (EASA) actually requires human factors training or maintainers and the curriculum (specified in EASA Part-145 and described in CAP 716) includes certain aspects of communication, such as shift turnover.

There are no FAA regulations that directly address specific shift turnover practices in aviation maintenance organizations. Part 121.369 (b)(9) requires an organization's maintenance manual to contain "Procedures to ensure that required inspections, other maintenance, preventative maintenance, and alterations that are not completed as a result of shift changes or similar work interruptions are properly completed before the aircraft is released to service." However, no guidance is given regarding what those procedures should (or might) be.

The most specific regulatory guidance related to shift turnover is given in Orders and Standards from the U.S. Department of Energy (DOE). Obviously, aviation maintenance facilities are not bound by DOE regulations. However, there is a lot of good information in these requirements that can be easily adapted to the aviation maintenance environment.

The DOE has a long history of operating facilities, many of which process potentially dangerous substances. A complicating factor is that contractors operate many, if not most, of these facilities. Recognizing that many incidents and accidents in these facilities were caused by poor communication during shift turnover, the DOE promulgated Order 5480.19, which details the conduct of operations at DOE facilities. Chapter 12 of this Order is titled "Operations Turnover" and lists a series of guidelines related to shift turnover procedures and checklists.

Order 5480.19 invokes or references several standards. Two that directly address shift turnover are DOE-STD-1038-93, "Guide to Good Practices for Operations Turnover", and DOE-STD-1041-93, "Guide to Good Practices for Shift Routines and Operating Practices".

In the Guidelines section of the Shiftwork and Scheduling chapter, we use material from these DOE sources, as well as from work sponsored by the FAA/AAM in the aviation maintenance environment to develop reasonable and effective shift turnover practices.

CONCEPTS

Active Listening

"You never learn nothin' talkin'." —attributed to Yogi Berra

The term "active listening" is meant to dispel the notion that the receiver in a verbal interchange is just a passive element. Effective communication requires the listener to take an active role in seeking details, clarification, reasons, and other types of information that might not be initally transferred by the "sender".

Assertive Communication

This term is generally used to describe a style of interpersonal communication in which both parties are open, straightforward, and willing to take active roles in ensuring the accuracy and completeness of the interchange. It is sometimes confused with "aggressive" communication, but aggressiveness is neither the intent nor perspective of assertive communication. A common example of assertive communication is the willingness of a person offering an opinion or comment to persist until the other person in the exchange answers the question or acknowledges the comment.

Asynchronous Communication

This term implies that the individuals exchanging information through a particular channel are not dealing with each other in real time. In asynchronous communication, the receiver typically responds to the sender after a time delay. E-mail is one of the most common types of asynchronous communication. Voice mail is another. As the sender or requestor of information, I send you a message to which you can respond at a time of your choosing—or not at all.

Body Language

Body language is one of the two dominant forms of non-verbal person-to-person communication. The use of facial expressions is the other. In any particular culture, people learn that certain body positions adopted by the sender of a message adds meaning or context to the message. There are entire books written about body language.

Channel

A communication "channel" is simply the conduit through which we choose to transmit information. In the study of human perception, channels are defined as sensory modalities, which typically include vision, hearing, smell, taste, and touch. When the term is used with respect to communication, it usually refers to the method or tool used to transmit and receive information. Typical communication channels are face-to-face voice conversation, telephone, radio, chat or instant messaging, and e-mail.

Communication

Communication is the process of exchanging information. In the context of aviation maintenance, communication means the exchange of information from one person to another.

Communication Protocol

A protocol is simply an agreed-upon way of doing things. A communication protocol can take many forms, such as having a consistent syntax, or using certain words to mean particular things. Simplified Technical English (STE) is a protocol for written procedures. Air traffic controllers and flight crews use an established protocol for radio communication.

Convention

Just as a protocol is an agreed-upon way of doing things, a convention is how something is done in the workplace. The difference between the two is subtle, but important. A protocol is usually formally designed and documented. A convention often comes about just because people do things a certain way over a long period of time. There are many types of conventions.

Of primary interest for the topic of communication are things like naming conventions, that is, what AMTs call certain things like specific tools, aircraft components, specific procedures, etc? It is very important for interpersonal communication to utilize accepted naming conventions. When my co-worker asks me to hand him or her a pair of "dykes", it's important that I know he or she is referring to diagonal cutting pliers. The act of "pinning" a control surface, i.e., immobilizing the surface by inserting a metal pin through the control mechanism, is a common element in various evaluation tasks. These are examples of naming conventions.

Formal

Usually, when people refer to "formal" communication, they mean written forms or documents. Verbal communication, in contrast, is typically considered to be informal. Certainly, most verbal exchanges contain less structure and less-constrained language than a written message on the same topic. However, it is not necessarily true that all verbal communication is informal. In some domains, such as the military, verbal communication can be quite formalized and adhere to a specific protocol.

Interpersonal Communication

Interpersonal communication means that information is being exchanged among individual people, rather than, for example, information that is sent using the mass media.

Maintenance Resource Management (MRM)

In its most general sense, MRM refers to using whatever resources are available to ensure the quality and safety of work being performed by a maintenance organization. MRM requires and supports a very high level of communication among all the people involved in maintaining aircraft.

Non-verbal Communication

As its name implies, non-verbal communication is any method of conveying information that does not involve speech. These non-verbal methods commonly include facial expressions, body language, and even the setting chosen for the information exchange. Non-verbal elements typically affect only synchronous, face-to-face communication. Emoticons, those little face-like figures that are often used for e-mails and instant messages, are an attempt to provide facial expressions to messages that are not delivered face to face.

Read-back

Read-back is a form of verification from the receiver to the sender of information that the information has been accurately transmitted. During read-back, the receiver repeats the message he or she believes was just transmitted. The sender can then make corrections if the read-back is inaccurate. This method is commonly used between flight crews and air traffic controllers, as well as among individuals using radios.

Receiver

The receiver(s) in a communication interchange is(are) the person or people to whom information is being conveyed. This does not imply that the receiver is a passive party to the communication interchanges (see Active Listening). Rather, defining senders and receivers is merely a convenient way of indicating the general direction in which information is flowing.

Sender

The sender in a communication interchange is the person attempting to convey information.

Synchronous Communication

Synchronous communication implies that the individuals exchanging information are dealing with each other in real time. The most common type of synchronous communication is the face-to-face conversation. However the participants do not have to be co-located to engage in synchronous communication. Telephone calls, instant messaging, chat rooms, and texting are all forms of synchronous communication.

Wiio's Laws

Professor Osmo Wiio was a famous Finnish communication researcher. He published a series of "laws", similar to Murphy's Law, which emphasizes the problematic nature of person-to-person communication. His "laws" are described in great detail on several Internet sites, such as http://www.cs.tut.fi/~jkorpela/wiio.html.

Some of Wiio's most frequently-cited laws are the following:

1. Communication usually fails, except by accident.
2. If a message can be interpreted in several ways, it will be interpreted in a manner that maximizes the damage.
3. There is always someone who knows better than you what you meant with your message.
4. The more we communicate, the worse communication succeeds.

METHODS

There are a number of methods that relate in one way or another to effective interpersonal communication. In this section, we describe some of the well-known settings and methods for communicating in the aviation maintenance world. They are presented in alphabetical order.

Checklists and Read-backs

Aircraft maintainers use written procedures every day. Some of these procedures contain checklists that are designed help complete tasks in an orderly and serial manner. Maintainers rarely verbalize checklists or read back verbal

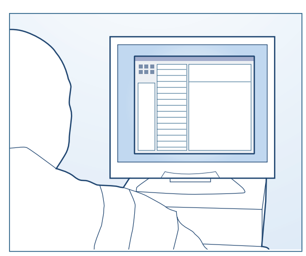
instructions, both of which are common methods used by flight crews to ensure they have properly completed various actions related to certain flight events, e.g., takeoff.

There are many reasons for the rare use of this method for initiating and confirming maintenance tasks. Probably the primary reason is that AMTs tend to work by themselves on many common maintenance tasks. However, in those instances in which more than one AMT must work together to accomplish a task, there is much to be gained by verbalizing checklist tasks and reading back verbal instructions and comments.

A common example of a task in which verbal instructions and read backs are useful is the functional check of a control surface. These checks typically require one person in the cockpit and another positioned near the control surface. These two individuals must communicate with each other. Sometimes this is done via handheld radio or cell phone. The AMT in the cockpit can describe a control action and the expected motion of the associated control surface(s). The AMT at the control surface can repeat the cockpit instruction and then describe the control surface movement.

E-mail

This method will require no explanation for anyone who is less than 40 years of age or who regularly uses a personal computer. E-mail has a lot to recommend it as an asynchronous communication method. It's typically easy to send and receive e-mail. The recipient doesn't have to be present in order for the e-mail to be "delivered" to its destination. It's easy to attach files, such as photos, procedures, technical information, etc., to e-mail. Also, since most work e-mail systems contain well-maintained servers, there will be a permanent record of the e-mails and copies of any attachments.



The main problems associated with e-mail, as a maintenance communication method, is that any particular e-mail message can get lost in the larger number of e-mails that typically flood everyone's in-box, it can get filtered by company spam filters, it can get inadvertently deleted by the recipient, or it can simply be lost or delayed due to network outages.

If the issue requires an immediate response, then e-mail is not the best communication method.

Informal Conversations

This is likely the most common form of verbal interpersonal communication—in all work domains. We all probably participate in many informal conversations each day. Often, perhaps usually, the topic(s) of an informal conversation have nothing to do with work tasks. Informal conversations do not typically adhere to a particular protocol, structure, word usage conventions, etc.

Informal conversations serve at least two worthwhile purposes. First, they provide a venue for socializing with co-workers, getting to know them, and understanding their perspective on life. This is actually a valuable function. The more we understand co-workers, the more likely we are to correctly interpret their meaning when we communicate regarding a work task. Second, informal conversations allow co-workers to internalize each other's type and level of word usage. In other words, we learn how to communicate with each other.

When our focus moves to a specific work task, informal conversation, because of its nature, can cause errors. Work tasks are likely to demand a very structured approach to communicating with co-workers. When tasks demand formality and structure, informal communication is not a good choice of methods.

Instant Messaging

Instant messaging, or IM, falls into the same category as e-mail, at least insofar as the age of people who know what it is and are comfortable using it. Anyone under 30 already knows how to use it and will likely be comfortable using it for real-time remote communication. There are a number of forms of IM, including text messages using cell phones, written messaging using a computer and one of many Internet IM programs, such as Yahoo and AOL Instant Messaging (AIM), and full two-way audio and video using computers equipped with web cameras and microphones.

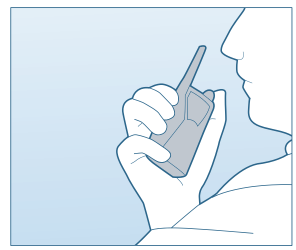
Text-only instant messaging is appropriate only for very short exchanges of information, such as part numbers, describing one's current location, etc. Audio and video IM, such as Apple's iChat, are underutilized in the maintenance domain. Properly equipped computers can easily support remote face-to-face discussions among AMTs, technical support representatives, support engineers and others.

Maintenance Resource Management (MRM)

MRM is the maintenance equivalent of Crew Resource Management, or CRM. Essentially, MRM combines and prioritizes all the resources available to a maintenance organization in order to provide the best maintenance outcomes and minimize the effects of human errors. The discussion of MRM is far beyond the scope of this chapter. However, effective communication is at the very heart of a good MRM program. A previous version of this Guide contained an entire chapter related to MRM.

Radio Communication

Aside from face-to-face conversations, the two-way radio is the workhorse of the aircraft maintenance world—especially for ramp maintenance. Ramp AMTs are dispatched, talk to supervisors and communicate with each other via hand-held two-way radios. As the military discovered over 60 years ago, radios introduce a number of problems into the communication channel.



Because of the compression and clipping that often mask the tone and vocal nuance of those communicating over radios, the military has developed various protocols for radio communication. Some of these protocols are very basic. For example, since it is often not easy to know who is speaking on a remote radio, it is necessary to identify the speaker and the intended target of the message before the message is spoken.

Since the speaker and listener cannot see each other, it is not obvious when the speaker has finished his or her message or that the listener has heard the message. Thus, radio protocols often of the terms “over” and “roger”, respectively. This protocol has been parodied a number of times in comedy routines, e.g., “Hey, they’re saying bad things about Roger, man.”

Radios work well for two-way communication, especially in locations that constrain an AMTs ability to hold a phone or other device in one hand. Two-way radios are routinely used with clip on microphones that free both hands for work or support.

Shift Turnover Meetings

Not all maintenance tasks can be accomplished within the time available in a single shift. It is a common occurrence for job cards to be partially completed on one shift and then handed off to another AMT or Engineer on the following shift. We know from studying human error that handing off a task is an error-prone activity and one that is almost entirely dependent on good communication between the departing and arriving AMTs.

The communication that occurs between the outgoing AMT and the incoming AMT is known as "shift turnover" and it can occur in a formal meeting or in a one-on-one conversation between the two individuals.

Start-of-shift Meetings

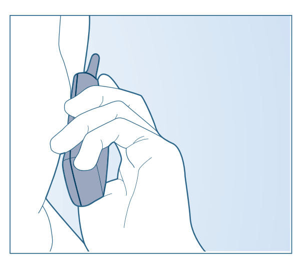
There are a number of pieces of information that need to be transferred from an outgoing to an incoming shift of AMTs or Engineers. Some of that information involves a detailed description of single, ongoing tasks between individual AMTs. However, there is often a larger context that needs to be provided, that is, information regarding the overall status of the "big picture", which can affect everyone on the shift, regardless of their individual tasks.

A start-of-shift meeting can occur either before or after the workers on the departing shift have left the facility. The purpose of a start-of-shift meeting is to bring everyone up to date on where things stand and what to expect during the upcoming shift. For example, aircraft might be scheduled to leave the maintenance hangar or arrive, an aircraft undergoing an extended maintenance check might be at a critical point in the process, such as engine re-attachment, etc.

Start-of-shift meetings usually involve supervisors speaking to all the mechanics as a group. These meetings can also be tailored to workers with a particular specialty, such as the tire shop or engine shop.

Telephone Consultation

It is likely that the most often used interpersonal communication tool is neither the two-way radio nor the Internet, but the telephone. Conversations via telephone are similar to those conducted with radios, with several significant exceptions. Phone conversations are technically classified as "full duplex", which means that we can talk and listen at the same time. This characteristic renders telephone calls similar to face-to-face conversations in that we don't have to wait for the other person (or people) to finish speaking before we comment or respond. Two-way radios are usually "half duplex", which means we can talk or we can listen, but not both at the same time.



The diffusion of mobile phones throughout society has had a profound effect on the availability of this channel for maintenance communication. The proportion of the population that possesses a mobile phone is even higher in some other countries than in the U.S. With the advent of “push to talk” (PTT) phones, the line between telephones and two-way radios is becoming increasingly blurred. Digital mobile phone networks provide high signal reception quality, so mobile phones tend to be much less susceptible to interference than radios.

Phone conversations are similar to radio communication in that the people on either end of the call cannot see each other. It is not clear that this limitation will remain for very long. New third- and fourth-generation phone networks hold the promise of using camera-equipped cell phones for live video “chat” sessions. These high-speed data networks also allow mechanics to use phones for exchanging e-mails, attachments, and web-based information.

GUIDELINES

Person-to-person communication is not an activity that we typically analyze. Instead, we simply talk to one another. Given the uncertainties associated with spoken language, perhaps the surprise isn’t that errors occur during communication, but that they don’t occur more often. The relative rarity of serious consequences from communication errors is a testament to our ability to properly fill in the gaps in transmitted and received information using the context of the message.

Knowing how to analyze communication actions is valuable regardless of whether we do such analysis on a regular basis. Such knowledge can sensitize us to the common weaknesses of interpersonal communication. In this section, we present guidelines related to the most fundamental aspects of communication analysis.

Bottom-Up Analysis

When human factors professionals are asked to evaluate a product or system for “usability”, we can choose from a number of techniques to accomplish that evaluation. The process of analysis and evaluation typically begins with the most fundamental characteristics of a product or system and proceeds to the most abstract. This process first examines issues of compatibility, then understandability, and, finally, effectiveness.

Compatibility relates to the match between the product and the perceptual, physical, and cognitive capabilities of the product’s intended users. Understandability encompasses the culture, experience, and training of users. Effectiveness relates to whether the product can actually be used for its intended purpose.

As an example of this type of analysis, consider a label for a medical device intended for home use. Compatibility issues include the size of the lettering on the label and the contrast between the lettering and its background. The reason we evaluate compatibility issues first is that it does no good to look at higher-level issues until we determine whether the lettering and symbols on the label are sufficiently large to be read.

If the label passes muster with respect to compatibility issues, then, and only then, should we evaluate its understandability. Is the terminology used on the label likely to be meaningful to the people who will use the product? Using medical terminology that is easily understood by doctors and nurses is not likely to work for non-expert home caregivers. Also, what is the native language of the product users? An English-only label is not likely to work if English is not the first language of the individuals using the product.

Finally, assuming compatibility and understandability requirements are met, we evaluate whether the label actually works. That is, if users follow the directions on the label can they use the device as its developers intended it to be used? This might seem ridiculous, but we're all familiar with products that just don't work according to their directions.

In terms of communication, these three fundamental categories can be further broken down into various issues that should be addressed during our analysis. We should note that these issues are perfectly congruent with the PEAR model that was introduced in the very first section of the Guide. Table 10-1 shows how various communication analysis issues can be grouped within the PEAR model.

Table 10-1. Some communication analysis issues and the PEAR model.

	People	Environment	Actions	Resources
Compatibility	Age Native language Hearing deficits	Noise Inside or outside Time constraints Location of AMTs	Task involves talking Task involves listening for a specific sound	Hearing protection Radio Telephone Computer
Understandability	Training Experience Terminology Native language Quality of speech	Radio or phone reception Noise Reverberation Competing PA system Sound insulation in working area	Meaningfulness of communication with respect to the task Time sharing between task and communication Hearing protection worn for tasks	Procedures Technical Data Availability of computer network Clear communication channel(s)
Effectiveness	Communication skills Ability to actively listen Common view of issues by sender and receiver Willingness to ask questions Cultural background	Ability to comply with message Compatibility of work rules with message Worker-management conflicts	Distractions Listening while working Applicability of the message to the task	Availability of proper communication channels Ability to communicate with appropriate people Ability to use information

Note that the issue of "noise" appears in both the compatibility and understandability rows of the table, since environmental noise can affect both the appropriateness of a particular communication channel, e.g., phone, and the understandability of vocal communication.

Selecting the Proper Channel

Communicating via the wrong channel can cause more problems than not communicating at all. Imagine a situation in which I need to show an AMT or Engineer a subtle point regarding an engineering drawing or schematic. Suppose the two of us are located in different buildings. What communication channel(s) might I reasonably choose to convey this information? Well, using the telephone or a radio isn't likely to work. Perhaps just walking over to the other building and meeting face to face is the best solution.

Table 10-2. Appropriate communication channels for various types of information.

Type of Information	Face-to-Face Conversation or group meeting	Radio or Telephone	Instant Messaging, Texting, or Non-video chat	Email or Web Browser	Video Teleconference/ Chat
Facts not requiring interpretation	✓	✓	✓	✓	✓
Information requiring interpretation or discussion	✓	✓			✓
Time sensitive information or questions	✓	✓	✓		✓
Visual Information	✓				✓
Information Requring handling of a component or tool	✓				
Information requiring demonstration	✓				✓
On-the-job Training	✓				

In real aircraft maintenance environments, AMTs and Engineers typically have certain communication channels at their disposal while other channels are more difficult to obtain. The issue then becomes whether the available channels are appropriate for the kind of information that needs to be exchanged. The tendency is to go ahead and use the available channel(s) regardless of its appropriateness.

Consider the situation in which an AMT is in a difficult-to-reach space inside an aircraft and needs to communicate the appearance of a component to other AMTs or a supervisor. If all the AMT has is a radio, then it's likely that he or she will use the radio, even if verbally describing the appearance of the component isn't likely to provide adequate information to those outside the workspace.

Table 10-2 shows the appropriateness of various communication channels for transmitting and receiving certain types of information. This is certainly not an exhaustive list of either communication channels or information elements, but it covers those we're most likely to encounter in the workplace.

We all use inappropriate communication channels on occasion. The key to effectively communicating is to think about what we're trying to accomplish before we settle on a particular channel. In the vast majority of cases, we're likely to be verbally communicating face to face with another AMT or a supervisor. This mode of communication is appropriate for communicating nearly any type of information, as shown in the first column of **Table 10-2.**

The receiver(s) as well as the sender can drive the proper choice of communication channel. If you're not getting the information you need in an information exchange, then don't be hesitant to tell the sender. This feedback can take the form of a blanket statement, e.g., "I can't understand you. There's too much noise.", or a comment on the appropriateness of a specific communication channel, e.g., "Holding the part up to the microphone isn't helping me see that connector."

Developing Effective Listening Skills

In order to give credit where it is due, the guidelines in this and the following subsection are taken from the Communication chapter that appeared in the original Human Factors Guide. Lawrence Rifkind wrote that original chapter. The wording has been updated, but the basic content is the same.

As noted in the Introduction, the ability to actively listen to someone who is trying to communicate with us is the cornerstone of effective communication. While there is no magic bullet that will allow someone to become a good listener, people who are good listeners share certain characteristics. Table 10-3 provides a quick way to assess your (or anyone else's) listening skills. We describe the most important of the good listening practices below after Table 10-3.

Table 10-3. Listening Characteristics

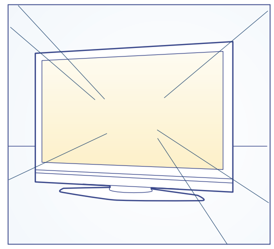
DIRECTIONS: Read the questions listed below and rate yourself on each of the listening characteristics using the following scale:

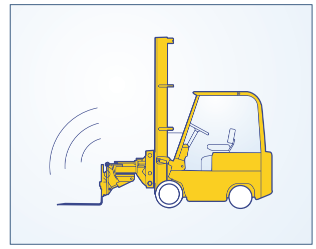
Always = 4 points
Almost always = 3 points
Rarely = 2 points
Never = 1 points

	Responses			
1. Do I allow the speaker to express his or her complete thoughts without interrupting?	4	3	2	1
2. Do I listen between the lines, especially when conversing with individuals who frequently use hidden meanings?	4	3	2	1
3. Do I actively try to develop retention ability to remember important facts?	4	3	2	1
4. Do I write down the most important details of a message?	4	3	2	1
5. In recording a message, do I concentrate on writing the major facts and key phrases?	4	3	2	1
6. Do I read essential details back to the speaker before the conversation ends to insure correct understanding?	4	3	2	1
7. Do I refrain from turning off the speaker because the message is dull or boring, or because I do not personally know or like the speaker?	4	3	2	1
8. Do I avoid becoming hostile or excited when a speaker's views differ from my own?	4	3	2	1
9. Do I ignore distractions when listening?	4	3	2	1
10. Do I express a genuine interest in the other individual's conversation?	4	3	2	1

Interest in the Topic. Effective listeners show an interest in the topic being discussed. If you seek out advice from another person, you will automatically have an interest in what they have to say. However, sometimes a person will begin talking to you without your solicitation. Brainstorm within yourself the reasons why you might benefit from listening to the other person with whom you are communicating. In doing so, you will afford yourself the opportunity to have an open mind toward what is being discussed.

Distraction Tolerance*.* Noise can serve as interference in our efforts to listen to someone else. Office equipment, low-flying aircraft, radio, televisions, and other people can serve to divert our attention away from the person to whom we are listening. Even our mood or an uncomfortable room temperature can serve as distractions. The key is to listen through, perhaps in spite of, the distractions and instead, to focus on the other person and the messages they are transmitting.





Appropriate Time and Place*.* The context of the discussion should be conducive to effective listening behaviors. For some people, the best time of day is first thing in the morning. For others, it is later in the day. Similarly, sometimes it is most appropriate to meet with someone else in their office or at a "neutral site." For most work-related discussions, the ramp, hangar, or shop is the appropriate place for communication. However, if a co-worker is obviously engaged in a job task, then they are not likely to be receptive to your conversation related to the latest personnel policy, etc.

Listening Instead of Talking*.* The more time spent talking, the less time we have available to actually listen to what the other person is saying. If you know you talk too much, curb your comments. If you don't know whether you talk to much, ask someone.

Preparation*.* To listen effectively, you must prepare yourself to be able to listen. Understand your own emotions and feelings. Try to perceive other people as they perceive themselves. Be sure that other things on your mind do not distract you. In particular, be sure you are physically and mentally ready to listen.

Eye Contact. Maintaining eye contact with the speaker confirms their existence; it lets them know that you are actually interested in what they are saying. If looking at their eyes is difficult, look at their hairline, mouth, forehead, or cheek area. Eye contact is a nonverbal message that says, "You have my undivided attention."

What is Said and What is Not Said*.* Words can tell us what other people are thinking. Often, we can infer more meaning from what they do not say rather than what they do say. For example, if issues are repeated, this might indicate an emphasis on those concerns.

Prejudices and Biases*.* If you enter into a conversation with your mind already made up, then you will likely miss most of what is being said to you. Maintain an open mind at all times by listening rather than judging. In short, suspend judgment and hear what the other person has to say. There's plenty of time to disagree or discuss the topic after you fully understand the other person's comments.

Active Listening. Listening is not necessarily a passive activity. Restate or paraphrase what the other person is saying. This not only provides clarification, but can also assist in determining the accuracy of what you have heard in the discussion. Focus on both verbal and nonverbal feedback from the other person. Factors such as their body position or posture, tone of voice, and physical appearance can be quite revealing.

Questions. Ask questions of the speaker. In doing so, you indicate an interest in what the other person is saying. It also helps you to better understand what they have communicated to you. Ask questions in an open-ended way so that the person does not become defensive. For example, "what are your thoughts pertaining to that matter" or "describe what occurred" provides for more disclosure on the part of the other person.

"Hair-Trigger" Syndrome. Do not react too quickly. Instead, be patient. Try not to complete the other person's statements for them until they have fully completed what they are saying. This is especially true in conflict or controversial contexts. Similarly, restrain yourself from the impulse to ask questions prematurely until the other person has fully expressed their thoughts.

Evaluation of Communicator Effectiveness

Some people do a good job of communicating and others do not. However, being a good communicator is not a skill that is present at birth. Communication is a learned skill, just as being a good aircraft mechanic. Effective communicators exhibit certain traits and skills that set them apart from people who are not consistently effective. Understanding these characteristics can help develop a roadmap for anyone who wants to be more effective as a communicator.

Skill for Creating Messages. Effective communicators can create messages that are meaningful to their audience and efficient in content. That is, messages are perceived as:

- semantically sane
- revealing something about the communicator
- demonstrating that the communicator knows what he or she is talking about
- clear and coherent
- making sense
- coming from someone who knows what they are doing
- being developed and presented in an open and positive manner

Similarity to Receiver. It is commonly observed that we place more credence in information coming from someone who is "one of us." That is, messages are perceived as coming from someone:

- with a similar background to the receiver
- who has interests similar to those of the receiver
- who has attitudes that are similar to those of the receiver
- who has opinions similar to those of the receiver

- who is liked by the receiver and others
- who is physically and psychologically attractive to the receiver
- who understands things through the other person's point-of-view
- who is poised
- who is genuine and sincere

Adaptability. We have all experienced the frustration that comes with applying inflexible corporate policies. Messages are given more credence, if they are viewed as adapting to changing situations and contexts. That is, messages are perceived as:

- coming from someone who is aware of the impact of the messages
- being appropriate to the purpose of the communication
- coming from someone who is able to adapt their communication behavior to the situation at hand
- coming from someone who is able to adapt to the prescribed role in the situation
- coming from someone who express themselves in more than one way
- coming from someone who uses language appropriate to the receiver
- being responsive to others

Commitment to Others. Messages from ego- or company-centric individuals are given less credence than messages from people with our best interests at heart. That is, the most effective messages are perceived as coming from someone who demonstrates:

- concern that the interaction be mutually beneficial
- reliability and dependability
- support for others
- concern for the needs and wants of others
- adaptation to others
- respect and acceptance of others
- the ability to avoid immediate value judgments

Listening Ability. The most effective communicator is one who knows how to receive, as well as give, information. That is, messages will be most effective when they are perceived as coming from someone who:

- is an effective listener
- is sensitive to verbal and nonverbal messages
- is interested in listening to what others have to say
- doesn't confuse the source with the message
- can say the right thing at the right time
- tolerates and adjusts to distractions

Table 10-4 provides a self-evaluation rating sheet that will allow people to assess their existing communication skills.

Table 10-4. How Competently Do You Communicate?
(from: *Communicating with Competency,* L.B. Rosenfeld and R.M. Berko, Glenview, IL: Scott, Foresman, Little, Brown)

Directions: Following is a list of communication skills. Indicate how often you use each skill and how satisfied you are with your ability.

Use the following scale to indicate how often you use each skill: 5 = All or most of the time (91-100% of the time) 4 = Often (71-90% of the time) 3 = Sometimes (31-70% of the time) 2 = Rarely (11-30% of the time) 1 = Never or almost never (0-10% of the time)	Use the following scale to indicate how satisfied you are with your use of each skill: 5 = Very Satisfied 4 = Somewhat Satisfied 3 = Neither Satisfied or Dissatisfied 2 = Somewhat Dissatisfied 1 = Very Dissatisfied	
	How Often	How Satisfied
1. I listen effectively.		
2. I use appropriate words for the situation.		
3. I use appropriate pronunciation for the situation.		
4. I use appropriate grammar for the situation.		
5. I use effective eye contact.		
6. I speak at a rate that is neither too fast or too slow.		
7. I speak fluently (avoiding “uh,” “you know,” awkward pauses, etc.)		
8. My movements, such as gestures, enhance what I say.		
9. I give appropriate verbal and nonverbal feedback.		
10. I use vocal variety when I speak.		
11. I speak neither too loudly nor too softly.		
12. I use appropriate facial expressions.		
13. I understand a speaker’s main ideas.		
14. I understand a speaker’s feelings.		
15. I distinguish facts from opinions.		
16. I distinguish between speaking to give someone information and speaking to persuade someone to think, feel, or act a paticular way.		
17. I recognize when a listener does not understand my message.		
18. I express ideas clearly and concisely.		
19. I express and defend my point of view		
20. I organize messages so others can understand them.		
21. I use questions and other forms of feedback to obtain and clarify messages.		

Table 10-4. How Competently Do You Communicate? (from: *Communicating with Competency,* L.B. Rosenfeld and R.M. Berko, Glenview, IL: Scott, Foresman, Little, Brown)		
22. I respond to questions and other forms of feedback to provide clarification.		
23. I give understandable directions and instructions.		
24. I summarize messages in my own words and/or by taking notes.		
25. I respect another's viewpoint.		
26. I respect differences of opinion.		
27. I express my feelings and opinions to others.		
28. I initiate and maintain conversations.		
29. I recognize and control my anxiety in communications situations.		
30. I involve the other person in what I am saying.		
Total:		
Scale: Compare your totals with the following ranges:		
How Often 135-150 = Communicate skillfully all or most of time 105-134 = Often communicate skillfully. 75-104 = Sometimes communicate skillfully. 45-74 = Rarely communicate skillfully. 30-44 = Never or almost never communicate skillfully.	**How Satisfied** 135-150 = Very satisfied with my communication skills 105-134 = Somewhat satisfied with my communication skills. 75-104 = Neither satisfied or dissatisfied with my communication skills. 45-74 = Somewhat dissatisfied with my communication skills. 30-44 = Very dissatisfied with my communication skills.	

WHERE TO GET HELP

The Human Factors and Ergonomics Society (HFES) is the primary professional organization in the U.S. for human factors professionals. There are a number of members of the HFES who specialize in communications and even directly in MRM.

Human Factors and Ergonomics Society (HFES)
PO Box 1369
Santa Monica, CA 90406
310.394.1811
http://www.hfes.org

The National Communication Association is basically a professional society that supports scholarship in the field of communication.

National Communication Association
1765 N Street, NW
Washington, DC 20036
202.464.4622
http://www.natcom.org

The Dogwood Project at the Northern Virginia Community College is a virtual learning environment that consists of several web-based products. The Interpersonal Web is a great resource for communication-related information and links.

Northern Virginia Community College
The Interpersonal Web
http://novaonline.nv.cc.va.us/eli/spd110td/interper/index.html

EXAMPLE SCENARIO

As a manager, you've come to believe that the ability to effectively communicate might be the single most important element in any manager's success (or lack of it). You'd like to objectively measure and improve the communication ability of your supervisors. You'd also like to evaluate the communication ability of the people you're thinking of promoting. You don't really know how to do these evaluations or if there are any formal criteria for doing them.

Issues

1. Are there any criteria this manager can use to evaluate the communication skills of his supervisors?

2. Is there any way the manager can use the opinions of each supervisor's technicians and inspectors regarding the supervisor's ability to effectively communicate?

3. If this manager wants to develop a written feedback survey related to effective communication skills, what sorts of items should he or she include on the survey?

Responses

1. Table 10-4 and its accompanying discussion contain a series of elements related to effective communicators. Table 10-4 is meant to assess an individual's communication skills. Although this table is designed to be a self-evaluation form, it can easily be adapted to evaluate other people. In addition, the GUIDELINES section contains a subsection, Evaluating Effective Communicators, that lists a number of necessary and desirable attributes of effective communicators. The manager in this scenario could extract a number of evaluation items from these sources.

2. Communication is a process that involves both the sender and the receiver of a message. A key element of being an effective communicator is that your audience perceives you as being effective. For this reason, surveying technicians and inspectors regarding a supervisor's communication skills is a very reasonable thing to do. While we don't address this issue directly in the Guide, it might be very interesting to ask supervisors to complete the self-evaluation form in Table 10-4 and then ask the workers who report to each supervisor to fill out the same form regarding their supervisors' communication skills. Comparing the two sets of responses might provide insight into any perception problems that exist.

3. The two sources noted in the previous response will also serve as a good starting point for developing a written survey. Often, the results from written surveys are misleading. The responses to survey items are easy to influence inadvertently by the construction of the questions or statements. If you have access to a human factors professional, it would be good to get their help when developing a written survey or an interview form.

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CHAPTER 11: ETHICS IN MAINTENANCE

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LANDING PAGE

Members of the flying public, flight crews, and their families routinely put their trust in the people who maintain commercial aircraft. This confidence in the abilities of aircraft maintainers has a solid basis in fact, experience, and statistically safe performance. Inherent in that trust, is the idea that the people who maintain aircraft and those who manage and regulate those maintainers will always do the "right" thing when it comes to ensuring the airworthiness of the aircraft on which we fly. For the overwhelming majority of maintenance decisions made each day, the people responsible for aircraft safety do the right thing—even at the cost of delays, lost revenue, and job security.

Doing the right thing implies that the thousands of decisions made each day are based on a solid moral and ethical foundation. However, in addition to being a professional vocation, aviation maintenance is also a business that is conducted and managed by people. As such, it is subject to the same personal, political, and financial pressures that often result in same poor decision-making we've seen in other businesses.

The study of ethics has a very long history, which is ample evidence of the general interest in the topic. Because ethical behavior has been extensively examined, there exists a commonly accepted framework within which aviation maintenance decisions and tasks can be evaluated.

This chapter describes some of the fundamental concepts related to ethical decision-making and job performance. It also relates these concepts directly to the aviation maintenance environment and uses some examples to illustrate the forces that drive maintainers and managers towards and away from making ethical decisions.

INTRODUCTION

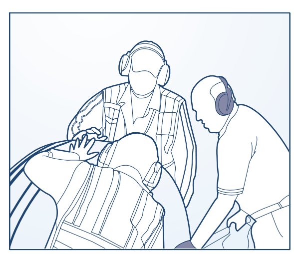
From an airline operations perspective, aircraft maintenance is not a revenue-producing activity. Anytime an aircraft is on the ground, it is not producing revenue. Therefore, there tends to be a significant amount of pressure (either implicit or explicit) on the maintenance personnel—whether within the airline organization or at a third-party repair station—to minimize the ground time and release the aircraft back in revenue service.

There are three groups with primary responsibility for aircraft maintenance: Aircraft maintenance technicians/engineers (AMTs), maintenance managers, and regulators. While all three groups have an overriding goal of ensuring airworthiness of the aircraft, each has a different perspective, as noted below.

- AMTs have a professional responsibility to ensure the airworthiness of the aircraft.
- Maintenance managers are responsible for minimizing the aircraft downtime
- Regulators are responsible for ensuring compliance with legal requirements

The responsibilities of these groups are not mutually exclusive. Most of the time, the groups work harmoniously and everyone is comfortable with the fulfillment of each other's roles and responsibilities. However, there are times when safety and productivity goals clash. Under such circumstances, if the AMTs decide to "hold the line" on all the maintenance standards, they tend to escalate the maintenance expenses. This might threaten the financial viability of the organization. On the other hand, if the managers decide to "hold the line" on the production schedule, they might put the passengers, employees, and ultimately the company at risk. Typically, the regulators do not know about the maintenance compromises because it is impossible for them to oversee the thousands of individual maintenance actions. Since regulators tend to get their information from maintenance records, which are reviewed after the maintenance has been completed, there is always a level of inherent risk on part of the regulator.

The purpose of this chapter is to present some fundamental concepts about ethics, apply them to the real world of aviation maintenance, and help maintainers, managers, and regulators understand and support each other's roles and responsibilities from an ethical perspective.



REGULATORY REQUIREMENTS

The ethical basis of safety in aviation is reinforced by a series of regulatory requirements. These regulations vary somewhat from country to country. For example, in the United States, the aircraft designers and manufacturers are required to demonstrate compliance with 14CFR § 23 or 25 for general aviation or transport category airplanes, respectively. Next, the operators (airlines) are required to maintain the airplanes in accordance with the requirements of §121.363 or 135.413. Next, the individual aircraft mechanics, inspectors, and repairmen are expected to perform maintenance actions in accordance with the privileges and limitations specified in 14CFR §§ 65.81, 65.95, and 65.103, respectively.

In general terms, the role of AMTs is to ensure that the aircraft on which they perform maintenance conform to the applicable airworthiness requirements. The role of the airline is to ensure that sufficient infrastructure exists for proper maintenance of its aircraft. Regulators are required to report any unsafe conditions or acts and have the authority to ground the aircraft. Per 14CFR 43.12, falsification, reproduction, or alteration of maintenance records is prohibited. Per 14CFR 43.13, maintenance personnel are required to use approved maintenance publications when performing maintenance; therefore, failure to follow approved maintenance procedures is a regulatory violation. The AMTs and the regulators are primarily entrusted with the safety of the aircraft.

In Canada, the responsibilities of the individual maintenance engineers, operating certificate holders (airlines) and regulators are similar to those in the United States, but there is one notable exception: the "Accountable Executive". The amendment to CAR 106.02 established the requirement for all air operators and approved maintenance organizations to designate a particular Accountable Executive who will be responsible for discharging the safety responsibilities of the certificate holder. The regulatory emphasis and the requirement for this individual to accept responsibility via a signed statement brings a higher level of visibility and accountability.

In addition to the basic maintenance standards, according to the European Aviation Safety Agency (Part 66.B500), a maintenance technician/mechanic/engineer's certification could be revoked if one of the following conditions exists:

- Failure to carry out requested maintenance combined with failure to report such fact to the organization or person who requested the maintenance.
- Failure to carry out required maintenance resulting from own inspection combined with failure to report such fact to the organization or person for whom the maintenance was intended to be carried out.
- Negligence in maintenance actions
- Falsification of the maintenance record.
- Issuance of a Certificate of Release to Service (CRS) knowing that the maintenance specified on the CRS has not been carried out or without verifying that such maintenance has been carried out.
- Carrying out maintenance or issuing a CRS when adversely af fected by alcohol or drugs.

Clearly, FAA, Transport Canada, and EASA are raising the specific performance expectations from the maintainers and maintenance organizations to a higher safety standard.

CONCEPTS

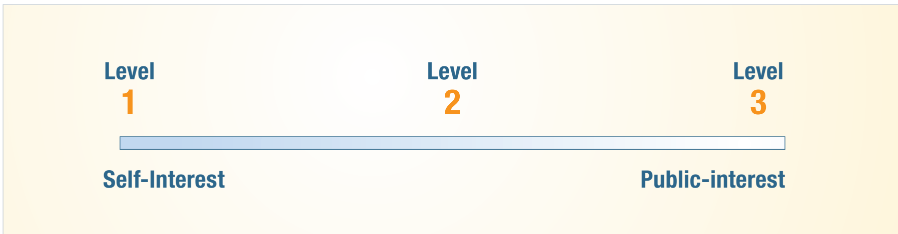
Ethics

Ethics, in overly simplified version, is a code of behavior that encourages human actions in support of a good life. In short, it's choosing the "right" course of action in situations where one can choose among several courses of options.

Levels of Decision Makers

When people make decisions in the aviation maintenance environment, they typically have a choice of deciding to do what is ethical or not. In the field of ethics, decision makers are classified as one of three general types, as follows:

Level 1: A person who makes decisions solely on the basis of self interest
Level 2: A person who makes decisions based primarily on social standards
Level 3: A person who makes decisions based primarily on the Principle of Respect



Principles of Ethical Behavior

The following seven key principles of ethical behavior, presented in a prioritized order, are discussed in this chapter:

1. The Principle of Respect—Treat others as you want to be treated.
2. The Principle of Non-Malevolence—Do no harm with your actions.
3. The Principle of Benevolence—Act to promote the well-being of others.
4. The Principle of Integrity—Conduct yourself professionally.
5. The Principle of Justice—Treat people fairly.
6. The Principle of Utility—Choose the actions that promote the greatest good for the greatest number of people.
7. The Principle of Double Effect—Choose actions so the good effects are greater than the bad effects.

Because they focus on the core issue of human dignity, these principles are independent of national, professional, and organizational cultures as well as religious beliefs.

METHODS

This section focuses on application of a moral decision-making process to the aviation maintenance environment.

Like many professional organizations, the Professional Aviation Maintenance Association (PAMA) has published the Code of Ethics for Maintenance Personnel and the Aircraft Engineers International organization has also published a Code of Professionalism. Some of the key elements common to these codes are as follows:

- Maintenance professionals are responsible to the general public.
- Maintenance professionals are expected to maintain currency of knowledge, exercise truth, integrity and honesty in their judgment,

and work within the scope of their expertise.
- As professionals, aircraft maintainers are expected to remain loyal to the general public and refrain from compromising safety for personal gains.
- Maintenance professionals are expected to exercise assertiveness and not allow their superior to pressure him/her to approve aircraft or equipment as airworthy under questionable circumstances.

The detailed Code of Ethics presents a general reminder of the responsibilities associated with the privileges of an aircraft maintenance technician/mechanic/engineer. It reminds the certificate holder that his/her primary obligation is to the flying public more than the employer.

PAMA/SAE Institute Code of Ethics

The Professional Aviation Maintenance Association implores each certified person to exemplify the philosophy and discipline of professional maintenance in every aspect of their life. Every PAMA/SAE Institute certified professional must be intolerant of unethical behavior and act to swiftly eradicate it. In this way, morality and integrity will remain the essence of the certified aviation maintenance professional.

To be in compliance with the PAMA/SAE Institute Code of Ethics, all certified members are to contribute to ensuring the highest levels of airworthiness and ethics. This includes the following responsibilities:

- Safety
- Continuous Education
- Respect
- Non-discrimination
- Honesty
- Orderly Behavior
- Loyalty
- Lawful Conduct
- Fairness
- Proper use of Influence of Position

Failure to Comply may result in Revocation of Certification

This code was originally developed by Jerry Lederer, founder of the Flight Safety Foundation. It is printed with permission from PAMA

Ethics Checklists

The Federal Aviation Administration has developed the following set of pre- and post-task checklists that are intended to remind the maintenance personnel of their responsibilities.

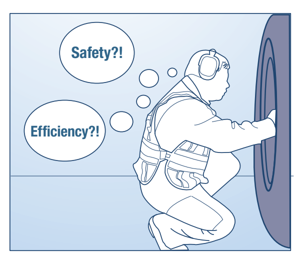
Pre-Task Checklist

- ☐ Do I have the knowledge to perform the task?
- ☐ Do I have the technical data to perform the task?
- ☐ Have I performed the task previously?
- ☐ Do I have the proper tools and equipment to perform the task?
- ☐ Am I mentally prepared to perform the job task?
- ☐ Am I physically prepared to perform the task?
- ☐ Have I taken the proper safety precautions to perform the task?
- ☐ Have I researched the FARs to ensure compliance?

Post-Task Checklist

- ☐ Did I perform the job task to the best of my abilities?
- ☐ Was the job task performed to be equal to the original?
- ☐ Was the job task performed in accordance with appropriate data?
- ☐ Did I use all the methods, techniques, and practices acceptable to the industry?
- ☐ Did I perform the job task without pressures, stress, and distractions?
- ☐ Did I reinspect my work or have someone inspect my work before return to service?
- ☐ Did I make the proper record of entries for the work performed?
- ☐ Did I perform the operational checks after the work was completed?
- ☐ Am I willing to sign on the bottom line for the work performed?
- ☐ Am I willing to fly in the aircraft once it is approved for the return to service?

AMTs are often placed in situations that tend to challenge them to trade off safety against efficiency. Sometimes, they find themselves faced with maintenance actions for which they are either not trained or don't have the appropriate tools, parts, supplies, or equipment. The following decision-making process is presented to help AMTs as well as managers make consistent ethical decisions that are grounded in the fundamental tenets of moral decision-making.



It is important to emphasize that the priorities of the different groups responsible for the aircraft maintenance process can be (and often are) quite different. For example, managers are evaluated based on their ability to get the work accomplished on time—hence production is a key yardstick of performance. Similarly, maintenance planners are evaluated on their ability to improve the efficiency of the maintenance process. Maintenance technicians/engineers, on the other hand, are evaluated by their ability to return the aircraft to service. Typically, there are no annual performance evaluations for mechanics; once they pass the probationary periods, the rest of the salary increments are typically based on seniority and specific qualifications/certifications.

Moral Decision-Making Framework

In reality, AMTs are often placed in situations that tend to force them to trade off safety against efficiency. Sometimes, they find themselves faced with maintenance tasks for which they are either not trained or don't have the appropriate tooling, parts, supplies, or equipment. The following decision-making process is presented to help maintenance AMTs as well as managers make consistent ethical decisions that are grounded in the fundamental tenets of moral decision-making.

Since ethical behavior implies doing the right thing, it is reasonable to ask how one determines the "right" thing in a particular situation. Answering the following questions can help establish a reasonable moral framework for making maintenance-related decisions:

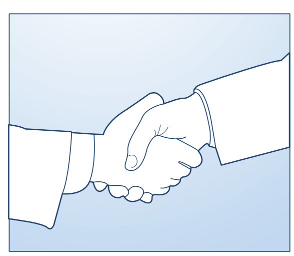
- **Intent:** What do you intend to do? How does it measure up against the Principle of Respect? Is it morally permissible, impermis sible, or obligatory?
- **Motive:** Why do you intend to do it? How does it measure up against the Principle of Respect? Is it morally permissible, impermissible, or obligatory?
- **Circumstances:** What are the circumstances under which you must act? What are the alternative actions or inactions?
- **Decision:** What is your final decision?
- **Action:** What action must you carryout?
- **Outcome:** What is the foreseeable good outcome of your action? What is the foreseeable bad outcome of your action? What is the unforeseeable bad outcome of your action? Is the intended good outcome clearly "worth" the unintended, foreseeable or unforeseeable bad outcome? Are you willing to live with the outcome?
- **Due Diligence:** Have you done everything possible to minimize the foreseeable bad outcome and made every effort to identify all of the bad outcomes?

GUIDELINES

This section describes in detail the seven key principles of ethical behavior, the three levels of decision-makers, and uses examples to illustrate how to use the moral decision-making framework described in the previous section. It might be useful to note that these principles can be used in any context—on the job or life in general.

The Seven Key Moral Principles

1. The Principle of Respect:
Treat every person with the respect befitting the dignity and worth of a fellow human being. In other words, treat others as you wish to be treated.

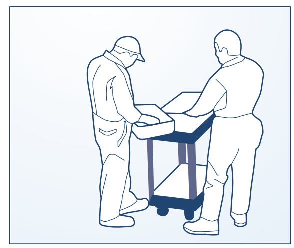


Applying this principle to the maintenance environment, treat co-workers, the flight crew, and the passengers with the same respect and dignity as with which you would want to be treated.

Passengers have paid the fare for their transportation and have an expectation of safe transportation in exchange. Similarly, the flight crew has an expectation of airworthiness, which, by extension, is an assurance of safety. The passengers and the crew are relying on the integrity of the airworthiness system, which in turn is assured by the regulatory oversight process. Therefore, they are expecting that the the maintainers, airlines, and the regulator have done everything possible to assure safe transportation.

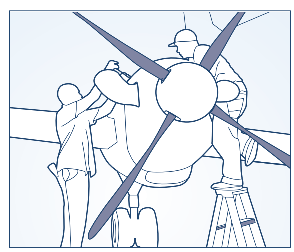
The principle of respect is at the intersection of the responsibility and obligation of every party involved in safe transportation by air.

2. The Principle of Non-Malevolence:
In all your actions, avoid harming people.



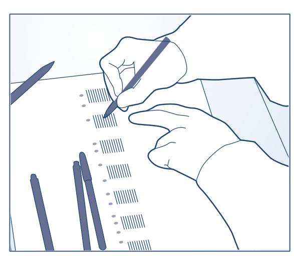
In the maintenance environment, don't harm people or property through negligence, either through omission or commission, or by deliberate sabotage. Aircraft maintenance personnel are entrusted with the security and care of expensive equipment and they are given access to restricted areas. These privileges must be respected and not used for personal or political gains.

3. The Principle of Benevolence:
Promote the well being of others.



Aircraft maintainers have the opportunity to help their fellow professionals improve their knowledge and skills as well as to use all available means to improve the maintenance system. If there are any known discrepancies in the system that creates safety hazards, maintainers, as professionals, are expected to address those issues and improve the system.

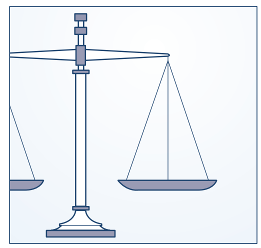
4. The Principle of Integrity:
Maintain personal standards of conduct befitting a professional. Respect yourself in all of your decisions so as to be worthy of living a fulfilling professional life



The entire airworthiness system, and by extension, the aviation safety system, is dependent on the professional integrity of all the individuals who participate and interact with the system.

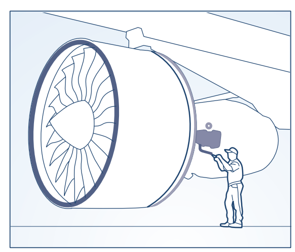
The pilots and the regulators trust the maintainers' signatures on the airworthiness release (and all the intermediate documentation). These signatures are essentially a promise that all maintenance actions have been accomplished in accordance with the appropriate functional regulatory requirements and that the aircraft conforms to the current airworthiness standards.

5. The Principle of Justice:
Treat people fairly as human beings. Do not judge them prematurely or unfairly.



In all professional endeavors, people commit errors. Errors are, by definition, unintentional. One must treat everyone fairly and examine the circumstances under which they committed the error. Would another equally qualified person in similar circumstances have committed a similar error? What can be learned from the error that would benefit the system and protect other people from harm? Similarly, from a manager's perspective, one must not place people into situations in which they are coerced to compromise their integrity.

6. The Principle of Utility: Given that one's intentions and goals are morally permissible or obligatory, one must choose the course of action that produces the greatest benefit for the greatest number of people.

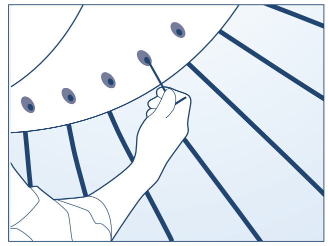


One place to apply this principle would be in the context of an error reporting system. When a person files an error report, that person expects fair and respectful treatment.

The standards applied to addressing reported errors must distinguish between those committed in the course of conscientious job performance and those that result from gross negligence. For most errors, analyzing and adjusting the conditions that produced the error will minimize recurrences. In extreme cases, the response to an error might include disciplining or even firing those directly involved in the committing the error.

In cases of intentional disregard for safety, a disciplinary action may be warranted. In such cases, the intention is to improve the safety of the aviation system and termination of employment is morally permissible. Arguably, such an action produces greatest benefit to the greatest number of people because it removes the inadequately prepared individual from the system, instills a sense of justice and fairness among competent hardworking professionals, and enforces performance standards that clearly distinguish between negligence and honest mistakes.

7. The Principle of Double Effect:
The foreseeable good effects of an action should heavily outweigh the foreseeable bad effects of the action.



If the main effect of an action is to ensure airworthiness of the aircraft, and taking a delay is the foreseeable bad side effect, the delay is a morally acceptable bad side-effect. The term “foreseeable” implies that one thinks about the consequences on their actions before they embark upon the actions.

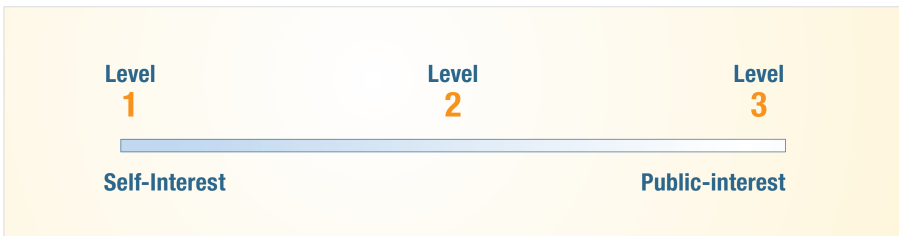
In the extreme (and hypothetical) case where an employee is outraged with the safety violations in the company, has tried all possible internal avenues to correct those safety problems, and is now ready to call the regulator or the media and blow the whistle, the individual should weigh the benefits of the intended good versus the foreseeable bad side-effects. The term “foreseeable” implies that one thinks about the consequences of one’s actions before embarking on them.

In this example, the employee may be successful in getting getting regulator or the media’s attention and thereby addressing the safety violations, but it is also possible that the entire company would shut down and hundreds of people would lose their livelihood. While one person might argue that nobody has the right to make decision that singularly impacts the livelihood of several people, another might argue that nobody has the right to make a living where people can get hurt. The point is that one should weigh the foreseeable bad side-effects and take actions that are consistent with the principle of respect.

Three Levels of Moral Decision-Making

Given a moral dilemma, people's decisions can be classified into three levels, , which define the degree to which the decision is based on self-interest or public-interest (not to be confused with popular opinion).

- Level-1 decision-makers choose their actions based on self-interest.
- Level-2 decision-makers choose their actions in accordance with the social norms.
- Level-3 decision-makers choose their actions in accordance with the principle of respect.



For example, a person who decides not to sign-off maintenance actions that have not been performed because he is afraid of getting caught and losing his license/certification, is a Level-1 decision-maker. A person who makes the same decision because he is afraid it would not be acceptable to his peers and he would risk social segregation, is a Level-2 decision-maker. A person who makes the same decision because it would be disrespectful to the passengers and crew who expect him to maintain the highest standards of integrity, is a Level-3 decision-maker.

This classification is based on the rationale that was used to arrive at the decision, rather than the decision itself. Therefore, the training goal should be to raise awareness of the principle of respect and encourage maintainers to make decisions that are consistent with that principle. Organizations such as labor unions and professional societies, as well as individual mentors, can be very effective in helping new AMTs develop such decision-making criteria.

Application of the Moral Decision-Making Framework

The basic moral decision-making framework was presented earlier in the form of intent, motive, circumstances, decision, action, outcomes, and due diligence. Under this framework, one must be able to demonstrate that the foreseeable-unintended-bad effects are not disproportionate to the intended-good effects of an action. Since most decisions have to be made under a certain level of uncertainty, as additional information becomes available and the degree of uncertainty changes, one must re-evaluate the decision and make appropriate changes, if possible. Such ability and willingness to continuously monitor the situation and make changes so as to keep the actions consistent with the ethical principles is due diligence.

In the aviation maintenance environment, most actions are governed by a number of legal requirements. Illegal actions, i.e., those that involve clear violations of a legal requirement, don't require the application of the moral framework. The actions are illegal, after all. For example, it is illegal for a mechanic to sign-off an aircraft that is not in full compliance with airworthiness requirements—regardless of his or her reasons for doing so.

This sounds straightforward. However, mechanics sometimes find themselves in a grey legal area. For example, suppose the available and approved procedures are flawed (and commonly acknowledged to be incorrect or unworkable). Adherence to such procedures may endanger the aircraft's safety. According to regulation, violation of the existing procedures is illegal. In these situations, mechanics tend to accomplish the maintenance task using a "workaround" solution, which they have developed through experience, and sign off the published procedures. Workarounds are almost always done with the full knowledge and implicit consent of management.

Workarounds are fraught with practical, legal, and ethical problems. Analyzing this scenario through the moral decision-making framework will reveal the following;

- **Intent—**The intent is to prevent making a mistake in accomplishing the maintenance task.
- **Motive—**The primary motive is to ensure the airworthiness of the aircraft being maintained.
- **Justification—**The justification for the workaround is that the published procedure is flawed.

Since the intent and motive are morally permissible, the analysis can proceed. The circumstance that prompts a workaround (rather than officially getting the procedures corrected) is that getting the procedures corrected is a time-consuming and mostly ineffective process. Maintenance on the aircraft could be held-up for a long time until the procedures are corrected.

An alternative to simply working around the flawed procedure based on personal judgment is to seek field authorization from the regulator or the aircraft or part manufacturer's engineering group. This would involve another party to objectively examine the task and assist in developing a mutually acceptable solution. Then, the decision could be to go ahead with the field-authorized procedures.

The intended good is completing the maintenance task without committing an error. The unintended foreseeable bad outcome is the failure of the new procedure. The unintended unforeseeable bad outcome is that the new procedures might introduce another error in the system and could potentially increase the risk of failure. Seeking field approval from the regulator or the engineering group provides for the necessary due diligence.

Ethics in Maintenance Management

The aviation maintenance workplace exhibits an interesting ethical contradiction. On the one hand, most maintenance managers rise from the mechanic/engineer ranks. However, the management-employee relationship is so strained that about one third of the AMTs in the United States don't trust their managers to act in the interest of safety. Why should this situation exist?

After studying a wide variety of aviation maintenance organizations for over 10 years, particularly in the United States, the author is able to make the following observations:

- The field level employees (AMTs/AMEs) are primarily concerned about the airworthiness of the aircraft—their professional licensure/certification demands that they pay attention to the effectiveness of the maintenance process.

- Mid-level managers are primarily concerned about the business success or production success of their organizational unit—their job evaluations demand that they pay attention to the efficiency of the maintenance process.

- Top-level managers are primarily concerned with the reputation of their organization, which is believed to drive business success. Therefore, their success rides on the overall ranking/rating of their organization by their stakeholders and customers.

- In times of fierce business competition or struggle for survival, cash flow tends to be over-emphasized. The thinking seems to be that the quality of maintenance will not be an issue if the company does not survive in the short term. Consequently, the number of compromises to maintenance safety tends to increase as managers take greater risks. They hope that they will be able to make the company last long enough to have the resources to address the maintenance needs in the future. In some cases, the managers know that they will be renewing their fleet and therefore tend to ignore the maintenance needs of the older aircraft.

- Ethical compromises tend to stem from resource challenges. When the resources are plentiful, it is easier to abide by ethical principles. When resources are scarce, one is forced to prioritize one's values and make a choice. Examples of poor choices include the following:
    - the manager who schedules inadequately trained mechanics to work on specific systems
    - the mechanic who chooses to work overtime in spite of exhaustion and deteriorated physical/mental capacity to handle the required tasks

When faced with limited resources, people tend to make risk-based decisions. In some cases, these decisions are grounded in well-established safety risk management framework; more frequently, however, such decisions are based on the individual/personal intuition of the manager.

WHERE TO GET HELP

Online Resources

General Resources in Applied Ethics
http://www.ethics.org/
http://www.scu.edu/ethics/
http://www.ethicsweb.ca/resources/

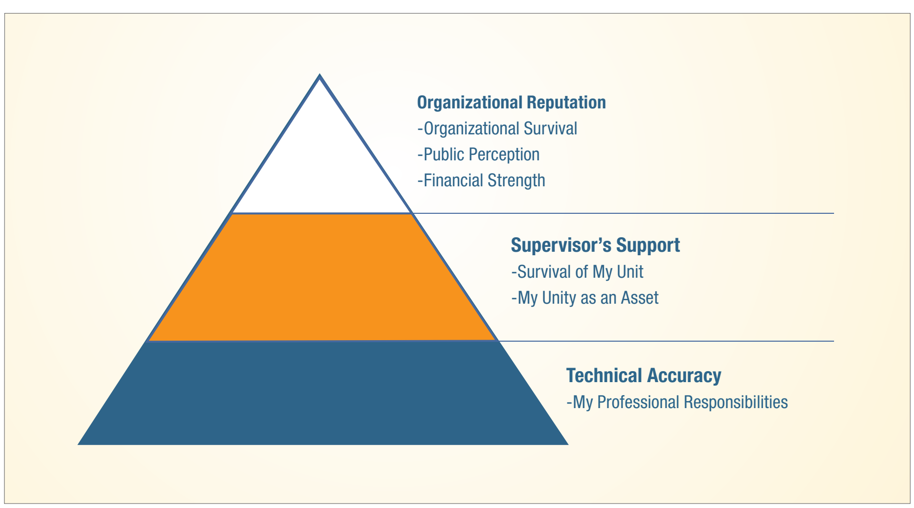
Aviation/Engineering Applications
Engineering Ethics: http://www.onlineethics.org/
PAMA's Code of Ethics for Aviation Maintenance Technicians: http://pama4.timberlakepublishing.com/content.asp?contentid=159
Aircraft Engineers International's Code of Professionalism: http://www.airengineers.org/Professionalism
Do Engineers Owe Duties to the Public? http://www.raeng.co.uk/news/publications/list/lectures/Engineering_Ethics_Lecture.pdf

Management Applications
http://www.ethicscentre.ca/EN/index.cfm
http://www.web-miner.com/busethics.htm

Case Studies
http://www.vanderbilt.edu/CenterforEthics/cases.html
http://www.engineering.com/Library/ArticlesPage/tabid/85/articleType/ArticleView/articleId/70/BF-Goodrich.aspx
http://www.scu.edu/ethics/dialogue/candc/cases/product-safety.html

EXAMPLE SCENARIOS

In a typical aviation maintenance organization, there is a pyramid of employees: at the bottom of the pyramid are the frontline employees who are primarily responsible for maintenance of the aircraft; at the middle of the pyramid are the supervisors and managers who are primarily responsible for the "production"—making sure that the maintenance tasks are carried out in the budgeted time and resources; at the top of the pyramid are the top managers who are primarily responsible for the organizational reputation, which includes public perception, financial strength, and overall organizational survival.



Since these three levels of employees have different perspectives and priorities, they often tend to have difficulty communicating amongst them, particularly on safety issues.

Three scenarios are presented below. These scenarios are drawn from interviews and archival document research of factual circumstances; however, they are sufficiently de-identified to protect the identity of the individuals as well as their organizations.

Scenario 1: The Safety Martyr

The Facts

"Bob," an administrative employee (not a licensed AMT), was responsible for managing the maintenance records and coordinating warranty claims with the Original Equipment Manufacturer (OEM). He discovered that three third-party maintenance providers were using unlicensed AMTs to sign-off work and return the aircraft to service. It is not unusual for third-party maintenance providers or repair stations to employ a much larger unlicensed technical workforce than airlines because they use the repair station authorization to approve the work, not their individual license. Only a select number of individuals are usually authorized to return the aircraft or the component to service under the repair station's authorization. However, the point is that Bob discovered a technical problem that could have a range of legal and safety consequences.

The Ethical Issue

If unlicensed people were signing off the maintenance work and it was not covered under the repair station's authorization, it was illegal. As a customer organization, Bob's airline is still liable for this work and could face fines from the FAA. The airworthiness of the aircraft is questionable If the maintenance work was not performed properly, nor inspected/approved by a licensed AMT. Clearly, Bob had an ethical challenge.

Bob's intent was to ensure safety was not being compromised; his motive was simply his respect for the flying public. As far as the flying public is concerned, they don't know or care where the maintenance was performed, as long as it was performed in accordance with the Federal Aviation Regulations. The circumstances were such that an increasing amount of maintenance work was being outsourced as the airline was engaged in aggressive cost-cutting, the labor unions were upset with the management, and it was difficult to clearly determine whether safety was being compromised.

The alternative to speaking up was to say nothing. If Bob did not say or do anything about this situation, the outsourced maintenance would continue and the apparent errors would go unchallenged. If Bob was correct in his assessment, the airline could lose an aircraft and such an accident could certainly accelerate the airline into bankruptcy (there are plenty of such examples in the industry). If Bob was wrong, and it was just a clerical error, the airline would continue to operate as before, but Bob would sleep much better—reassured that the aircraft and the flying public are not in any danger.

The Analysis

Bob had to make a decision: to act or not to act. Bob spent a month collecting data and determining the gravity of the problem. In his research, Bob discovered several documentation discrepancies—it was not conclusive whether these were just documentation issues or they were just symptoms that maintenance was not being accomplished.

Bob contacted his supervisor, but was brushed off. The supervisor told Bob that it was just a clerical issue and it's not his concern—the persons who are responsible for accepting the aircraft from the repair station should be concerned about these issues. Bob was not satisfied with the answer, so he complained to the FAA.

Bob did not fully analyze the potential consequences of his action. He thought he was doing the right thing by going to the FAA. He also thought that the federal Whistleblower Protection Act would protect him from any retaliation by the employer. However, he did not know of any previous incidents where an employee was protected by the Whistleblower Protection Act or how he would go about securing such protection. The undesirable side-effect of his filing a complaint with the FAA was that he could lose his job.

From the perspective of the three levels of decision-makers, Bob was clearly a level-3 decision maker. He wanted to go to the FAA because he thought it was the right thing to do. He was aware of the possible intended and unintended consequences of his decision. He was willing to accept the consequences.

The Consequences

The airline terminated Bob for violating the airline's confidentiality policy. Moreover, the whistleblower protection can be trumped if the company is under bankruptcy protection—Bob did not know this critical fact. Six months after Bob was terminated, the FAA discovered that there were legitimate problems with the maintenance documentation. They fined the airline, but the fine was reduced after negotiations. Eventually, the repair station reimbursed the airline.

The Moral of the Story

In this case, Bob became a safety martyr. He sacrificed his job to seek improvements in safety. It is not clear whether there were legitimate safety issues at stake or not because the evidence only points toward documentation errors.

The key point to take away from this example is don't be in a hurry to be a martyr—do your homework, find appropriate internal channels to improve safety, and collect documentation regarding the effectiveness of the existing channels. Consult an attorney to ensure that you can be protected by the Wendell H. Ford Aviation Investment and Reform Act (http://www.osha.gov/dep/oia/whistleblower/acts/air21.html) because the burden of proof rests on the complainer. Then, decide whether or not you are ready to take the next step. In similar cases, people have taken a stand and complained to the company. The company has terminated them for insubordination, but subsequently, the company has taken them back and given them back pay because they could not find sufficient grounds to terminate them.

Scenario 2: Cost-cutting can lead to safety concerns

Reportedly, an airline's three major costs are labor, fuel, and maintenance. For an airline that is battling an impending bankruptcy or other serious financial challenge, the pressures on managers are twofold: first, reduce operating costs and second, improve production. The following is a scenario from a manager's perspective.

The Facts

"John" started with the airline as a mechanic, learned the maintenance tasks and progressed to management. As a mechanic, his priority was airworthiness of the aircraft. As a manager, his priority is on-time performance. His year-end bonus is tied to the performance of his unit—he needs to be effective in releasing his aircraft for revenue flight within the short time available on a gate. If his aircraft is delayed, he doesn't get his annual bonus; his mechanics on the other hand do not receive such a performance bonus. Also, his maintenance budget has been shrinking—he cannot simply assign more people on a job or hold extra parts in inventory because he doesn't have the budget to do so.

One night, an airplane arrived at John's gate and the pilot noted that the right aileron jerked to the right while airborne. The aircraft also had a blown tire. John did not have sufficient mechanics to address both issues.

The Ethical Issue

While the blown tire was obvious and had to be replaced in order for the flight to continue, John did not have the time or the resources to open up the aileron assembly and investigate that problem further. There was a chance that it was just an anomaly and may not happen in the air again. There was also the chance that something more serious was wrong, and because this was a primary flight control surface, he should investigate if further, repair if needed, and test fly the airplane in order to thoroughly assure that the problem has been addressed. However, none of this was possible during the limited turnaround at the gate.

The Analysis

John's intent was to release the aircraft on time; his motivation was rooted in his performance evaluation. The circumstances were that the airline had an aging fleet and it was nearly impossible for John to meet his performance targets if the airplanes kept breaking down on his shift. The airline had announced fleet replacement within the next two years, after it had improved its financial health. The foreseeable, unintended consequence was that the aileron could fail in flight and the airplane would have to declare an emergency; worse, the airplane could have an accident. Another unintended consequence, and perhaps unforeseeable for John, was that if more people were to sign off aircraft as airworthy, when they are not, the management is likely to underestimate the urgency to replace the fleet and decide to postpone its decision.

John had to decide whether or not to release the aircraft. Even if his mechanics refused to sign-off the aircraft, he could. He marked the logbook as "no fault found" and released the aircraft. That way, he was legally protected.

The Consequences
Fortunately for John, the material consequence of his decision was not so severe. The pilots experienced the same problem on the next flight, reported it to the next station. Once on the ground, the flight crew refused to accept the airplane and that station had to open up the aileron assembly and adjust the cables and pulleys to prevent them from jamming. The maintenance supervisor at that station took a hit on his performance.

On the moral side of the consequence, John received a "free" lesson – at least it was free for him. Not so free for the maintenance supervisor at the other station. He now faces another choice: does he continue to take risks or does he learn to not take similar risks in the future.

The Moral of the Story
The key point in this scenario is that material incentives are sometimes tied to the wrong performance metrics: have the courage to hold safety higher than production; earn the respect of your workforce by standing up for them.

Scenario 3: Corporate Integrity Program

This is an example of what is possible when employees and management embrace open communication and hold each other accountable for their actions as well as inactions.

The Facts
One company uses enterprise software that allows all the employees—technical as well as non-technical workforce—to submit any problems, hazards, or systemic issues that need to be addressed. Customer complaints as well as technical challenges are handled through this system. All the communication is logged and is retrievable for analysis.

This company had an event. A mechanic lowered the flight controls on to a work stand and damaged the airplane. As a result of this event, there was an internal investigation. The event, the people involved in the event, the damages caused, and the investigation report were recorded in the enterprise software. Thereafter, a list of corrective action recommendations was generated and each recommendation was assigned to a specific manager. Each such manager received one week to respond. The manager may respond as the task is in progress or may respond as completed, but if there is no response from the manager, his manager is notified. Again, this manager gets one week to act. If he doesn't act, the next higher level manager is notified. Ultimately, the system is setup to notify the CEO.

The Ethical Issue
The most obvious issue in this scenario relates to the transparency of the event investigation and follow-up processes. Because the software is available to everyone in the company there is no easy way to hide reported problems, event-related processes, or people's identities. Such a system could be abused, especially if the company employees do not buy into its intent, implementation and execution.

The Analysis

The goal of using this software is to address all the issues pertaining to real or perceived maintenance problems. Because all records of the transactions and communication are maintained in the centralized system, this is the cleanest way to improve the overall integrity of the organization.

The organizational intent of using such a system, particularly in the instance cited in this example, is to improve its quality, performance, and safety. The motivation is that unresolved problems with quality or safety will affect performance and thereby impact both the employee morale and the financial bottom line. The circumstances as such that the company has the technical resources to build the software, the leadership to insist on the use of such a system, and the employees that have grown to trust the management.

The Consequences

While the intended consequences of such a system are focused on organizational improvement or learning, the unintended, but positive, consequences are in the areas of employee morale and employee-management trust.

The Moral of the Story

When conceived and implemented correctly, transparent problem resolution systems work well and can become the cornerstone of a company's integrity and reputation.

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