Chapter 16
MAINTENANCE RESOURCE MANAGEMENT

INTRODUCTION

Aviation maintenance is a complex and demanding endeavor. Its success, which is ultimately measured by the safety of the flying public, depends on communication and teamwork. Aviation maintenance operations are most successful when crews function as integrated, communicating teams -- rather than as a collection of individuals engaged in independent actions.

Over the past decade, the importance of teamwork in the maintenance setting has been widely recognized.[1,2,3,4,5,6,7,8] The result has been the emergence of human factors training, Maintenance Resource Management (MRM) programs, and other team-centered activities within the aviation maintenance community.

Maintenance Resource Management is a general process for improving communication, effectiveness, and safety in airline maintenance operations. Effectiveness is measured through the reduction of maintenance errors, and improved individual and unit coordination and performance. MRM is also used to change the "safety culture" of an organization by establishing a pervasive, positive attitude toward safety. Such attitudes, if positively reinforced, can lead to changed behaviors and better performance.

Safety is typically measured by occupational injuries, ground damage incidents, reliability, and airworthiness. **MRM** improves safety by increasing the coordination and exchange of information between team members, and between teams of airline maintenance crews.

The details of **MRM** programs vary from organization to organization. However, all MRM programs link and integrate traditional human factors topics, such as equipment design, human physiology, workload, and workplace safety. Likewise, the goal of any MRM program is to improve work performance and safety. They do this by reducing maintenance errors through improved coordination and communication.

Not surprisingly, a prerequisite for implementing successful **MRM** is the will to do so. As with any program intended to be diffused throughout an organization, MRM must have the positive, explicit, and demonstrated support of senior management.

A typical **MRM** training program addresses each of the following components:

1. Understanding the maintenance operation as a system
2. Identifying and understanding basic human factors issues
3. Recognizing contributing causes to human errors
4. Situation awareness
5. Decision-making; Leadership
6. Assertiveness (how to effectively speak up during critical times)
7. Peer-to-peer work performance feedback techniques
8. Stress management and fatigue
9. Coordination and planning
10. Teamwork and conflict resolution
11. Communication (written and verbal)
12. Norms

In this chapter, we describe the background and evolution of **MRM**. We discuss current practices and describe some real-life implementation experiences. We present a systems approach to designing and developing an MRM training program. Finally, we provide a generic MRM course outline with examples of activities designed to promote the use of MRM skills.

BACKGROUND

There is some confusion regarding the definition of Maintenance Resource Management. Much of this confusion is most likely the result of trying to portray **MRM** as a "thing," like a training program or an organizational intervention. It is, instead, a process, a perspective, and a philosophy. Put another way, many typically view MRM as a singular tool , such as a training intervention, through which safety is achieved. In contrast, we view MRM more holistically by defining MRM by what it <u>does</u>, rather than what it is.

MRM encompasses much more than a training program or "teamwork" skills; it involves a change in individuals' perspectives through which safety becomes chief priority. In this context, MRM addresses human errors and problem resolution through open and honest communication among **AMT**s, managers, and the FAA.[3,8,9,10,11,12,13]

MRM is characterized by working together and using available resources to reduce errors and to promote safety. There is a growing body of evidence that team coordination among aviation crews improves safety, product quality, and system effectiveness.[1,6,14,15,16,17,18,19,20,21]

Maintenance Resource Management, as with other human-factors-oriented processes, is based on a systems approach. It incorporates a variety of human factors methods, such as job and work design, and considers the overall socio-technical maintenance system (see **Chapters 2** & **6**).[2,9] For example, the **SHELL** model, **Figure 16-1**, shows how we define human factors as a system and illustrates the various interactions that occur between sub-systems and the human operator. This is a modification of the **SHEL** model described in **Chapter 1**.

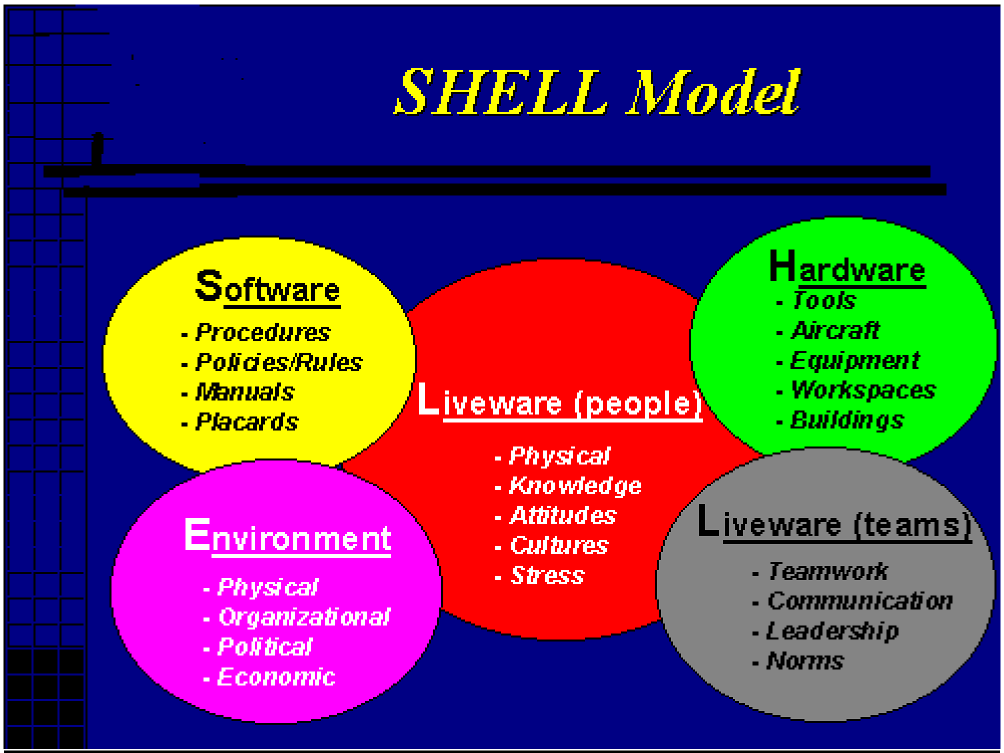


Figure 16-1. *The SHELL model.*

The interactions in this model can affect both individual and team performance. **MRM** training typically focuses on the interaction between the individual **AMT** and other team/crew members: liveware/liveware interactions in **SHELL** terminology. This person-to-person interaction can be considered the most detailed level of communication and team-building. The interactions among teams and departments occur at a more general level.

There are also external forces that can affect individual and team performance. These include political and regulatory considerations (e.g., **FAA**, **OSHA**, **NTSB**) and economic factors (e.g., global competition). Achieving the goals of **MRM** requires improving interactions at both the detailed and general levels. These improvements must occur within the context of external factors and an understanding of their effects. To this end, the **SHELL** model depicts the systems approach to integrating human factors methods and principles to design an MRM program.

Evolution of MRM

MRM is the result of a series of events that drove its development. **Figure 16-2** outlines the evolution of MRM and human factors training programs. The catalyst for the development of cockpit resource management (CRM), the United Airlines (UAL) Flight 173 DC-8 accident, is described below:[22]

As the DC-8 was approaching Portland, the flight crew noticed a problem with the landing gear. The pilots kept flying while trying to resolve the problem, thus diverting their attention from the task of monitoring other critical systems. Eventually, they ran out of fuel and crashed short of the runway, killing 10 people. This accident resulted in United Airlines initiating Cockpit Resource Management (CRM) training.

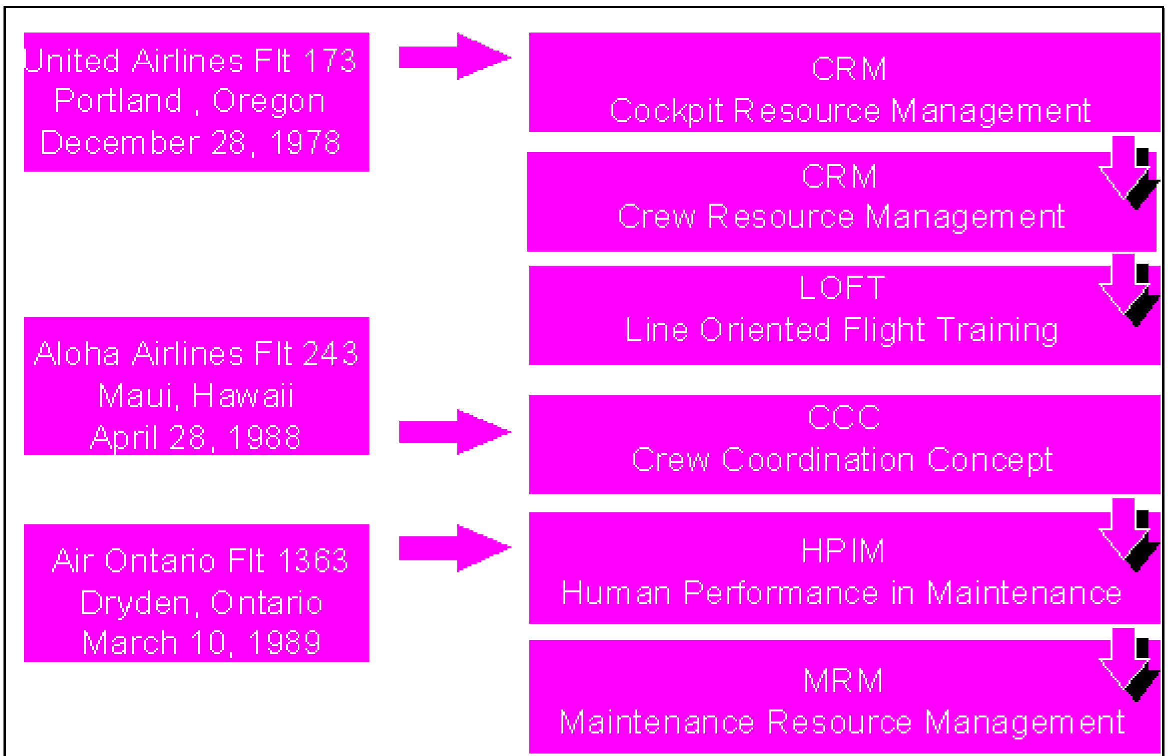


Figure 16-2. *The evolution of MRM and human factors training programs.*

The **UAL CRM** workshop concentrated on improving communication among pilots and other crew members on the flight deck. This program eventually evolved into Crew Resource Management, which pertains to utilizing resources outside the cockpit. This training is now sometimes called Command/Leadership/Resource Management (CLR).[14]

In addition to **CRM** and **CLR**, airlines also created Line Oriented Flight Training (LOFT). LOFT incorporates flight simulators to create better working relationships by employing stressful situations in realistic scenarios. The feedback that can be given to teams after this type of training reinforces the development of communication and coordination skills.[14]

Just as **CRM** grew from a reaction to a tragic event, another key mishap led to the development of **MRM** and maintenance-based human factors training. In 1988, Aloha Airlines Flight 243 suffered a near-catastrophic failrure.[23] Eighteen feet of fuselage skin ripped off the aircraft at an altitude of 24,000 feet, forcing an emergency landing. Following this accident, the **FAA** issued an Airworthiness Directive (AD) requiring a close visual inspection of 1300 rivets on B-737 aircraft.[24]

The Aloha B-737 involved in this accident had been examined by two inspectors, one with 22 years experience, the other, the chief inspector, with 33 years experience. Neither found any cracks in their inspection. However, post-accident analysis determined there were over 240 cracks in the skin of this aircraft.[23] The ensuing investigation identified many human-factors-related problems leading to the failed inspections. These findings focused attention onto maintenance as a potential accident causal factor, and led to the development of **MRM** and human factors training.

In 1991, due in part to this new focus, Continental Airlines expanded and modified its Crew Resource Management training to become Crew Coordination Concept (CCC) training -- designed specifically for its Maintenance Technical Operations personnel. CCC is the precursor of what has become known as **MRM**.[11,15,25] MRM shares certain basic features with **CRM**, including addressing the issues of communication and team coordination. However, the target audience for MRM includes **AMT**s, staff support personnel, inspectors, engineers, and managers -- a much more diverse group than cockpit crews.

Since 1991, over 2,000 technical operations workers and managers have attended this 16-hour course. The objective was "To equip all technical operations personnel with the skill to use all resources to improve safety and efficiency."[11,25] Subsequent evaluation of **CCC**, over the course of three years, showed positive and significant effects on safety, assertive communication, team coordination, stress management and dependability.[8,11,15,19]

CCC was shown to reduce maintenance error rates, and to improve human reliability in measurable terms based on a wide variety of objective performance data.[8,15,19] Thus, Continental Airlines was able to demonstrate successfully the positive effects of its first "**MRM**" training course.[8,15,19,35] This course provided, in part, the inspiration to develop other MRM training courses.

Similarly, in response to the 1989 crash of Air Ontario Flight # 1363, Transport Canada developed the Human Performance in Maintenance workshop.[18] These efforts were conducted in parallel to **CCC**. Crew coordination was identified as a contributing factor to this accident. The first workshop, held in January 1994, was successful in providing a heightened awareness of human factors problems and solutions in the maintenance environment. One outcome was the identification of the "Dirty Dozen": 12 human factors elements that degrade people's ability to perform effectively and safely.[27]

These "Dirty Dozen" are as follows:[27]

Lack of Communication
Complacency
Lack of Knowledge
Distraction
Lack of Teamwork
Fatigue
Lack of Resources
Pressure
Lack of Assertiveness
Stress
Lack of Awareness
Norms

In response to these initial successes, industry began to develop their own, organization-specific **MRM** programs. US Airways (formerly USAir) developed an MRM program that continues to evolve.[12,13,28] This program is the product of a partnership consisting of:

- maintenance management,
- labor, i.e., the International Association of Machinists & Aerospace Workers (IAM&AW), and
- the **FAA** Flight Standards District Offices (FSDO).

Their **MRM** activities include:

- participatory methods to reduce paperwork errors
- a paperwork training course and pre-shift meetings
- problem solving meetings (called round tables) that involve management, **IAM&AW** representatives, **AMT**s, and the **FAA**.

US Airways designed and developed an **MRM** training course using a participatory design process. The development group was an interdisciplinary team of Subject Matter Experts (SMEs) including **AMT**s, inspectors, managers, human factors and training experts, academic researchers, and representatives from the **FAA**.[45]

The US Airways **MRM** course provides all maintenance and technical operations personnel with human factors knowledge, an understanding of how maintenance errors occur, safety awareness, and communication skills. After the first course is delivered, a follow-up MRM course is given in 90-120 days for further skill development and practice in MRM principles.[28,45]

Several other airlines (e.g., United, Northwest, Southwest, American Eagle) have designed human factors training courses for maintenance operations.[20,42,69] These courses are typically based on what is known as Human Performance Improvement Methods, or HPIM. (This is to be differentiated from Human Performance in Maintenance, also shortened to HPIM.[18]) Common HPIM elements include basic human factors courses, other human factors training materials developed for the **FAA**, and the airline's own human-factors-related experiences and case studies.

Some companies are currently undertaking the design and development of additional **MRM** training that incorporates team situation awareness training.[29,44] Many repair stations are buying MRM training courses from contractors, and some **AMT** schools have incorporated an advanced technology team training program into their curriculum.[30]

Delta Air Lines has designed and developed a Team Resource Management (TRM) course for their ramp workers. They have begun to implement this training course and are concurrently establishing practices that will reinforce TRM skills in the working environment.[31] A comprehensive study of European ground service and ramp personnel has also been completed.[32]

Industry practices and experiences

There has been significant progress in the area of **MRM** and human factors training within the aviation maintenance industry.[15,18,20,33,34,42,68,69] Each company creates, develops, and implements their human factors training program and overarching MRM program differently. Some companies have built robust MRM programs using bottom-up strategies, such as group problem-solving techniques. These focus groups are typically composed of maintenance users representing various functions, such as line and depot maintenance, engineering, technical documents, and management.

Other companies have used a more top-down approach to implementing human factors and **MRM** training programs. Some are creating human factors engineering/quality assurance/ human reliability programs, which incorporate MRM principles and activities. These include:

- workplace design evaluation
- safety & health committees
- participatory processes, such as self-directed teams
- maintenance policies and procedures manual re-design
- engineering directives

All of these activities involve **AMT**s, managers, and other departmental representatives.[2,5,12,13,16,36,37] These companies are taking a systems perspective by applying human factors and **MRM** principles at the organizational, group, and individual levels, as shown in the **SHELL** model (**Figure 16-1**).

The movement toward human-centered work principles represents a cultural change within the aviation maintenance domain, in general, and within each organization. Such a pervasive cultural re-orientation requires changes in management behavior, job and organizational structure, strategy, policies, and values. The companies that have taken the initial steps in this direction are moving toward a culture that supports more open and trusting communication among management, labor, and the **FAA**.[1,5,12,13,15,33,38,39]

MRM and human factors training programs are not the only approaches to understanding, identifying, and providing solutions for maintenance errors. Companies are also integrating maintenance error analysis programs such as **MEDA**, **AMMS**, **MESH**, **ASRS**, and **BASIS**, with human factors training.[40,41,42]

Training other departments in human factors and **MRM** principles creates a common language within an organization. Some international and national airline companies are beginning to train their cabin and flight crews together in human factors principles.[28,37] The aviation maintenance industry has recognized the value of providing human factors and MRM training across departments and divisions.

Over the next several years, we expect several companies to begin implementing their **MRM** and human factors programs across all departments, including cabin, ground, and ramp crews. Some airlines have expressed interest in designing cross-departmental human factors courses involving ramp, ground, cabin, and flight crews.[13,31,68]

Elements of successful MRM programs

Even though every company designs and implements a slightly different **MRM** training program, there are common elements across the industry. We have identified five common elements of successful MRM programs:

- Senior management support
- Training for supervisors and middle managers
- Continuous communication and feedback
- Use of the systems approach
- Full participation

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 through the use of **MRM**. When top decision makers clearly support the mission and purpose of MRM, an organizational culture change can occur. Without such a commitment, a pervasive organizational change is unlikely.

Training for supervisors and middle managers

Linked to the first element is training for supervisors and middle managers. These individuals interact daily with the workers who are ultimately responsible for implementing the new strategies. Mid-level managers also need the support of upper-level management in implementing the new **MRM** skills and approaches in the field. This support can take many forms, but certainly includes the time to attend appropriate MRM training courses. With this commitment, supervisors will have the opportunity to use their own MRM skills in addition to managing a cultural change.

Continuous feedback

It has been said that nature abhors a vacuum. The same can be said for organizations undergoing pervasive changes. To sustain the change process, continuous communication and feedback must occur. Several communication channels exist to distribute the results of **MRM** training programs. These include newsletters, group meetings, 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 effects on the company's overall performance (i.e., quality, safety, dependability).

The systems approach

The fourth element of a successful **MRM** program is the use of a systems approach in designing and implementing MRM training. **Chapters 2** and **6** discuss work design and human factors from a systems approach. Following an instructional systems design (ISD) approach when managing and developing training ensures a comprehensive and effective program. (See **Chapter 7** and the **METHODS** section of this chapter for a discussion of the ISD approach). Applying a systems approach to MRM development leads to a well-planned program and relevant interventions.

Full participation

The fifth element of successful **MRM** programs is the participation by all people who have a significant stake in its outcome. Active participation increases feelings of personal ownership and motivation to implement new ideas. A typical MRM stakeholder group includes **AMT**s, inspectors, engineers, **QA** personnel, managers, and **FAA** regulators (typically from the **FSDO**). There are several examples in the industry demonstrating the positive effects of full participation while designing training programs, re-designing log books and manuals, and facilitating courses in MRM, human factors, and self-directed team building.[21,28,43,44,45]

ISSUES AND PROBLEMS

The ultimate goal of **MRM** is to increase aviation safety. To accomplish this goal, MRM addresses a number of factors contributing to maintenance and inspection errors. These include issues related to workplace communication, organizational culture, and situation awareness. Below, we describe the most salient issues and problems to be addressed by MRM.

Safety Record

There is little argument that air travel, at least in the developed world and via scheduled commercial flights, is, by any measure, very safe.[46] However, maintenance errors contribute significantly to aviation accidents and, perhaps more importantly, to events that initiate accidents or unsafe flight conditions. It has been shown that "...39 percent of [widebody] aircraft accidents began with a problem in aircraft systems and maintenance, and that 'pilot error' comes later in the sequence of events after something has gone wrong with the airplane itself".[47,48]

One study reported that maintenance and inspection errors accounted for 12% of major aircraft accidents.[49] These data show that maintenance and inspection errors contribute significantly to many aircraft accidents. Twelve percent of major aircraft disasters involving Boeing aircraft were attributable to maintenance and inspection errors and to 15% of onboard fatalities.[49,50,51]

Table 16-1 illustrates the most frequently-occurring maintenance discrepancies (UK CAA, 1992). **Table 16-2** lists occurrences involving human factors errors and engineer factors during 1989-1991 for one airline. The main categories of maintenance error and their frequency of occurrence are given in **Table 16-2**.[49]

Table 16-1. Leading maintenance problems[52]
Leading Maintenance Problems: Listed in order of occurrence
1. Incorrect installation of components
2. Fitting of wrong parts
3. Electrical wiring discrepancies (including cross-connections)
4. Inadequate lubrication
5. Cowlings, access panels and fairings not secured
6. Landing gear ground lock pins not removed before departure

Table 16-2. Maintenance Error Categories	
Category	**Occurrence (%)**
Omissions	56
Incorrect installations	30
Wrong parts	8
Other	6

Communication

Conclusions from several studies show that poor communication practices and skills exist throughout the aviation industry.[2,9,14,23,53] Poor communication among management, teams, and individual workers can compromise safe and cost-effective maintenance operations. One study confirmed that effective communication is the most important factor for ensuring team coordination and effective work performance.[2,33,55]

Communication plays an important role in the quality of maintenance, and also has a significant impact on the safety of flight. Maintenance workers do not always understand their company's policies and goals, or their individual roles in meeting those goals. The effects of assigning a low priority to communication may include delays, employee turnover, and low morale.[33,55]

Organizational Culture and Management Commitment

The **FAA** National Plan for Human Factors (1991)[56] reported that the overall culture of commercial aviation still emphasized individual rather than team aspects of cockpit work. That report and others emphasized that the same "crew resource management" (CRM) techniques successfully used in flight operations could be applied to aviation maintenance with positive results.[57] However, approaching this issue in the maintenance domain requires an expanded, system view that considers individual, team, technology, and environment[58] (i.e., a **socio-technical systems** view, see **Chapter 6**).

When a poor organizational culture is coupled with a low level of management commitment to change the system, the result is ineffective, and sometimes unsafe, performance. Many companies find that solving communication and coordination problems requires changes in management, internal organization, and the organizational culture.

Situation Awareness

One of the most pervasive problems facing **AMT**s is the **loss of situation awareness** (see **CONCEPTS**). Failures in situation awareness have been linked to conditions which lead to reductions in the safety of flight, flight delays, ground damage, and other problems that directly increase costs. In certain severe cases, the viability of a company has been affected by situation awareness errors.[44]

The results of poor situation awareness can be seen in a variety of common maintenance-related errors. These include loose objects left in an aircraft, missing fuel and oil caps, loose panels and other unsecured parts, and pre-flight pins not removed prior to operation.[49] Putting together observed cues to form a proper understanding of malfunctions is a challenging and significant problem in diagnostic activities. For example, in more that 60% of cases, an incorrect avionics component is replaced in an aircraft.[60]

In team-oriented environments, such as aviation maintenance, the level of situation awareness within and among teams is an issue of concern. The overall goal of providing safe aircraft can be compromised if any team member loses a sufficient level of situation awareness. Aviation maintenance tasks are typically coordinated within teams and among teams on different shifts or in different geographic locations. The well-known Eastern Airlines incident (EAL 855 on May 5, 1983 en route to Nassau from Miami) involving an L-1011 with missing chip detector O-rings has been directly linked to the lack of coordination across shifts (along with other contributing factors).[61]

REGULATORY REQUIREMENTS

Federal Aviation Regulations

Maintenance Resource Management (MRM)

Currently, there are no **FAA** regulations mandating any type of human factors knowledge or training program, including **MRM**-specific knowledge or training. However, an Advisory Circular is being planned and written and will be distributed to the airline industry. The Aviation Rule Making Advisory Committee (ARAC) has revised **FAR** Part 121.375 to include Maintenance Resource Management and human factors training. The new rule has not yet approved and released by the FAA.

Crew Resource Management (CRM)

Advisory Circular Number 120-51 presents guidelines for developing, implementing, reinforcing, and assessing Crew Resource Management (CRM) training programs for flight crew members and other people essential to flight safety.[62] These programs are designed to become an integral part of training and operations. The guidelines in AC-120-51, while not carrying the weight of an official rule making, are intended to help Part 121 and 135 certificate holders improve the safety and efficiency of their flight crews by focusing on CRM-related skills.

Committees and Advisory Boards

ATA Human Factors Sub-committee

This committee consists of interested representatives from aviation companies, **FAA**, **IAM**, labor, academia, and others involved in maintenance and ground/ramp work issues. The committee is a forum for exchanging information and case studies related to maintenance operations. They also are active in working with the FAA to define applied research projects and programs.

International regulations and advisory boards

United Kingdom Joint Aviation Authority (UK JAA); Civil Aviation Authority (UK CAA)

The Civil Aviation Authority (CAA), a member of the Joint Aviation Authorities (JAA), has actively participated in a JAA Human Factors Steering Group review of the current maintenance requirements to determine if they are adequately human-centered. The recommendations from this Working Group identified **MRM** and human factors training to be the number one priority. The JAA Maintenance Committee has established a small group of specialists to consider the recommendations with a view to further rule making.

In the absence of any current requirements for human factors training, the **CAA** is actively promoting the benefits and encouraging the implementation of **MRM** and human factors training by maintainers of large transport aircraft. The goal of the CAA is to provide the motivation for the maintenance organizations to implement human factors training and to support a positive organizational safety culture. The CAA realizes that the training program must take account of each organization's culture. Therefore, the knowledge and skills to be acquired, as well as the design of the overall program, are viewed as a flexible curriculum.

Bureau of Air Safety Investigation, (BASI), Canberra , Australia

This governmental agency conducts research in the aviation area and provides recommendations and directions for further government and industry policies. Several **BASI** researchers are involved in maintenance human factors. They have conducted field research projects to understand and describe the contributing human factors causes related to maintenance errors. Their research is based on a systems approach aimed at describing **latent and active**

variables (See **Chapter 14**) and **SHEL** model components (See **Chapter 1**).

In June 1997, **BASI** published a series of 18 suggested safety actions that maintenance organizations could implement to address the problem of human error. Included in these was a recommendation that maintenance organizations should consider introducing **CRM** training for maintenance workers.

Transport Canada

The Canadian equivalent to the **FAA** is Transport Canada. As of this writing (early 1998), Transport Canada has no **MRM** or other human factors training requirement. The well-known Dryden, Ontario, accident prompted Transport Canada to recognize the importance of human factors training.[63]

Gordon Dupont, Special Progams Coordinator with Transport Canada, developed a human factors training course called Human Performance in Maintenance (HPIM-Part 1 and 2).[64] He and his colleagues are active implementers of HPIM, which has greatly enhanced the delivery of **MRM** and human factors skills. These courses provide a valuable information repository that can be used for implementing a MRM and human factors training courses.

CONCEPTS

Many of the basic **MRM** concepts are applicable to other human factors elements and techniques. Some of these concepts have been presented in other parts of the *Guide*, but with a different emphasis. Our intent here is to present the concepts that are most directly applicable to establishing an MRM training program. We briefly describe each core concept below.

Systems Approach

The "**systems approach**" concept is first presented in Chapter 1 and underlies the **SHELL** model described in this chapter (**Figure 16-1**). It is exemplified by a hierarchical, top-down, structured approach to design and development. Chapter 7 discusses the **systems approach** as it applies to developing training programs. Using a systems approach to design, implement, and evaluate an **MRM** training program ensures that it will meet the needs of the learners and the organization.

The systems approach consists of the following five processes:

- Analysis
- Design
- Development
- Implementation
- Evaluation

It includes setting goals and defining objectives, developing and implementing the training program, measuring the effects of the training, and providing feedback to the developers.

Continuous Learning and Improvement

Every system changes over time. In the systems approach, **MRM** training and practice must be viewed as part of the overall aviation maintenance system. As such, MRM must be adapted to changes that occur elsewhere in the system, as well as to changes in training practice and technology. The idea of continuous change and adaptation is fundamental to making any system responsive to the needs of its users.

Financial and organizational resources must be committed to actively support the **MRM** change process. This includes the commitment of human resources within the company, such as administrators, trainers and curriculum developers, quality assurance managers, and media and computer application developers. Continuous improvement is not a short-term activity. Rather, it requires long-term management commitment to continuously adapt and improve the program.

Measurement and Evaluation

Once an **MRM** program is in place, we must determine how well (or whether) it is working. This measurement and evaluation process is typically the weak link in the systems approach. However, it is necessary to measure the effects of the MRM program *over time.* It is also necessary to use multiple measures in order to gauge the effectiveness of the program. It is also important to keep in mind that we are not measuring only the effects of the MRM training program, but the effects of on-the-job MRM practice.

We list both "measurement" and "evaluation" in this concept because they are not necessarily synonymous. Measurement implies some type of objective technique that lets us view the state of certain variables, such as flight delays, in-flight turn backs, personal injuries, etc. Evaluation is a much broader concept that can involve using both objective and subjective data.

During the **MRM** evaluation process, it is important to look at multiple measures taken over time to track the effects of the MRM program and the success of the resulting cultural change. Evaluation tools can include assessment instruments and questionnaires, behavioral observation and analysis, and unit and organizational performance measurements.

These tools can be used to assess the cost of designing and delivering an **MRM** training course. In addition, performance measures establish the basis for calculating the company's return on investment. We will describe these measurement tools and procedures in the **METHODS** and **GUIDELINES** sections.

Feedback

Feedback is one of the most generally applied concepts in the domain of performance improvement. Simply put, performance improves more quickly when people are given feedback concerning their successes (or lack them). It is vital that timely feedback is given to all workers and managers about the results of their **MRM** program. Feedback provides information to accomplish two performance improvement goals:

1) Improve the program and identify necessary corrective actions, and
2) Reinforce the positive outcomes and benefits of using **MRM** skills in the workplace.

Feedback can take several forms. Internal newsletters can be used to describe a specific **MRM** outcome in the workplace. An example in one organization is reporting how an MRM group exercise led to initiating a positive change in a specific maintenance operation.[65,68] A more active feedback method is to have **AMT**s write their own "MRM story" describing their experiences in using MRM principles and skills.[28]

Team Situation Awareness

Situation awareness is one of the foundation concepts of **MRM**. Typically, we think of situation awareness in terms of the individual **AMT**. However, many of the most common maintenance errors involve the loss of situation awareness among different individuals, often across different teams or shifts. The concept of team situation awareness relates to maintaining a collective awareness of important job-related conditions.

Researchers have identified five elements and activities that are necessary to improve Team Situation Awareness in the maintenance environment.[29,34,44] These are:

- Shared mental models
- Verbalization of decisions
- Better team meetings
- Teamwork and feedback
- Individual situation awareness training

Shared mental models

A mental model is simply how we depict a subsystem in our minds -- how we think it is put together and how it works. Good situation awareness at the team level depends on having a clear understanding of what information means when it is conveyed across team members. Such shared mental models are provided by developing a good understanding of what other team members know, don't know, or need to know. Team members need to share not only data, but also the significance of data relative to their jobs and the team's goals.

Verbalization of decisions

Despite some claims to the contrary, **AMT**s cannot read their co-workers' minds. It is very difficult to know why a team member has taken a course of action unless they tell us. Teams need to do a better job of passing information regarding why they decide to (or not to) take a particular course of action.

Team meetings

Having team meetings is critical to pass on valuable and necessary information. This applies to teams on the same shift and to teams passing information across shifts. (See **Chapter 4** for a discussion of **shift turnover practices**.) To increase team situation awareness, Team Leads need to receive explicit training in the following:

- How to run a shift meeting and state common goals for the team.
- Provide a common group understanding of who is doing what.
- Set up an understanding of the inter-relationship between tasks and personnel activities.
- Provide expectations regarding teamwork.

Teamwork and feedback

A tricky diagnosis and repair may have been totally successful, or may have failed again a few days later at another station. It is important that **AMT**s know the outcome of their work. Such feedback is crucial to the development of better mental models. Without such feedback, it is difficult to improve one's diagnostic skills.

Individual situation awareness training

Many common problems can be linked to situation awareness failures, including the following:

- forgetting information or steps -- frequently associated with task interruptions
- not passing information between shifts or team members
- missing critical information due to task-related distractions, and
- misinterpreting information due to false expectations.

These problems can be minimized by training **AMT**s to recognize threats to situation awareness and cope with their effects.

Participation

Participating in the creation, development, and implementation of an **MRM** program stimulates a feeling of individual ownership. Active involvement creates a sense of commitment to supporting the MRM program goals and a willingness to engage in the required cultural change process.

Being a member of a team that is designing and implementing an **MRM** program is motivating, rewarding, and beneficial to the individual and the organization. Working together on a cross-functional, interdisciplinary team provides a unique strength in designing and developing an MRM program.

Active learning

Training is often a passive experience. An instructor stands in front of a class of **AMT**s and lectures while the students take notes. More effective instructional methods, sometimes called "inquiry" or "discover" learning, emphasize the involvement of learners. These methods involve students by having them participate in problem-solving activities and group discussions. This type of training environment is categorized as "active learning".

The strength of this approach for the maintenance environment is that the use of group exercises and maintenance-related case studies promotes an active and motivating learning environment. It creates an interactive, highly-motivating approach, since students are doing more than just passively receiving the information -- they are actively applying and using the concepts and skills.

To further strengthen this instructional approach, training courses can be co-facilitated by subject matter experts in maintenance operations (e.g., **AMT**s, inspectors, **QA**). They can encourage students to participate, by bringing "real world" experiences into the classroom, and are viewed as relevant and valid experts.

Transfer of training

The efficiency with which knowledge and skills taught in a training course are transferred to the work environment is called "transfer of training". Training transfer can be positive, negative, or neutral. For training to be considered effective, **AMT**s must be able to apply their newly-acquired skills in their real work environment -- a positive transfer of training.

Transfer of training is enhanced by reinforcement from co-workers and supervisors. A practice period occurs when **AMT**s return to their workplace after a training course. The reactions of others during the practice period either reinforces newly-learned **MRM** skills or discourages their use. Therefore, it is important that managers receive MRM training in advance of workers. Transfer of training is also enhanced when classroom exercises are similar to actual workplace experiences.

METHODS

In the **INTRODUCTION** and **BACKGROUND** sections, we described the definition, evolution, and status of **MRM**. In this section, we could describe a number of techniques to analyze the necessity and identify the benefits of implementing MRM in an aviation maintenance organization. However, rather than spend the space and time to justify the value of MRM, we would prefer simply to accept that MRM is a worthwhile framework within which to maintain aircraft. The emphasis of this section, therefore, is the introduction of MRM-related knowledge and skills into the workplace, i.e., MRM training.

As noted in the **READER TASKS** section, we do not anticipate that most aviation maintenance managers, the primary readers of this *Guide*, will have the training, skills, time, or inclination to develop an **MRM** training program. However, there are many tasks associated with such a program that will be within the responsibility of managers. Since we propose a specific framework within which MRM training programs should be developed and evaluated, it will be useful for managers to understand the most important aspects of this framework.

In **Chapter 7**, we describe the Instructional Systems Design (ISD) method of developing training programs and modules. For **MRM**, we advocate using the ISD method -- modified to be applicable directly to MRM and the aviation maintenance workplace. In this section, we describe this tailored ISD approach.

Figure 16-3 depicts the **ISD** model. The ISD approach places a heavy emphasis on user needs. It incorporates extensive user testing during the design and development phases. Involving maintenance workers and managers on an **MRM** design team is essential when using the systems design approach. We describe each of the major activities in the ISD framework in the following paragraphs.[66,67,72,73,74]

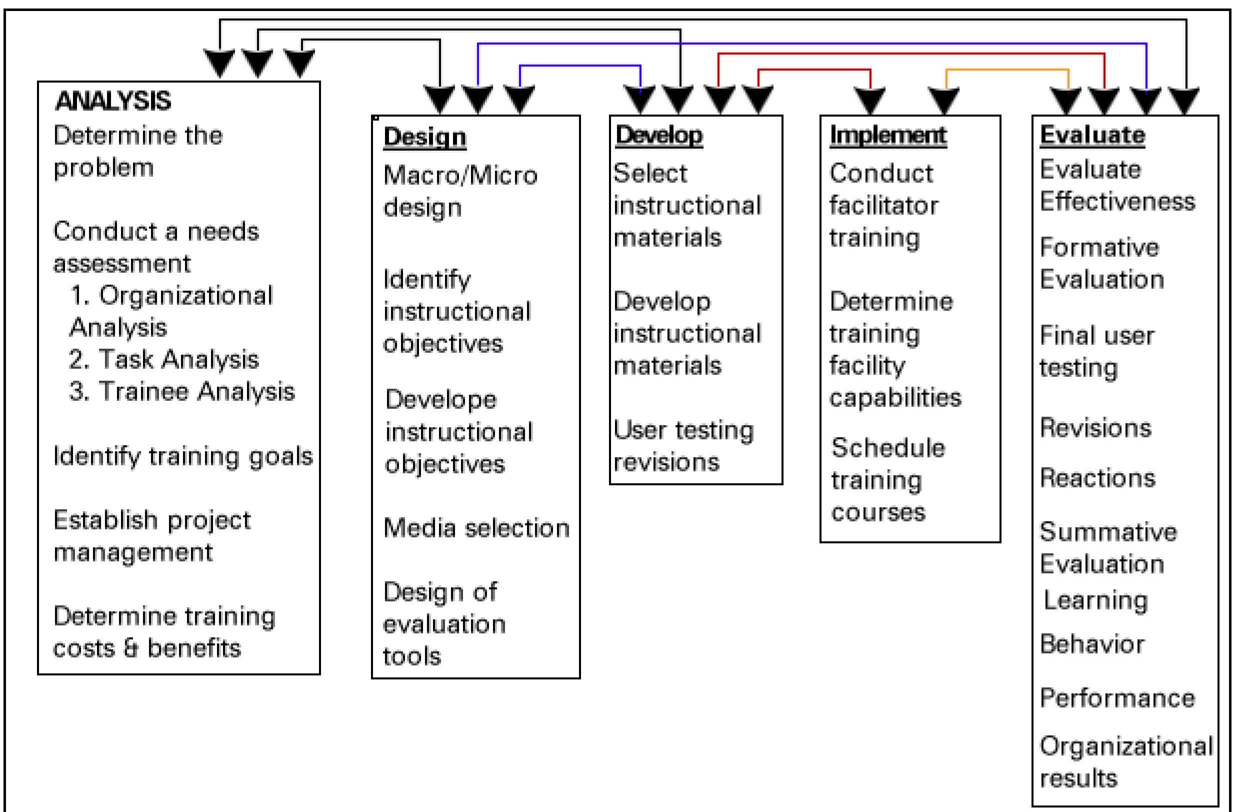


***Figure 16-3.** The Instructional Systems Development (ISD) Model.*

Analysis

The first phase of the **ISD** process consists of analysis, usually called "front-end" analysis. Activities in this phase consist of gathering and analyzing information, followed by writing the objectives, goals and functional specifications for the training program. The idea is for the **MRM** design team to identify the organizational and trainee needs and constraints before it begins designing the training program.

Needs Assessment

The analysis phase begins by assessing the requirements, or needs, that the **MRM** training program must satisfy. There are three levels of needs assessment: 1) organizational analysis, 2) task analysis, and 3) trainee analysis.[72,73,74]

Organizational analysis.

Organizational analysis consists of an evaluation of the organization and/or industry in which the trainee performs the job, and an evaluation of the organization expected to provide the training. These may or may not be the same organization.

The **MRM** training design and development team is selected during this phase of the process. It is critical to the success of the training program to include representatives from all of the essential areas of the maintenance organization. Likewise, senior management must allow team members to devote the necessary time to the project.

In determining the reasons why an **MRM** training program is being undertaken, it is important to answer two basic questions:

1) What is the current performance of the organization and workers?
2) What is the desired performance of the organization and workers?

If a difference between current and desired performance exists, then we say there is a "performance gap". Organizational analysis determines the probable cause(s) of performance gaps and includes a distinction between needs that can be solved by training and other needs that must be addressed by a change in organizational procedures or policies.[66,72,73]

For example, issues that should be addressed by developing a company policy might be re-designing workcards or re-formatting an Engineering Authorization form. A training need might be teaching engineers and technical writers how to write a workcard or EA effectively. An **MRM** training need would be to teach **AMT**s the skills that allow them to recognize how the environment impacts human performance.

The second part of organizational analyses is evaluating the resources available for the development and delivery of the **MRM** training program. This consists of identifying various constraints, such as the availability of equipment, time, money, and instructors. This information is transformed into a set of functional design specifications, a specific list of training goals, and system requirements that will provide the boundaries of the training program.[66,72,73]

The initial specifications document helps the training designer(s) generate appropriate design solutions. Later in the design phase, these functional specifications may be expanded to include detailed specifications for training program development.

As part of organizational analysis, we identify training costs and the outcomes or benefits from implementing **MRM** training. Benefits can be measured by the company's typical performance measures related to maintenance tasks, such as dependability (departures, **RON**s), safety (ground damage, occupational injuries), and efficiency and quality (component shop statistics).

Task analysis.

Conducting a task analysis is the second step in a needs assessment. Task analysis is performed to determine the tasks required in a job, the subtasks performed for each task, and the knowledge and skills required to successfully perform the subtasks. Task analysis is a critical step in the design process. If the knowledge and skill requirements are not adequately identified, then the designers will have difficulty determining the required content for the training program.

Trainee analysis.

One of the major goals of **MRM** training is to provide **AMT**s with the knowledge and skills that will allow them to function well as part of a maintenance team. Trainee analysis is performed to identify the relevant characteristics of the people who will be participants in the program.

Information obtained in this analysis includes demographic data (such as age and gender), occupational experience, existing knowledge and skills relevant to the training program, and a list of elements the trainees regard as important.[66,72,74] Trainee analysis should identify the trainees' perceptions of the job-related skills and knowledge they need to effectively perform their jobs.

Design

In the design phase, goals and objectives are developed to select content, instructional strategies, and testing procedures for each training topic identified in the front-end analysis. The design process consists of four hierarchical levels: 1) program, 2) curriculum, 3) course, and 4) lesson. The "program" and "curriculum" levels are associated with a *macro* type of design.[74] At this point, training is linked with the strategic plans of the organization, and a series of course needs are identified for different groups of trainees.

The "course" and "lesson" levels comprise a more in-depth, or *micro*, type of design. At this point, decisions are based on instructional theory and research. Thus the designers are concerned with the learners' ability to understand, remember, and transfer the training concepts to the work site.

It is important to note that a successful training design for **MRM** courses includes a high level of interaction, i.e., group exercises, case studies, and practice sessions. This type of design is known as "adult inquiry learning," in that learners manipulate materials and equipment, participate in problem solving discussion groups, respond to open-ended questions, and collect data from direct observations of instructional events.[72] This type of learning promotes effectively acquiring and processing information. Concrete experiential activities (actually doing something) are highly motivating and tend to promote better retention.

Macro Design

During the macro design step, goals are developed that position the **MRM** training program to achieve the company's goals and mission. General training areas are specified and organized into curricula. Curricula may be organized by subject matter, such as MRM awareness or MRM skills development. Once training needs are placed into curricula categories, they are further organized into individual courses or modules, that are then prioritized and scheduled for development and implementation. An additional component of macro design is the initial selection of methods and media that can be used to deliver the training.

Instructional design vs. media technology.

It is important to note that it is *not* the choice of a particular technology that ultimately determines the effectiveness of a training program. Rather, the soundness of the instructional design will set the stage for the efficiency and effectiveness of the training.[66,67,72,73] The design process should not be media technology driven. We should not decide on a particular delivery system or medium until our analyses are complete.

Sometimes we want to deliver a training lesson via video-tape or lecture without considering the underlying instructional objectives. A medium inherently is neither "good" nor "bad", but it can be either appropriate or inappropriate. If sound instructional design principles are used, the designer will choose instructional materials and technologies that meet identified learning objectives and functional requirements.

Micro Design

Micro design moves from the broad categorization of curricula into courses or modules to the detailed design of the individual courses and the lessons within each course. Micro design is based on the educational goals for each training topic. Learning objectives -- what the trainees are expected to know and be able to do after training -- guide the selection of "enabling objectives". Course prerequisite knowledge and skills are established. The differences between pre-training and post-training knowledge and skills are transformed into learning objectives for individual lessons.

Learning objectives are used to develop a content outline for individual lessons and finalize the selection of instructional methods and media. A curriculum hierarchy is developed. The terminal objectives are at the top of the hierarchy, followed by enabling objectives. At the bottom of the curriculum hierarchy are the trainees' prerequisites and prior knowledge analysis.

This learning task hierarchy flows from the bottom to the top. A trainee must successfully meet one training objective before moving to the next higher level. Training designers next determine if it is possible to purchase existing courses, lessons, and audio-visual materials from vendors that will meet their requirements, or if training materials need to be developed.

Media selection.

During the micro design phase, media and instructional methods are selected for each lesson. For example, a video-tape clip may be selected to present the lesson objective, followed by a group exercise. Media selection is dependent on the learning objectives that are to be achieved. There are media selection models that suggest what media (technology) is optimal for specific types of learning objectives.

Often, the design of a lesson will include several complementary media. A module related to shift turnover might include a one- to two-hour videotape describing and demonstrating an effective shift turnover meeting followed by role-playing at a mock shift turnover meeting with feedback from the training facilitators.

The design concept includes a description of one, or more, delivery method, as well as the form and content of the actual lesson material. In some cases, several alternative design concepts might be generated for preliminary testing, and evaluation.

Design of evaluation tools.

The tools for evaluating the training program should be identified and developed during the design phase. A number of evaluation tools are commonly used for **MRM** training. Typically, questionnaires are used to measure how well the trainees have learned the course objective(s) immediately after completing the training course. Included in the post-training and follow-up questionnaires (given 2-12 months after training) are questions concerning how useful the course was to the learner, and his opinions on how he felt the course accomplished the stated training goals. All of these questionnaires need to be designed, validated, and developed in order to be included in the evaluation phase of the **ISD** model.

Development

Following the design phase, the actual **MRM** courseware must be developed. This includes developing all training material, in whichever media are selected during the design process. Since various media interact with certain instructional methods, the development phase includes walkthroughs of all modules that include some type of live instructor/trainee interaction.

Developing training materials.

The design team develops drafts of the materials required and seeks the artistic and production expertise of audio-visual specialists. Specifications developed in the design phase are completed for each lesson. Tasks include writing a detailed outline and developing conceptual sketches for audio-visual aids. The outline and sketches are generally reviewed by the entire design team before they are fully developed into instructor scripts, handouts, and participant exercises. Generally, drafts are reviewed and revised before a formal walkthrough takes place.

Prior to conducting a walkthrough, or other type of formative testing, the training materials should be considered to be prototypes. They should have the look and feel of the final product to the extent possible. Prototyping provides the basis for a formative evaluation in which feedback is solicited from the trainee population, managers, peer professionals, and subject matter experts. The prototype test, or walkthrough, is designed to identify and correct problems before the materials are produced for company-wide use.

Walkthrough.

It's necessary to identify problems or shortcomings early in the design cycle. Therefore, a walkthrough evaluation is conducted. In a walkthrough, the design team meets with members of a review team and walks them through the prototype course materials. The two groups identify potential problems and discusses any suggestions for improving the materials.

It is possible at this time to have the design team test various instructional options with the actual learners to determine whether less resource-intensive alternatives will result in satisfactory learning. This prototyping phase determines whether certain instructional strategies are necessary and sufficient to accomplish the training goals. User testing should be carried out to ensure that the training program fulfills the needs identified in the instructional functional specifications and learning task hierarchy. Based on the data obtained through user testing, the prototype can be modified and re-tested.

Final development.

Final user testing and full-scale development occur after the materials have been modified and re-tested, based on information obtained during the walkthrough and other user testing. After the training program is fully developed, it should be subjected to final user testing before being implemented.

Final development of the training program includes developing all training material and media. This is usually the most time-consuming step of the entire design process. Final pre-implementation user testing consists of actually conducting the training in a typical training environment. This "test training" uses all the training materials and the trainees perform all of the course exercises. The follow-up questionnaires should be administered after the test training is complete.

Implementation

In this phase of the **ISD** process, the fully pre-tested **MRM** training is moved to the production environment. Implementation typically consists of two parts: scheduling and facilitator training.

Scheduling.

A schedule delineates how and when **MRM** training is to be delivered. For most large-scale programs, it is beneficial to implement the training in stages. A staged approach is useful because it allows trainers, trainees, and management to evaluate the program as it is being rolled out. It also promotes a readiness for change by demonstrating results.

Often, a tentative implementation plan is developed at the end of the front-end analysis phase, once curriculum requirements are identified and a schedule for course development can be determined. As part of this plan, program evaluation criteria should be specified.

Facilitator training.

In many instances, the facilitators or instructors are not part of the design team. Even when they are involved in the design process, they may have to learn certain facilitator skills, as well as learning the course materials and the intent of the training. Such training is usually designed and written during the development phase and presented as required throughout the prototyping and implementation stages of the **ISD** process.

For **MRM** training programs, co-facilitation is essential as it provides the opportunity for two representative workers to actively present and facilitate the instructional process. Having co-facilitators allows for a high level of interaction among the course participants as well as providing subject matter expertise in the field of aviation maintenance.

Early experience from **MRM** courses has shown that MRM training is highly effective when **AMT**s 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 training concepts being presented.

Evaluation

It is very important to evaluate the effects of the **MRM** training program. This step is often overlooked in industrial settings. However, a reasonable evaluation effort can determine whether the overall program was successful and met the training program goals. The output of the evaluation can be used to determine whether and what type of revisions or modifications need to take place.

Evaluation types.

There are two types of evaluation: formative and summative. Formative evaluation occurs as the instructional program is being developed. Summative evaluation occurs after the training is implemented. Summative evaluation takes place during the implementation stage of the **ISD** process. It is typically conducted at the end of each training presentation. It acts as a summation of that course session.

Summative data collection includes the assessment of the trainees' mastery of the course material, as well as the appropriateness of the training design. Summative evaluation can also be conducted some time after the instruction has been taught. In these instances, it is often called follow-up evaluation. Its purpose is to determine if the training is being used by the participants. It is most often used to determine the success and effectiveness of the training program.

Summative evaluation.

The summative evaluation process can be viewed as a five-step process:

1) **Pre-training Assessment:** Pre-training questionnaires are administered before the training occurs. This establishes a baseline of the trainees' knowledge, attitudes, and skills.

2) **Reaction:** Post-training questionnaires are administered immediately after the training to evaluate and measure the program success. The facilitators are also evaluated. The main thrust of this evaluation should occur during final user testing as well as upon completion of the course.

3) **Learning:** Subject mastery is measured before and after training. Criteria used to measure the level of learning is identified in the design phase. Typically a pre/post training questionnaire is used to evaluate the learning that takes place as a result of the training. Learning includes gaining principles, facts, techniques and attitudes.

4) **Behavior (Performance):** The effect of training on the learners' work performance is evaluated at this step. Has the trainee transferred the concepts from the training program to the work site and applied them so that there is an observable difference? Self-reported comments on follow-up questionnaires as well as interviews and observations of the trainees in the field are most valuable.

5) **Organizational results:** At this step, organizational performance measures identified in the analysis phase are tracked over time to determine if a difference (attributable to the training program) has occurred. Any evaluation at this point can be viewed as a secondary result of the training program. That is, changes in attitudes and behavior affect job performance, which, in turn, affects organizational factors such as safety, dependability,

quality, and efficiency.

It is important to measure the effectiveness of the training program using all five evaluation criteria levels. Commonly, organizations apply only level 2 and 3, reaction and learning, evaluation criteria, and do not conduct an evaluation at levels 1, 4, and 5.[75] This is because it typically takes additional resources to conduct these evaluations. However it is critical to evaluate the training program in a comprehensive manner to fully understand its effects.

READER TASKS

The typical tasks in an **MRM** program include designing, developing, and managing a human factors/MRM training course, adopting an error reporting system, and establishing a quality assurance and/or human factors group. These tasks need to be managed internally by a human factors, quality assurance, or training group. Creating and supporting an MRM program is resource intensive. Therefore, successful MRM and human factors programs and training courses are typically managed by an internal group supported by corporate resources.

External human factors and training experts can directly support the initial design stages of an **MRM** program. Outside expertise might also be necessary when expanding an existing program. The most effective locus of responsibility for an MRM program depends on its size and scope. Large-scale MRM programs can include a risk and error management system (e.g., Aurora, **MEDA**), an internal maintenance operations hot-line, and an MRM training program.

In this chapter, we are focusing on **MRM** training. Below, we describe the most common MRM training-related tasks that maintenance supervisors can reasonably be expected to perform. Readers may find themselves involved in several of the tasks listed here. Depending on the level at which it is performed, each of these tasks requires the involvement of professional human factors and training practitioners. However, as in other chapters, we advocate the active involvement of maintenance supervisors, since they will have to live with the results.

Participating on a Design Team

Maintenance workers, including supervisors and **AMT**s, may be asked to participate as members of an **MRM** design team. Their level of involvement can range from a few hours to a full-time commitment. Depending on the level of expertise and experience, a supervisor or AMT may be considered an essential subject matter expert, thus a valuable content contributor. An experienced maintenance worker might be asked to participate in any or all phases of the instructional system design process, as outlined in the **METHODS** and **GUIDELINES** sections.

Technicians may find themselves specifying the type of **MRM** skills essential to include in a training program. They may also be involved in writing a case study illustrating how MRM or human factors principles play a role in their own operation. A maintenance supervisor may script a video clip to demonstrate positive and effective verbal shift turnovers. Another task may include being trained as a co-facilitator for delivering an MRM training course. Supervisors,

AMTs, inspectors, and other maintenance people on an MRM design team will usually be working closely with maintenance management, the **FAA**, a Training Department, and a human factors expert.

Facilitating MRM Activities

Maintenance managers and supervisors will typically be expected to provide a supporting environment in which workers can practice their newly acquired **MRM** and human factors skills. Reinforcing MRM skills is an ongoing task. One way of practicing MRM skills is to facilitate an MRM activity that can be conducted during a shift or safety meeting. This can include discussing a case study of a recent or well-known maintenance incident. Case studies can be developed by the MRM design team or human factors group.

The maintenance supervisor's task in this example would be to facilitate a discussion of the human factors and **MRM** principles involved in the incident and what actions should be taken to address the root causes of the incident. Having maintenance personnel actively involved in diagnosing and discussing the case study provides an excellent opportunity for the maintenance supervisor to reinforce MRM skills.

Evaluating Performance

The success and effectiveness of an **MRM** training program will be determined in large measure by the use of MRM skills in the workplace. Managers and supervisors will be expected to assess whether MRM and human factors skills are being used by workers. These skills can observed in the interactions among technicians, inspectors, and others. Adequate practice of MRM skills should be reflected in enhanced team performance -- including completing tasks on time, safely, and alerting other members of the team about potential human factors issues and problems.

Managers and supervisors will not usually be expected to develop written performance tests related to **MRM** skills. However, they may be trained by MRM specialists regarding how and what to observe in order to evaluate the use of MRM principles and techniques. Readers of this *Guide* will certainly be involved in administering follow-up training questionnaires.

Selecting Training

MRM training courses are sometimes provided by outside vendors. Even if only part of the training program is purchased, managers and supervisors should participate in selecting the vendor and training materials. If your organization has a Training or Human Factors Department, it should have most of the responsibility for making this selection. However, maintenance people should be actively involved by providing subject matter expertise regarding content validity and training objectives.

For help in making or understanding training-related decisions, see the selection criteria contained in the **GUIDELINES** section of **Chapter 7** (**Table 7-2**, and **Table 7-3)** and also **Table 16-7** and the GUIDELINES Section (**Development Phase)** in this chapter).

GUIDELINES

The following guidelines are keyed to the implementation steps of the instructional systems design (ISD) model described in the **METHODS** section. Figure 16-4 presents the phases of the ISD process along with the associated activities and tasks in each phase.[66,67,72,73,74]

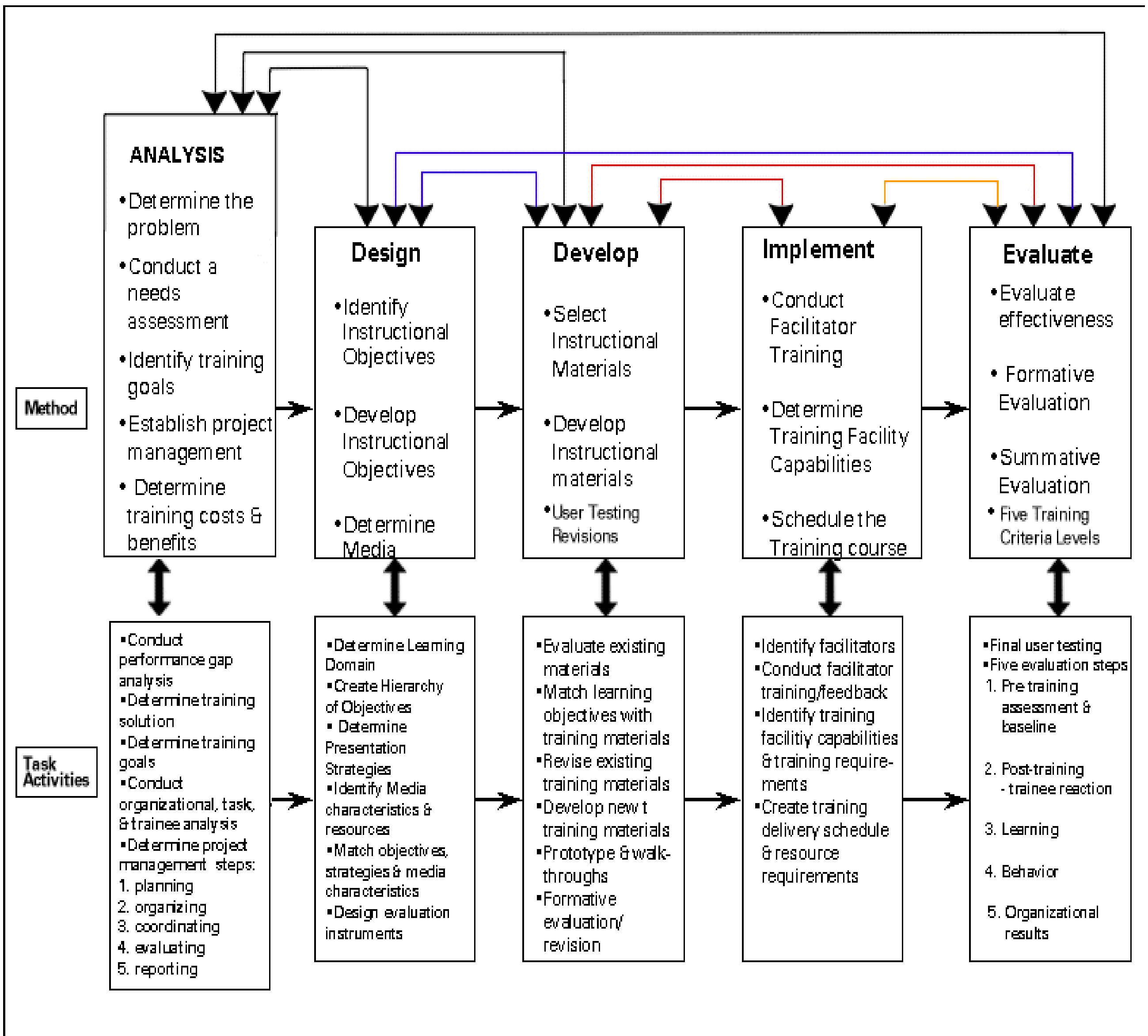


Figure 16-4. *ISD phases and activities.*

Phase 1- Analysis

Analysis is the foundation for all later work related to implementing an **MRM** training program. A front-end analysis is conducted to determine strategic training needs and to assess the company's return on investment in training. A thorough needs assessment helps reduce the risk of funding inappropriate or unnecessary training. Analysis precedes development and implementation.

These guidelines provide maintenance managers with an overview of the typical activities required to develop and implement an **MRM** training program. MRM training should be developed by a team that includes, among others, training professionals, a human factors practitioner, and various maintenance supervisors and workers. Maintenance roles in MRM development are described in the **READERS TASKS** and **SCENARIOS** sections.

Needs Assessment

Assessing needs ensures that **MRM** training addresses real workplace problems. A "need" is the difference between what exists and what is desired. Once a need is identified, it must be examined to see if it has an instructional solution. Some problem statements can then be further refined by using task analysis to isolate and relate specific worker activities. In other situations, a task hierarchy is constructed to determine how various work tasks are related. There are three levels of a needs assessment:[72,73]

1. Organizational Analysis
2. Task Analysis
3. Trainee Analysis

Guidelines for each level of assessment are given below.

Organizational Analysis

A framework for an organizational analysis is provided in **Table 16-3**.[66,72,74] In general, an organizational analysis should determine the problem(s), prioritize the need(s), and assess the organizational climate and readiness to design and implement training. The outcome of this analysis establishes the performance gap and identifies potential solutions. Organizational analysis consists of two general areas of evaluations:

- Evaluation of the organization and/or industry where the workers performs their job.
- Evaluation of the organization that will provide the training.

Table 16-3. Organizational Analysis

· Problem Identification
· Analyze incidence of problem: Information gathering and data collection
    · Calculate quantitative and qualitative data; assessment of baseline performance
    · Compare data against existing baseline or norm data to determine performance gaps
    · Analyze importance of performance gaps
· Determine probable cause(s) of performance gaps
    · Distinguish between needs that can be solved by training and those related needs that must be addressed by a change in organizational procedures/methods or policies
· Document and discuss training-related needs that must be addressed by the organization
· Prioritize identified training needs
· Determine financial commitment and resource needs
· Determine training costs
· Determine organizational and training benefits
· Determine knowledge, skills and abilities required
· Identify and target organizational performance measures
· Identify the trainee's characteristics, demographics and prior knowledge, abilities & skills

It is critical to collect organizational data. They allow us to determine the training needs and problems, as well as understand the organizational culture. It is also important to document these data. They establish quantitative baseline measures of the current organizational performance and climate, as well as the status of training programs and activities. **Table 16-4** outlines several areas that should be assessed and documented during organizational analysis.[66,72,74]

Table 16-4. Organizational Culture Assessment Categories
· Organization's mission statement, strategic plans, goals
· Values of the company in general
· Current operating procedures
· Current standing or benchmark in the industry, and/or society
· Environmental restrictions and impacts from politics, legislation, economics, global market and/competition
· Organization's performance; goal setting and accomplishment
· Organizational performance gap- Where are the gaps?
· Management style; authoritative, participate, flexible, latitude of decision making, trends in the organizational structure
· Economics performance; degree of accountability to outside funding, stockholders, grants
· Morale and climate
· Employee turnover
· Health and Safety performance; occupational injuries and illnesses; stress
· Financial commitment to training
· Management commitment to training
· Management attitude toward training and/or performance support systems
· Will managers be supportive of the program and skills taught
· How much would they be willing to invest in training of potential or current employees
· Expectations and attitudes of employees regarding their job, job environment, company as a whole, managers, peers, etc.
· Performance criteria for training program success

Table 16-5 lists topical areas that can provide data to assess and establish an organization's baseline performance.[72,73] **Table 16-6** lists categories for determining training policies and procedures.[72,74]

Table 16-5. Categories for Assessing Baseline Performance
· History of performance problems
· Impact of performance on organizational goals
· Personnel involved
· Job descriptions (steps, sequence)
· Job importance and complexity
· Morale and turnover
· Lifecycle of job
· Organizational constraints on performance

Table 16-6. Determining Training Policies and Procedures
· History of training programs
· Training policies concerning revising and customizing existing training procedures
· Accessibility of trainees (time and locale)
· Deadlines
· Budgetary and other resource constraints
· Mandatory or voluntary training
· Training program evaluation process
· Delivery of training and training personnel

After the organizational analyses have been conducted, the company's training resources must be identified and evaluated. This includes a complete evaluation of the organization that will be responsible for developing and implementing the **MRM** training program. The purpose of this analysis is to gather information that can support instructional system design decisions. Most critical is evaluating resources for developing and delivering the MRM training program. **Table 16-7** lists the factors that should be evaluated during this analysis.[66,72,73]

Table 16-7. Factors to be considered in evaluating training resources
· Financial resources available for the training project
· Time
· Training facilities
· Available personnel and their skills
· Equipment
· Cost of resources at prospective development site
· Similar or usable existing training programs
· Storage and delivery services
· Dissemination resources
· Cost of delivery or dissemination resources

We would next like to determine the cost of the **MRM** training program. Training costs are typically compared to benefits (both tangible and others) to calculate a return on investment for the training program. Various cost categories are listed in **Table 16-8**.[66,72,73,74] The benefits of an **MRM** training course include reducing errors and increasing safety, dependability, and efficiency. These benefits can be quantified and estimated by unit and overall performance measures.[8,15,19]

Table 16-8. Training Cost Factors

- **Student and Instructor Costs**
  - Number of students and instructors
  - Course length (including travel time)
  - Student and instructor salary
  - Per diem and travel costs
  - Loss opportunity cost (the student and instructor are away from the job and their skills are being used on the job)
- **Facilities Costs**
  - Administration of building
  - Space maintenance
  - Rent (these costs should consider course length and the number of students)
- **Administrative Costs**
  - Line management costs (i.e. percentage devoted to employee training administration)
  - Line clerical costs
  - Staff management within the training department
    - Maintaining records
    - Tracking of students
    - Notification of students
- **Instructional Development Costs**
  - Project leader
  - Instructional designer
  - Production costs
    - Writers
    - Artists
    - Actors, talent, (i.e. direct costs)
  - Materials cost
    - Books
    - Equipment
    - Time in days on project

- Evaluation costs
    - Tracking and measuring the effectiveness of the course
    - Survey(s) administration
    - Development of behavioral measurements
    - Identification and tracking of operational performance measures

There are a number of methods that we can use to obtain information and collect data for an organizational analysis. Several methods are listed in **Table 16-9**.[72,73,74] Probably the most efficient approach is a combination of document analysis, interviews, and questionnaires. That is, the training designer would start by obtaining and analyzing organizational documents relevant to the items listed above. Once this has been completed, a few key interviews will yield additional relevant information. This information may then be verified on a wider population sample via questionnaires. We would not expect maintenance supervisors or managers to be overseeing or conducting an organizational analysis. However, maintenance supervisors might be involved in arranging interviews, allowing time to respond to questionnaires, etc.

Table 16-9. Methods for obtaining data for organizational analysis

- **Document Analysis**
    - Organizational statements of mission and long-range goals
    - Organizational policies and procedures
    - Budgets
    - Productivity reports
    - Performance appraisals
    - Annual reports
    - Financial reports
    - Annual reviews
    - Schedules
    - Training materials
- **Interviews and Questionnaires**
    - Upper management
    - Unit management
    - Work groups
    - Individual employees
    - Prospective/new employees
- **Observation of Employees**
    - Observation of employees who are performing below expectation levels
    - Observation of "experts"
- **Testing Written or performance tests of knowledge and skills**
- **Observation/analysis of physical or organizational environment**

Task Analysis

The second level of an organizational analysis is conducting a task analysis. Task analysis determines the tasks required in a job, the subtasks that compose each task, and the knowledge and skills required to successfully complete the subtasks. Task analysis helps the instructional designer determine exactly what the learner needs to be able to do. It also allows the designer to develop objectives from the task elements. A task analysis may be accomplished by:

1. Observing a skilled and knowledgeable employee.

2. Reviewing documents/manuals on the tasks.
3. Interviewing employees who perform the tasks.
4. Performing the tasks.[66,67,72,74]

Figure 16-5 is a flow chart of a task analysis process.[66] It is critical to remember that the best sequence for instruction might be quite different than the sequence of tasks in the workplace. An instructional designer may be able to generate the instructional objectives directly from the task analysis results.

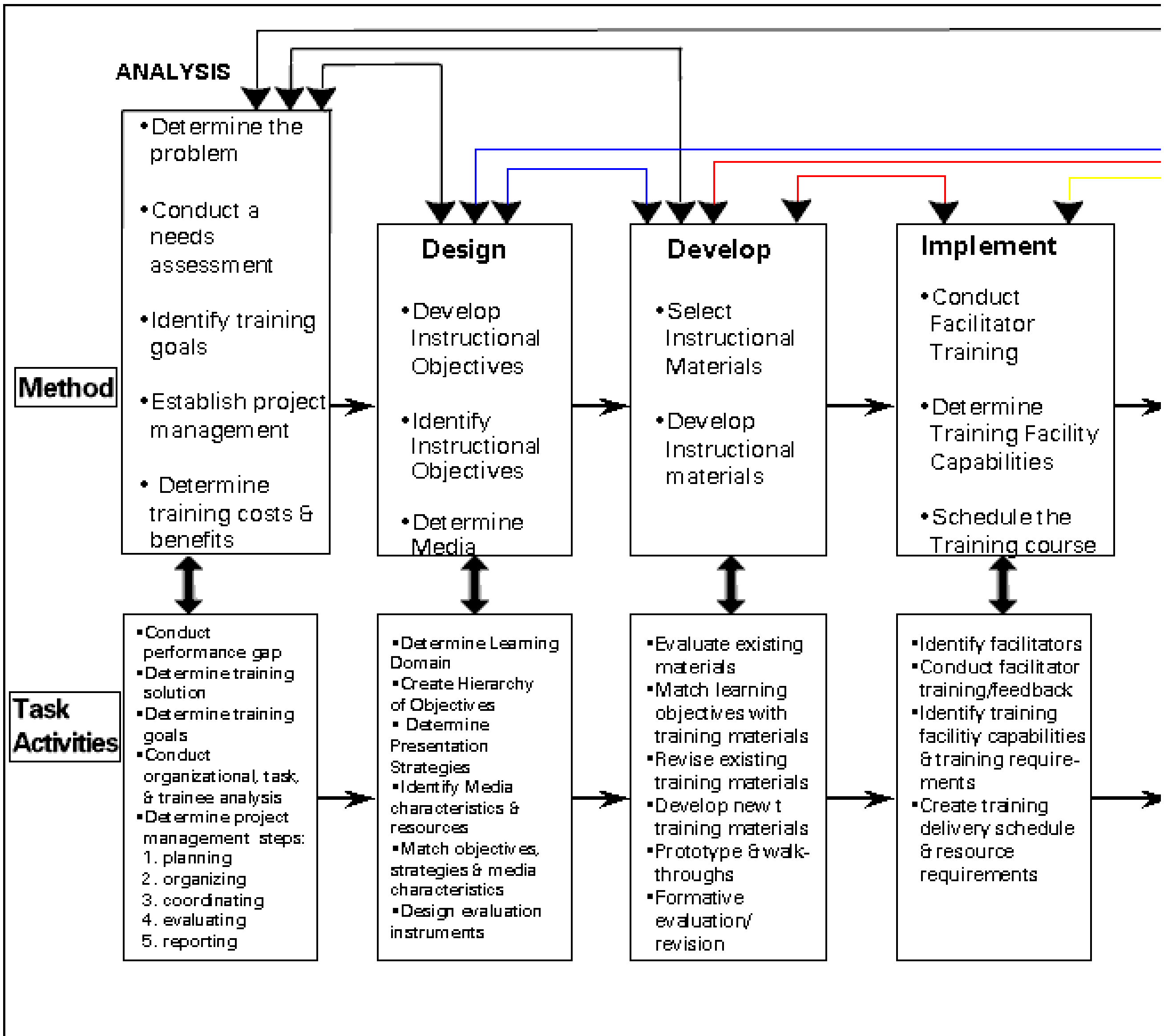


Figure 16-5. *Task analysis flow chart.*

Trainee Analysis

Trainee analysis is performed to identify the relevant characteristics of the learners who will be participating in the MRM training program. An outline of these characteristics and associated learning issues is presented in **Table 16-10**.[66,72,73,74]

Table 16-10. Factors to consider in describing training audience
· Entry-level abilities and skills of the training audience
· communication skills
· knowledge base
· comprehension level
· Size of training group(s)
· Educational background and job history
· Who do they report to?
· Career path expectations
· Attitude towards the need and motivation for better performance
· attitude towards specific tasks
· attitude towards their organization
· Previous experiences with the content of the training program
· attitude toward the effects of potential training program
· Individual learning styles
· feedback and reinforcement
· Culture
· Predominant language
· Physiological conditions/capabilities
· physical and mental health

Phase 2- Design

This phase of the **ISD** model involves developing the goals and objectives of the **MRM** training program, selecting the instructional content, specifying the instructional strategies, designing evaluation instruments, and specifying the training media. The design process consists of four levels:[74]

1. Program

2. Curriculum
3. Course
4. Lesson

The program and curriculum levels are associated with a macro (general) type of organizational analysis. Whereas the course and lesson levels are defined as the micro type of planning, such as developing instructional objectives, learning task hierarchies, evaluating and testing procedures, and selecting media. **Figure 16-6** illustrates the four levels of **MRM** training program design.

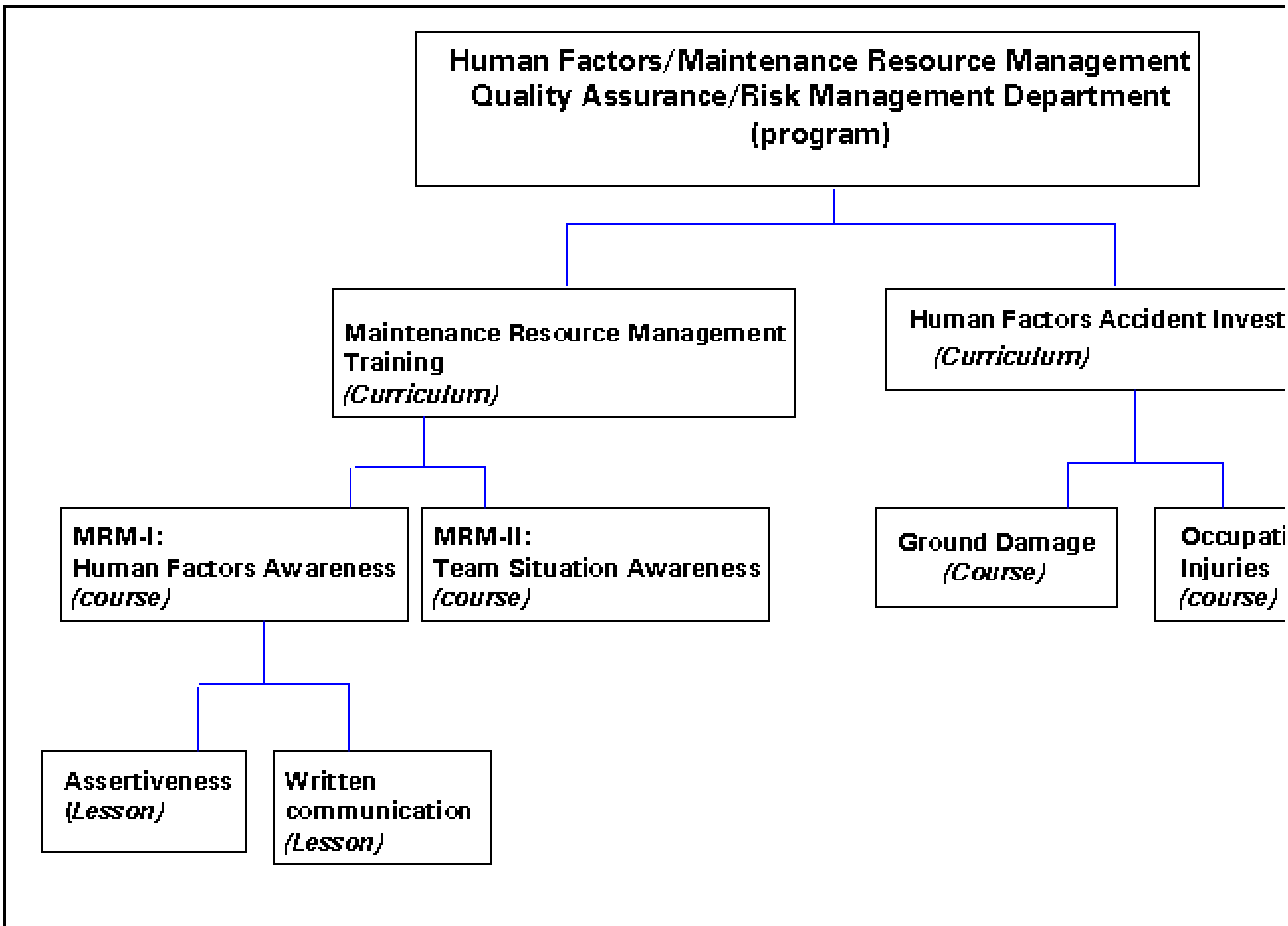


***Figure 16-6.** The four levels of MRM training program design.*

A training program can include several curricula. Each curriculum consists of a series of courses and each course will usually include a number of different lessons. The time required to design a curriculum containing several courses varies from a few weeks to a few months, depending on the level of effort expended and the complexity of the curriculum. Designing a course might require several days to a week. A lesson usually can be designed in 1 to 3 hours.

A typical **MRM** training program could be located and managed under a Systems Training group or a Human Factors, Quality Assurance, or Risk Management department. Several curricula could be identified in these departments, such as MRM training, Human Factors Risk management, Ground Damage Investigation, and Occupational and Accident Investigations. Specific MRM courses could be developed for each curriculum. For example, MRM-I: Human Factors Awareness; MRM-II, Team Situation Awareness, Human Factors and MRM Skill development, MRM -III, Scenarios and Simulations.

Each **MRM** course consists of lessons or modules, such as assertiveness, communication, team building, conflict resolution, stress management, decision making, and human factors performance elements.

Macro Design

At the macro level, the aim is to develop **MRM** training program and curriculum goals and objectives. Program-level goals and objectives are generally associated with long-range planning. Curriculum-level goals will be translated into actual curricula, which will then be organized into individual courses.[74] The example given in **Table 16-11** lists training goals and objectives on both the program and curriculum levels. This format may be used to outline the goals and objectives for each level.

Table 16-11. Example of training goals and objectives for program and curriculum levels

Program Level

Program Goal

To develop a training program that reduces the incidence of paperwork errors.

Program Objectives

1. To institutionalize the practice and procedures required to accurately complete required paperwork.
2. To enhance the capability of supervisors to assist their employees in completing the required paperwork.
3. To improve the involvement of the maintenance personnel in the design and layout of the required paperwork.

Curriculum Level

Program Objectives #1 and 2

Target Population

Supervisors

Curriculum Goal

Supervisors will be able to contribute to ensuring that the required paperwork is accurately and correctly completed by their employees.

Curriculum Objectives

Supervisors will be able to conduct better and more timely quality control reviews regarding paperwork errors.

Supervisors will be able to conduct on-the-job training for workers on how to complete the required paperwork.

Supervisors will be able to better supervise and manage employee work.

Likely Training Areas

Paperwork requirements

Quality control planning and testing

Mentoring skills

Management and supervision

Conflict resolution

Program Objective #3

Target Population

Aviation Maintenance Technicians

Curriculum goal

Technicians (**AMT**s) will understand why paperwork errors occur and will reduce paperwork errors

Curriculum Objective

Workers will employ writing proficiency skills to correctly complete their paperwork

Micro Design

During micro design, we develop the course and instructional objectives and plan the courses and lessons. We also develop the learning task hierarchies, testing evaluation procedures, and, finally, select the training media. Course-level design requires a careful analysis of goals and objectives to ensure they are observable and measurable.

Once goals are specified, an instructional analysis identifies prerequisite skills, which can be converted into learning objectives. The learning objectives are organized into a learning objective hierarchy. Lesson plans are then developed to implement the objectives and determine the sequencing of the course.

Benefits

There are several benefits to using this careful development process. These include:

1) ensuring that the required instructional content is presented in the correct order,
2) substantial cost and time savings due to eliminating unnecessary content,
3) selecting effective instructional media, and
4) effectively evaluating the **MRM** training process.[66,74]

Organizing and Sequencing Instructional Content

To organize and sequence **MRM** training program content, we first assign large units of related content to courses. Then the related content within each course is grouped into individual lessons. Finally, the content of each lesson is analyzed to determine the necessary supporting content or prerequisite knowledge and skills. Once the content of individual lessons is set, the instructional events that are components of a lesson are developed and sequenced.

Courses and Lessons

The first step in organizing and sequencing courses for a given curriculum is to link the courses with their expected outcomes and instructional objectives. Related instructional goals are organized into course groups. Every training program will have differing amount of instruction depending on the training content. A course typically contains several lessons completed over several days.

Learning Task Analysis

It is important to determine exactly what a person must learn in an **MRM** training course in order to reach the desired performance goals. The task analyses that were conducted in the needs assessment phase are used as the starting point for a learning task analysis. To complete a learning task analysis, we identify the types of learning (the learning "domain") implied by each instructional goal. The different learning domains are described below. Since the learning outcomes are different in each domain, analyzing these learning outcomes requires different techniques. Once the particular domain is identified, the appropriate analysis technique can be applied.

Domains of Learning and Learning Outcomes

Human performance can be organized by categories of learning outcomes.[66,67,73] Understanding and identifying these learning outcomes helps determine the appropriate instructional conditions for the trainees. Sometimes the performance objectives cross several domains. For example, driving a car involves psychomotor skills, intellectual skills, and attitudes. Learning outcomes can be placed into one of the five domains of learning which are[66,67,73]:

1. Intellectual skills
2. Information
3. Cognitive strategies
4. Attitudes
5. Psychomotor skills

Intellectual skills include understanding and articulating concepts, rules and procedures. These skills are sometimes referred to as procedural knowledge. Mathematical computation is an example of an intellectual skill.

Information refers to the ability of individuals to verbalize declarative information. For example, the ability to state five **active listening skills** (see **Chapter 13**) is an information learning outcome. Cognitive strategies refer to acquiring strategic knowledge. These strategies include intellectual and verbal skills. Such strategies are created when the learner brings intellectual skills and information, and the knowledge of how and when to use them, to a new task.

Attitude is concerned with the emotions and values adopted by trainees. Psychomotor outcomes include skills in the general area of muscle development and coordination. This includes complex, overt behavior that is smooth, and efficient. These behaviors are usually accomplished with minimum time and effort, such as writing and using tools.

Sequencing Instructional Content

There are two aspects to sequencing lessons: 1) instructional content and 2) instructional events.[66,74] Instructional content includes those facts, ideas, concepts, skills, etc., that are defined in the instructional objectives. This is the material we expect the learners to master by going through the lesson. Instructional events are those features of a lesson that, when present, facilitate learning. These include informing the learner of the objectives of the lesson, providing examples, and giving feedback.

The content in different learning domains has a different natural organization. For example, motor skills have procedural structures; intellectual skills have learning prerequisite structures, and attitudes have a behavioral structure. These different structures imply different instructional sequences. There is not one instructional sequence that is effective for all types of instructional outcomes. Learning is more complex than that. Different types of instructional content, i.e., different domains of learning, require different instructional sequences.

Learning Objectives

The learning objectives related to each learning outcome are ordered so that an instructional developer can specify the level or depth to which the potential learners must be able to know the information. Using the learning categories outlined earlier ensures that the instruction is properly focused. Identifying and understanding the learning outcomes can ensure that is implemented in a logical and sequential manner.

Learning Hierarchy

Learning objectives are usually arranged in a hierarchy with the terminal, or highest-level, objective at the top and the enabling objectives or subordinate elements arranged below. A course task hierarchy shows the relationship between the teaching/learning tasks and activities.[66] The training objective (terminal objective) and learning outcome is at the top. Entering behaviors and the skills, knowledge and abilities of the trainees are labeled "entering behaviors".

An example of a learning task hierarchy specifically constructed for an MRM Team Situation Awareness course is presented in **Figure 16-7**.[44] The terminal objective is specified at the top of the hierarchy and the enabling objectives are on the lower portion. Prior knowledge and entering skills are stated at the bottom, depicted below the line.

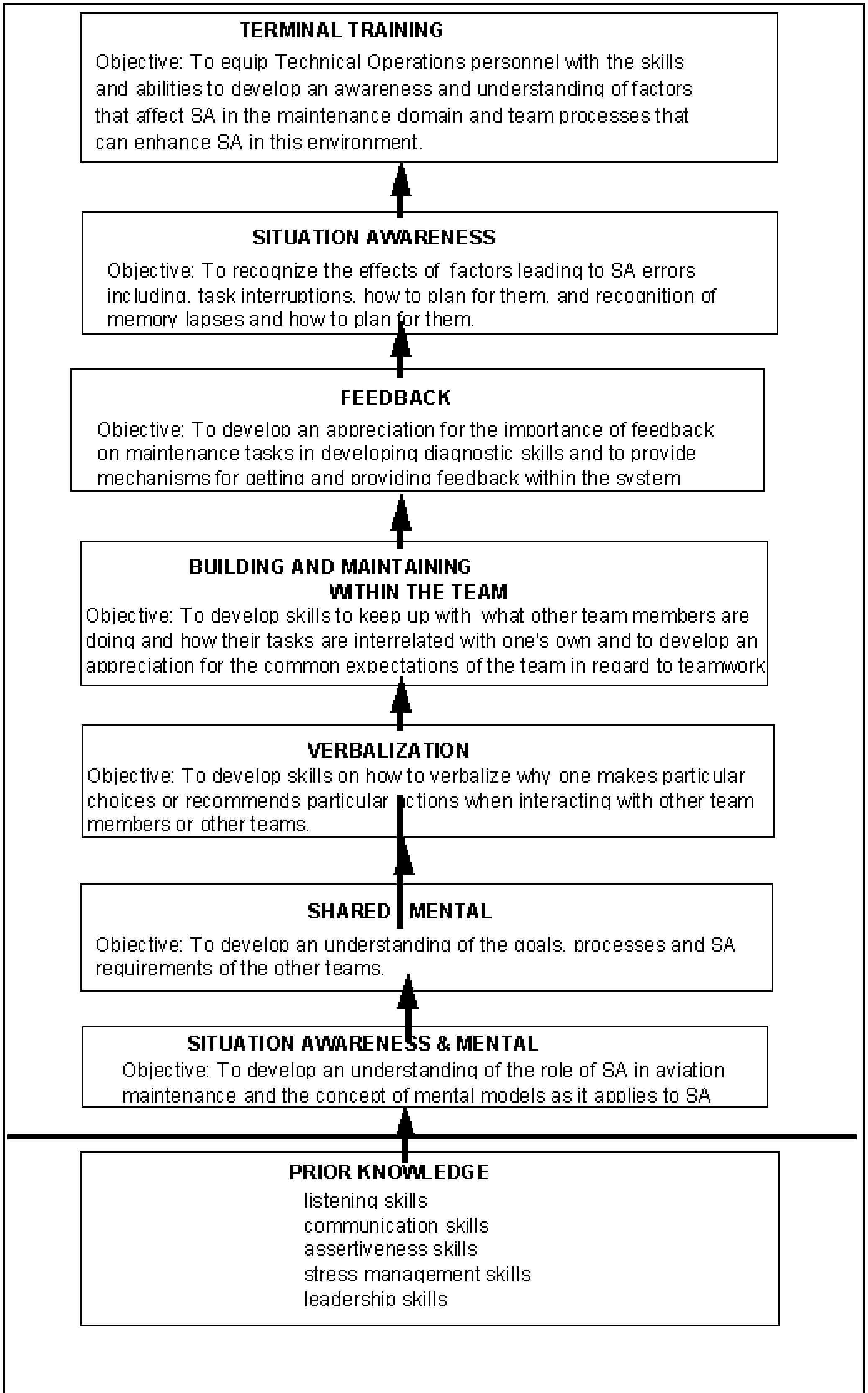


Figure 16-7. Learning Task Hierachy

Performance Objectives.

Developing and writing performance or instructional objectives should follow the "ABCD" format shown in **Table 16-12**.[66,67] It is more important to include all four components than to follow the exact sequence implied by the format. Clearly-stated and written performance objectives establish the basis for evaluating the training. Basically, we are trying to determine whether the trainees have successfully accomplished the stated instructional objectives.

Learning objectives can serve as an organizer for trainees. They explicitly state what trainees are expected to learn and demonstrate. Conversely, objectives can actually be too detailed and explicit. At this extreme, they hinder the adult learning style of active inquiry and discovery learning. Generally, we need communicate only the behavior statement. Individual instructors will have their own criteria of successful performance within the acceptable range.

Table 16-12. ABCD format for writing performance objectives
1. **A** is for the training **audience** that will perform the objective. Who is to be doing the learning? What is the entry level of the students expected to perform the objectives? When are they expected to perform?
2. **B** is the expected **behavior** of the performer. What will be the observable action or product of the action of the learner?
3. **C** is the **condition** under which the audience will perform when assessed. What resources will be used and what time limitations or resource limitations will be placed on the trainees' performance when they are being evaluated to determine if they have achieved the objective?
4. **D** is for **degree** of measurement used to determine an acceptable performance level. That is, have they mastered the objective satisfactorily?

Table 16-13 presents several industry examples of MRM/Human Factors training objectives. These objectives are grouped by terminal objectives (i.e., what trainees are expected to learn) and enabling objectives (i.e., how trainees will demonstrate their newly acquired knowledge using a pre-established set of criteria).[18,28,42,68,69]

Table 16-13. Examples of MRM instructional objectives of Trainees.

Terminal objectives (goals):

1. To increase awareness of the ways in which human factors and technical skills interrelate to create safe and efficient maintenance operations

2. To provide you with specific Human Factors techniques that will help you do your job safer

3. To examine the human role in maintenance in the chain of events that cause an aviation occurrence and develop ways to prevent or lessen the seriousness of the occurrence

4. To provide and enhance your human factors techniques and skills that will help you interact with others thus promoting a safe and error free workplace

5. To provide you with skills that when you leave this course, you can immediately use these skills

6. This course will build on the skills and knowledge previously presented in MRM Phase 1, which are: Increase situation awareness, develop "link busters" and mental models, reduce human error and increase safety

7. To understand human factors concepts as they relate to maintenance

8. To create the human role of maintenance in the chain of events that cause an aviation occurrence and develop ways to prevent of lessen the seriousness of the occurrence

Enabling objectives:

1. Demonstrate an understanding of crew performance indicators, as defined in the model

2. Appreciate the need to apply crew performance indicators to maintenance operations

3. To identify how the environment can impact performance

4. To state active listening skills

5. To understand the importance of the written word

6. Demonstrates how to seek information and direction from others when necessary

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

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

9. Demonstrates the ability to involve other crew members in the decision making process

10. Uses appropriate communication techniques to manage interpersonal and operational conflict

11. Understands different crew members behavioral style and interpersonal differences

12. Demonstrates the use of tools and resources to maximize effectiveness and reduce errors.

Sequencing instructional events

A useful design format that supports learning consists of nine steps or instructional events.[67] These instructional events are based on how we process information as we learn. They are appropriate for all learning situations and outcomes. **Table 16-14** presents these nine instructional events.

Table 16-14. Instructional events for supporting learning
1. Gain the trainee's attention -- gain and maintain student attention by the use of novel, surprising, incongruous, or uncertain events instruction.
2. Describe the objectives of training -- use an advanced organizer.
3. Stimulate recall of prerequisite skills -- what did they learn before?
4. Present the content to be learned -- examples and non-examples.
5. Provide guidance and support -- performance aids/directions.
6. Elicit performance.
7. Provide feedback -- verbal and written.
8. Assess performance -- criteria.
9. Enhance retention and transfer -- transfer skills to work site -- manuals/pamphlets.

When designing a training course, the instructional design strategy should embody the following five guidelines related to sequencing instructional events:[66,67]

1. Prepare the learner
2. Direct the learner's attention
3. Provide learner participation
4. Provide feedback to the learner
5. Provide repetition

Specifying training media

After instructional objectives have been developed, designers must select instructional strategies and media. These decisions tend to be interrelated and should be made concurrently.

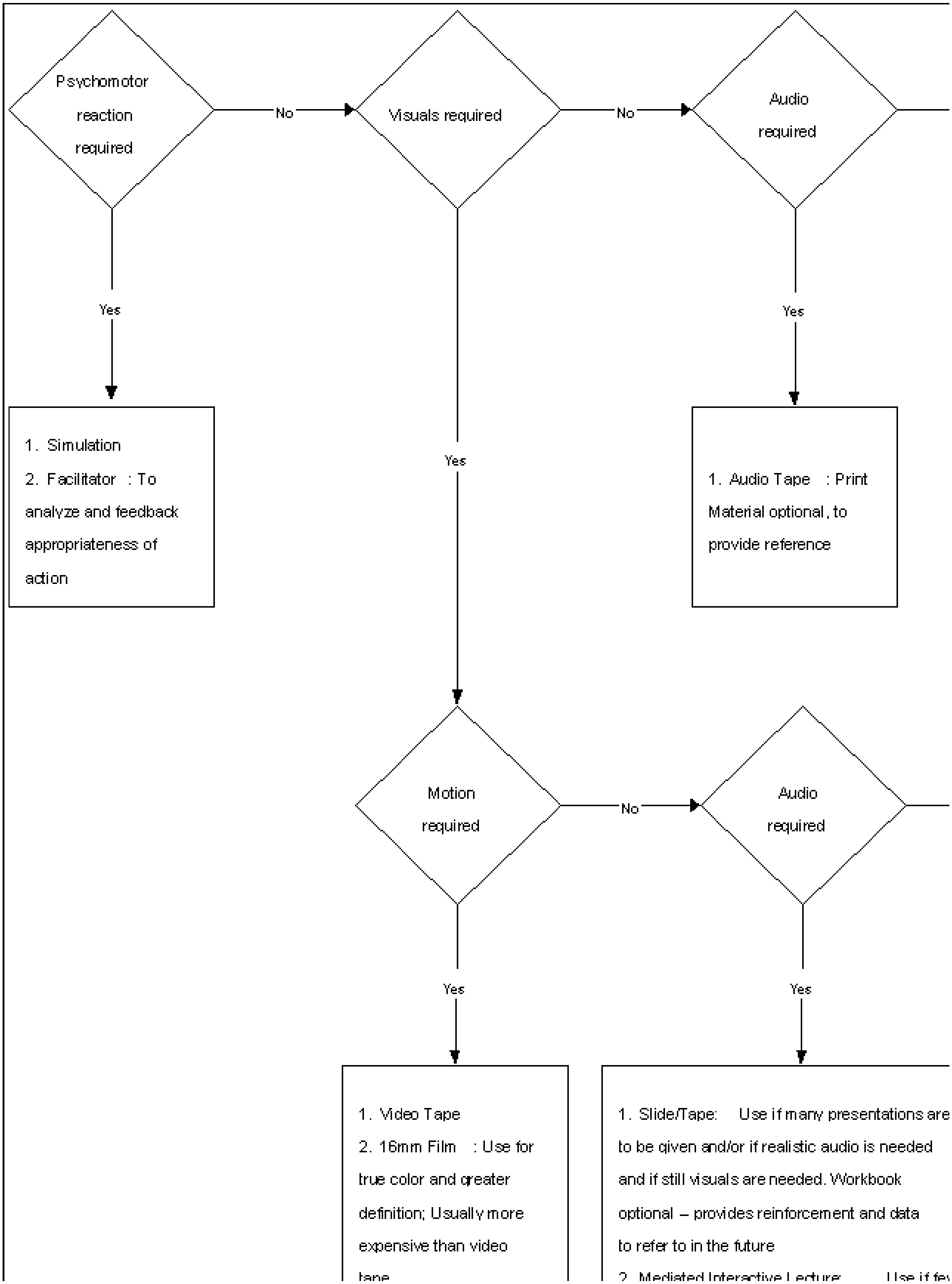
Many instructional strategies use a combination of methods and media to deliver the training. **Table 16-15** lists several kinds of training methods and media. Methods and media tend to interact. For example, the discussion method, in which the trainer and participants exchange ideas about a given topic, can be enhanced by a videotape showing a maintenance situation.

The model used to select an instructional media can range from simple to complex. The instructional medium should present instructional stimuli in an efficient, easily understood manner. Complex media, which tend to be costly and time-consuming, are often inefficient and unreliable. However, using an inefficient low-cost medium can be just as costly as using an expensive, but efficient medium. Use the least expensive medium that will result in trainees' attaining the desired objectives within a reasonable amount of time.

Table 16-15. Examples of training methods and media.[66,72,73]

Methods	Media
Lecture	Text and print
Discussion	Visual aids (e.g., stills, graphics)
Tutorial	Audio (e.g., radio, cassettes)
Self-Study and programmed instruction	Audiovisual techniques (e.g., videotapes)
Demonstration	Computerized media
Simulation and business games	Interactive video
Role Play and behavior modeling	
On-the Job training	
Inquiry Learning	
Computer based-instruction/training	
Intelligent computer-assisted instruction	

Choose as the primary medium of instruction one that is appropriate for the majority of objectives – one that can be used throughout the instructional program. Additional media, such as simulations or animated visualization, can be used for emphasis or motivation. It is desirable to have a mix of instructional methods that actively involve the learner. However, frequent media changes are often confusing, time-consuming, and expensive. Group exercises, role playing, and games or simulations that involve the trainee, promote the sense that the training is relevant and useful.



Psychomotor reaction required
No
Yes
1. Simulation
2. Facilitator : To analyze and feedback appropriateness of action
Visuals required
No
Yes
Audio required
Yes
1. Audio Tape : Print Material optional, to provide reference
Motion required
No
Yes
Audio required
Yes
1. Video Tape
2. 16mm Film : Use for true color and greater definition; Usually more expensive than video
1. Slide/Tape: Use if many presentations are to be given and/or if realistic audio is needed and if still visuals are needed. Workbook optional – provides reinforcement and data to refer to in the future
2. Mediated Interactive Lecture

Figure 16-8. If-Then media selection model. *Note. From <u>Instructional technology: A systematic a</u>*
and K. L. Gustafson, 1986, New York, NY: Holt, Rinehart and Winston, Inc. Copyright 1986 by F. G
with permission.

There are several media selection models. Each represents a different approach to the task. The major selection question for any medium is: "Will it cause the trainee to learn the objectives?" If an instructional format or medium is not appropriate for the objectives, then it should not be considered. If there are alternate media that work equally well, the least expensive should be chosen.

A relatively simple "If-Then" media selection model[66] can be used where a maximum of five decisions must be made by an in order to choose an instructional medium. This model, shown in **Figure 16-8**, is based on a military instructional development project. It is relatively easy to use and is based on the behavior and condition statements contained in learning objectives.

The media-selection form in **Figure 16-9** shows the relationships of objectives to each other and to the alternate media choices.[66] The objectives listed in columns on the left side of the form are in the order in which they will be experienced by the learner. A check mark is placed in the appropriate cell of the matrix. An instructional developer can easily see the suggested sequence of media usage. Using such a matrix is an excellent way of understanding and communicating media decisions, regardless of the media-selection model. It also helps to see the mix of the training media and the frequency of changing media.

Order media (1 high)	Psychomotor		Audio No Visual		Motion Visual		Visual No Audio					Audio and Visual				
Objective Number	Trainer/Simulator	Facilitator	Audio Tape	Lecture	Video Tape	16mm Film	Animation Models	Booklet/Handout	Programmed Booklet	Slide/Tape	Computer Assisted Instruction	Side /Tape	Mediated Interactive Lecture	Booklet/Tape	Interactive Computer Assisted Instruction	Computer Based Training

Figure 16-9. Media selection form. *Note. From <u>Instructional technology: A systematic approach to education</u> (p. 173), by F. G. Knirk and K. L. Gustafson, 1986, New York, NY: Holt, Rinehart and Winston, Inc. Copyright 1986 by F. G. Knirk and K. L.*

Gustafson. Adapted with permission.

Another method of making media selection decisions is to relate the general domain of each objective to student grouping requirements. For example, if the course objectives are at the lower end of the cognitive taxonomy (e.g., knowledge of specifics and comprehension), then certain types of teaching activities or media are more appropriate for individualized instruction. Others may be more appropriate for group instruction. Typically, **MRM** and **HF** courses are designed for group learning and the media selections should be appropriate for these learning and group requirements.

Figure 16-10 presents three categories of learning: 1) lower-order cognitive, 2) psychomotor, and 3) affective and higher-order cognitive combined.[66] For each category, instructional media are suggested for individual, small-group, and large-group instruction. One of the main assets of this framework is that it forces designers to carefully consider the range of available media before making a selection.[66]

Objective Categories	***Individual Instruction***	***Small Group***	***Large Group***
Cognitive (lower order)	Textbooks Workbooks Audio tapes Programmed materials	Study groups Case studies	Lectures Video Tape 16mm Films
Psychomotor	Laboratory-directed practice	Simulator/Scenarios	Demonstrations
Affective and cognitive (higher order)	Research Fieldwork	Discussion Simulation, gaming and scenarios Human relations, feedback training	On-site experiences

Figure 16-10. Categories of learning. *Note. From Instructional technology: A systematic approach to education (p. 174), by F. G. Knirk and K. L. Gustafson, 1986, New York, NY: Holt, Rinehart and Winston, Inc. Copyright 1986 by F. G. Knirk and K. L. Gustafson. Adapted with permission.*

Each combination of instructional method and medium has advantages and disadvantages. For a further discussion of the strengths and weaknesses of each training medium and method, see the **FURTHER READING** section. **Table 16-16** shows a list of selection criteria that should be considered when determining training methods and media.[66,67,72] It is also important to consider the media technology capabilities, support, and lay-out of the training facility where the instruction will take place.

Media and method decisions should be driven by the objectives, conditions and events specified in the instructional strategy. This approach is supported by research indicating that there is nothing inherent in any particular method or medium that makes it better or worse than another. It is also important to consider the overall cost-effectiveness of options. Some material may be more expensive to initially produce, but actually cost less in the long run.

Limitations on instructional format can also affect what methods and media will be more effective. For example, lectures may be more effective when large groups are assembled, just as role playing or simulations are likely to work better when individuals can be trained in small groups. Organizations are not typically capable of producing all types of media. It is generally more cost-effective to first review the availability of existing materials or the possible purchase of vendor materials before deciding to produce new, original materials.

Table 16-16. Factors to consider in training methods and media selection.
· Objectives (e.g., supporting the learning objectives)
· Conditions and events (e.g., which media provide more of the desired instructional events?
· Which media provide the best for incorporating most of the conditions of the learning appropriate for the objective?)
· Time and money: Overall cost-effectiveness of media and method options (e.g., lifecycle, number of trainees, total media cost for course; instructional media trade-offs)
· Trainees and Instructor familiarity of training method and media (e.g., using the media)
· Instructors familiarity of using the method or media in the designing the course
· Availability of trained personnel and their per-hour costs
· Size of group and frequency of instruction
· Format of media and method
· Accessibility, durability and convenience
· Ease and speed of production of the various methods and media options
· Training Facilities design and media support
· Flexibility of media (e.g., adaptive to changes in the training course)
· Cost for spare parts, repairs and replacement of items that become damaged; backups
· Disruption of using the media

Instructional Facilities Design

Table 16-17 lists essential training facilities factors that should be considered in determining instructional facility requirements.[66,67]

Table 16-17. Instructional Facilities Design

Computers and Facilities Requirements
- Computer workstation Design: Ergonomic workstation (e.g., chair, work surfaces, keyboard, mouse, storage)
- Monitor, CPU, input devices
- Equipment for display images (e.g., Powerpoint presentations)
- Power requirements and cables

Audiovisual Media and Training Facilities
- Image projection requirements
- Power distribution systems and conduit requirements
- Viewing Angles and Projection Screens
- Media and Materials Storage Requirements

Grouped and Individualized Learning Environments
- Grouped instruction and facilitation
- Individualized learning and instruction
- Seminar Areas
- Facilitator preparation areas

Lighting and color characteristics
- Light Level and contrast
- Color
- Natural lighting and windows

Heating, Ventilation and Air Conditioning Considerations

- Acoustical Considerations
- Noise and Disruptions

Furniture and Ergonomic Design Considerations

- Individual workstation design
- Chairs and Tables
- Carpeting and flooring materials
- Training furnishings

Categories of Instructional Technologies

Instructional technologies can be categorized according to two dimensions -- abstraction and interaction.[66,72,73,74] At one end of the abstraction scale are totally abstract methods. At the other are very realistic, concrete methods. Likewise, some methods are totally passive and one-way, such as videotape. At the other end of this scale are very interactive methods, such as group discussions, role-playing, etc.

These two dimensions are critical in determining the effectiveness of any particular instructional technology. Older technologies, such as text and lecture, tend to be more one-way and abstract. Newer instructional methods, such as simulation, tend to be more concrete and interactive.

Earlier in this chapter, we noted that **MRM** training is typically considered a form of adult education, characterized by inquiry learning. Inquiry learning leans more toward the abstract and interactive ends of the technology dimensions. Since MRM training includes inquiry learning, it is essential to understand its strengths and weaknesses. The general strength of inquiry learning is that it promotes active, generative knowledge acquisition in the learners.[67,72] It relies on concrete, experiential activities, is highly-adaptive to the level of the learner, and is interactive.

Inquiry learning tends to be highly motivating, since trainees are active and actually perform job-like tasks. The primary weakness of inquiry learning is that it is resource intensive.[72] Instructors must take the time to identify and plan activities that promote inquiry learning. Learners must be in a centralized location in order to interact and learn together.

Training plan: course outline and lessons

After the previous steps and activities are completed, a training plan is prepared. A training plan provides a blueprint or "road map" for the training development phase. First, an outline of the lesson sequence should be developed. This includes a general framework or schedule for the course. **Table 16-18** shows an **MRM** course outline.[18,28,42,68,69]

Table 16-18. Example of an MRM course outline.
Introduction to Human Factors in aviation maintenance
Human Factors and **MRM** elements
Human errors
Chain of events
Safety nets and link busters
Norms
Individual differences and behavioral styles: Assertiveness
Communication in the maintenance workplace
Stress Management
Interpersonal skills: Decision Making and Problem Solving
Fatigue and shiftwork
Situation Awareness
Task Interruptions and complacency
Human Factors initiatives in this company
Human Factors and **MRM** resources in this company and other outside references

The training outline is then further developed to include the lesson details. This involves providing a description of the training objectives, content, media, training aids, and other elements required for actual instruction. The lesson plan also includes estimated time required for each training topic. An example of an **MRM** lesson plan is provided in **Table 16-19**.[18,28,42,68,69]

Table 16-19. Example of an MRM lesson plan.

Module Title: Maintenance Resource Management Awareness Course

Module Goal: To have an awareness of how human factors and maintenance resource management skills can reduce maintenance errors and increase safety.

Lessons objectives:

1. To identify 12 human factors elements and their role in the chain of events leading to maintenance-related errors
2. To identify behaviors in maintenance that are risk behaviors and ones that are valued
3. To understand the importance of the written word
4. To develop safety nets or link busters to minimize risk and maximize performance
5. To identify norms and list actions on how to manage them
6. To understand and identify five ways to manage stress

Lesson #1 Topic	Content	Training Media	Time
Introduction	**What is human factors?** **Definition of MRM** **How Human Factors impacts performance**	**Videotape** **Lecture with powerpoint** **Case study** **Group exercise** **Class de-brief**	**20 minutes** **10 minutes** **25 minutes** **10 minutes**
Human error in Maintenance	Accident statistics Types of human error Consequences of errors	Graphs & charts Graphs & charts Videotape Slides/pictures	5 minutes 5 minutes 7 minutes 5 minutes
Chain of events	Multiple causes of accidents Active and latent variables Identify chain of events	Graphs & charts Graphs & charts Videotape Group exercise Class de-brief	10 minutes 10 minutes 20 minutes 20 minutes 10 minutes

Design of Evaluation Instruments

There are several training evaluation instruments that need to be designed to measure the effectiveness of **MRM** training. Evaluating the training program involves measuring the degree to which the learning objectives were met. Using the information from the task analyses and the learning objectives hierarchy, we can establish performance criteria that can be subsequently measured and evaluated. These training evaluation instruments may include:[66,71,72,73]

- questionnaires
- observations
- interviews
- verbal protocols
- task performance measures
- work unit and organizational performance measures

These training assessment tools should be developed by training or human factors specialists. A maintenance supervisor's most likely role during this part of the design phase will be providing subject matter expertise regarding maintenance operations and procedures. Certain instruments collect essential training-related performance data before and after the training program takes place. These assessment tools are used at different times during the training evaluation process. **Table 16-20** presents a typical evaluation assessment process.[70,71,72,73] It serves as a basis for creating a training evaluation task timeline.[70,71,72]

Table 16-20. Evaluation assessment process and outline.

- Prototype testing: Usability and Measures of attitude toward the instructional strategy and approach
    - observation protocols
    - questionnaires
    - interview protocols
    - user verbal protocols
- Final User testing: Measures of comprehension, retention, and transfer
    - pre and post training questionnaire
    - interview protocols
    - observation protocols
    - user retrospective verbal protocols
- Pre training assessment and baseline
    - Current task performance measures
    - Current attitudes, opinions
    - Current skills, knowledge, abilities
- Post training assessment
    - Trainee reaction; Post-training questionnaire; Interviews
        - Usefulness
        - Relevant
        - Valuable
    - Learning outcomes; measured by pre and post training questionnaires
    - Post-training questionnaire
        - Self-reported intentions
            - attitudes and behaviors
- Follow-up questionnaires
    - 2, 6, and 12 month follow-up training questionnaires
- Observable Behaviors; Work tasks, interactions and performance assessment
    - Interview and observation protocols
    - Supervisors, work unit leader and peer assessment instrument
- Organizational results and outcomes
    - Work unit performance data
        - Trend analysis and tracking

- Organization performance data
  - Trend analysis, forecasting, and tracking

It is important to plan and design the course evaluation process carefully. Creating an evaluation plan during the design phase will ensure that the process is more efficient and provides useful information. The evaluation process establishes the link between the goals and objectives of the training program and its results. Information collected from the course evaluation creates an important feedback loop -- demonstrating the overall effectiveness of the training. This information is also useful for revising the course.

Instructional lessons should be scheduled for prototyping and user testing as soon as feasible to provide timely feedback to the instructional designers. Early testing and feedback lowers development costs and makes the evaluation process more efficient. Also, it is important to plan for the resources that will be necessary to develop, administer, analyze, and manage the evaluation process. These resources include personnel time, administration and production costs, training time for observers and evaluators, and computer support for data collection and analysis.

Phase-3 Development

The primary activities in the development phase are developing training materials and media, as well as developing and testing prototypes. Training materials are modified during this phase, based on the results of prototype and user testing. An outline of typical activities for selecting and developing training materials is shown below:[66,72,73,74]

- Create a development plan
- Search for existing content related training materials
- Evaluate existing instructional materials
- Match objectives with training content and materials
- Make trade-offs of objectives and training materials (economic and effectiveness)
- Examine copyright requirements (obtain copyright permissions)
- Revise/modify existing training materials
- Develop and produce new training materials
- Develop facilitator and participant handbooks
- Prototype and walk through of new training materials
- Revise/modify new training materials and handbooks
- Final user testing of training materials and handbooks
- Final development of training materials and handbooks

Training Development Plan

With the existence of the instructional program it is easier to develop a detailed plan for specifying training resources, cost, and time for completion. A training development project plan should specify the following elements:[66,72,73,74]

- Personnel -- training and human factor specialists, content specialists (maintenance)
- Budget -- money to develop the training materials and handbooks; personnel cost of developing the course; travel time and expenses; evaluation costs
- Equipment -- technical equipment, audio/video facility, video cameras, studio equipment, editing equipment, audio equipment
- Outside services and consultants -- scriptwriters, actors, graphic designers, videographers, computer programmers
- Tasks and activities to be completed and by whom
- Training tasks and activities timeline

An example of a project budget form is shown in **Table 16-21**.[72]

Table 16-21. Example of project budget form. Note. From Systematic training program design: Maximizing and minimizing liability, by S. Gordon, 1994, Englewood Cliffs, NJ: Prentice Hall. copyright 1994 by S. Gordon. Adapted with permission.			
Training Factors	**Dollar/Hour**	**Numbers of hours**	**Total Cost**
Personnel: 1. Training Design Team Salaries 2. Project Team Manager Salary 3. Instructional Designers 4. Script Writers 5. Videographers 6. Consultants/Specialist Fees 7. Graphic designers 8. Computer Programmers 9. Actors 10. Media Technicians			
Training Design Facilities: 1. Computer Time & Usage 2. Rental Fees of facilities 3. Rental Fees of training equipment			
Media Development & Materials: 1. Audio/video equipment 2. Audio equipment 3. Video cameras 4. Studio equipment 5. Editing equipment 6. Training materials 7. Computer software 8. Videodiscs 9. Computer discs 10. Computer discs or other storage media 11. Videodisc production			
Facilitator Handbook: 1. Reproduction costs			
Training Delivery 1. Instructional materials 2. Travel time			

Evaluating Instructional Materials

When selecting commercial instructional materials, each candidate material should be evaluated by asking and answering the following questions:[66,67,72,74]

- Is the product well organized? The instructional material should clearly relate its facts to a few basic ideas in an organized manner.
- Do the materials prepare the learner for the presentation?
- Is there an advanced organizer?
- Do the materials keep the learners' attention? Media and instructional technology should be attractive and relevant to the trainee.
- Do the materials provide sufficient repetition through examples, illustrations, and questions resulting in a understanding of the content?
- Is the instructional presentation well-paced?
- Do the trainees have time to think about and accept the instructional presentation?
- Have the materials been presented in a technically-competent manner? This includes instructional technologies and media characteristics, such as the clarity of slides, music and the narrator have appropriate relative volume, the absence of extraneous and annoying sounds on audio tape, etc.

An evaluation form should be created that allows the training development team to critically and thoroughly evaluate each instructional technology or medium. A generic training media evaluation form is shown below.[66,72,73] (See **Figure 16-11**.) A five point Likert-type scale can be used to evaluate the technical and content characteristics of each training media. Additionally, **Table 7-5** in Chapter 7 presents human factors criteria for evaluating computer-based training products.

Designer(s)_______________

Evaluator(s)______________

Date_____________

Instructional Media Evaluation Form

1. Instructional Module:
2. Trainee Population:
3. Training Course Goal:
4. Performance Objectives:

5. Media evaluation: Example: PowerPoint slides and other 35mm slides

    A. Technical Quality:
        1. Legibility
        2. Color
        3. Framing

4. Composition
5. Clarity
6. Framing
7. Animation/Clip Art

B. Content:
1. Originality
2. Continuity
3. Use of Humor or Drama
4. Support visuals
5. Vocabulary

6. Overall, were the media appropriate for the performance objectives?

7. What I particularly liked about this program is:

8. What I did not particularly like about this program is:

Figure 16-11. *Instructional Media Evaluation Form*

Developing training materials

Training materials are developed by first creating an outline and then a draft. The media selection model(s) chosen in the design phase will serve as the framework for developing training media. The sequence of instruction that was designed earlier provides the structure for developing the training materials.

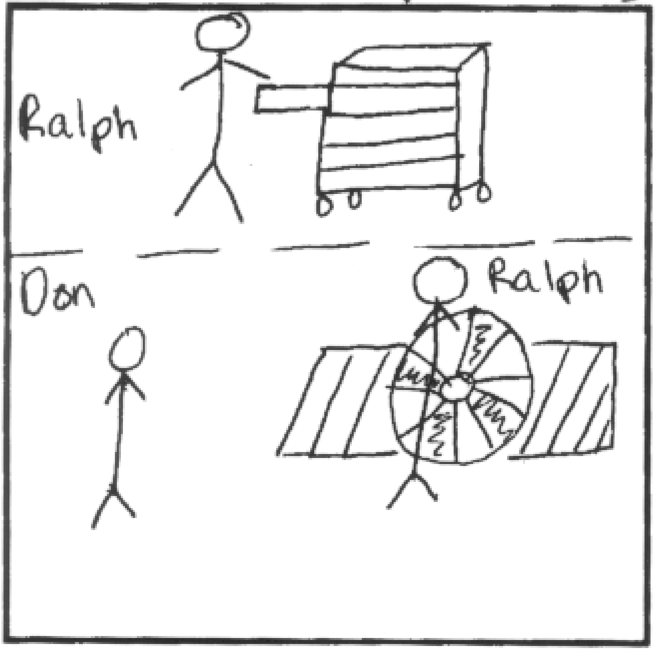
Before beginning production, instructional objectives should be reviewed to confirm their sequential order. Conceptual sketches and outlines of the audio-visual aids are developed and then reviewed by other members of the design team and relevant subject matter experts.

People often use "storyboards" to plan out their training activities. A storyboard is a series of static pictures or graphics that sketch out the nature of the program. Storyboards are visual representations that can be as simple as a series of index cards with stick figures with simple directions written out on them or as complicated as a computer slide show (PowerPoint and /or linked computer screens with animation).

Two types of storyboards are presented here. The first, shown in **Table 16-22**, is an example of a maintenance training video storyboard.[28] Maintenance supervisors often participate on a design team developing a video. They typically help write and review the script to ensure technical accuracy. Sometimes, supervisors also act in the video.

Table 16-22. Maintenance Training Video Storyboard/Script

Title **Wheel Shop** Wrong Bearings Installed | Scene



Description of Visual

Description of Visual

Don and Ralph are working in the final assembly section of the Wheel shop.

- Ralph gets a bearing from the bearing cabinet, and walks over to the main wheel final area, where Don is standing.

Comment

Script

Script:

Narrator: "Due to improper bearings bei installed on an main wheel during final assembly, wheel fall off aircraft on takeo Fortunately there were no injuries."

Ralph "Don, I'm going to go ahead and install the bearings."

Don " OK, Ralph, but don't forget to ch the part numbers."

Ralph " Hey, don't worry about it Don, I installed a million of em."

Don " Yeah, I know, but just be sure the part number is OK."

Ralph, "Look, don, do you wanna do thi think I know what I'm doing!

Ron "Naw, that's OK. I just want to be certain. We had a problem before."

Ralph "I'm not an idiot. Just do your job and I'll do mine."

Requester's Supervisor Approval	Date
Supervisor Graphics Approval	Date

Other storyboards can be created to plan out what happens in an actual training program. An example of such a storyboard, which incorporates PowerPoint slides with a written script, is shown in **Table 16-23**. This storyboard can serve as the basis for developing a facilitator handbook.[13,28]

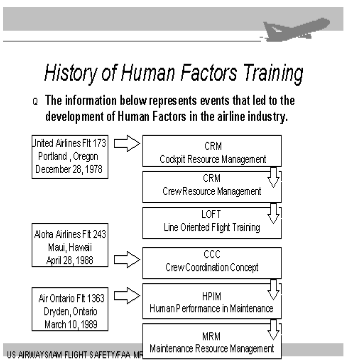
Table 16-23. Example of a Storyboard with Powerpoint and Facilitator Notes	
Facilitator Handbook: MRM Training	
MRM Human Factors Training: Introduction	
Activity/Overhead	**Facilitator Notes**

Handout
Pre-training questionnaire

Explain: This course is being evaluated. We need a before and after picture. Here is a survey we want you to complete. Your answers, combined with all other people in Maintenance who take this course, will help us better understand our Human Factors training program. Of course, the survey is completely confidential. Please do not put you name on it anywhere.

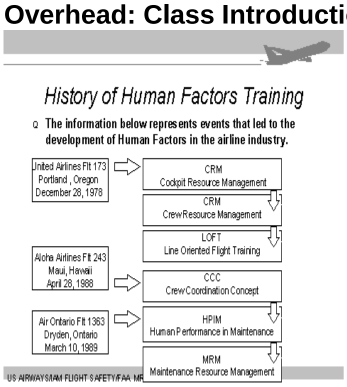
Assign group names: Example:
types of aircraft

Overhead: History



Explain: This overhead illustrates the events that led to the development of Human Factors training. We are here today in our MRM course to learn about error management, by using human factors skills and understand what error prone tasks are.

Overhead: Class Introduction



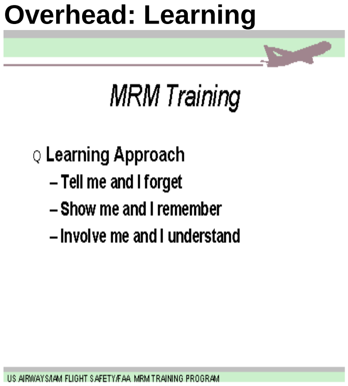
Introduce facilitators & participants (Allow 30 seconds for each participants)

Name/Title
Years of service
How did you get into aviation?

Overhead: Workshop Agenda

We understand that some of these terms may be new to you, but as the day goes on, you will understand what these terms mean. Please be prompt on returning from your breaks. Lunch will be from 11:00 a.m. to 11:30 am. Feel free to use the restroom.

Overhead: Learning



This is a workshop, not a lecture. You will get out of it what you are willing to put into it. If I lecture you will not remember, but if I involve you will get more from this course. Involvement is an important way of doing business at this company. This class has us doing case studies, reviewing videos, and group activities. It is highly interactive.

Looking at a complete storyboard can give a general overview of how the training program will look when it is complete. It is beneficial to have a large area in which to layout the storyboard sketches. Linked computer screens can be used to prototype lectures, simulations, and videotapes. When a draft outline and storyboard are created (with sketches), this product can be considered a prototype of the training course.

Storyboard scripting

Developing a script requires the instructional designers and other team members to think visually. Sound and the written word are often not as reliable as a visual presentation for developing the trainees' retention. Visuals can carry the message and narration can be used to clarify and reinforce the visuals. The development team should be certain that the graphics, written material, and audio support each other. Scripting the training materials requires the instructional designer to:[66]

- Clarify difficult points through visual illustrations.
- Simultaneously present to two different human senses, i.e., the eyes and ears.

- Determine the best approach to convey the message quickly and clearly.
- Isolate and focus the trainees' attention on the central points specified by the performance objectives.

Walkthrough and formative evaluation

It is much easier to modify the training materials during the design and development cycle, rather than after the training program has been implemented. Conducting a formative evaluation of the training program while the training materials are in a draft form allows essential and meaningful feedback to be collected from the learners.

A simple formative evaluation consists of having the trainees read and review a storyboard. If the storyboard requires many visuals, use a quick-draw artist to facilitate its development. This will permit the subject matter experts reviewing the storyboards to see actual rough visuals and will also give the trainees a better understanding of the training format.

Conducting a user test on the training materials should include evaluating the trainees general reactions to and comprehension of the materials. It should also measure the usefulness of the materials. User testing will give the development team a good idea whether the general training approach is a sound one. **Table 16-20** lists various formative evaluation methods.[70,71,72,73]

The advantages of prototyping and user testing are that they allow us to solicit meaningful feedback from the users. They will improve the quality and completeness of the final training program. Additionally, early user testing can reduce program costs and increase the probability that the product will perform as required.

Final development and user testing

After the prototyping and walkthroughs have been completed, the training materials are put through the final development and production steps. After the production training materials are available, but before they are actually implemented, they should be subjected to one more stage of user (learner) testing.

Why should we do user testing with the production materials? The main reason is that the testing results can be different than those obtained earlier in the development process. Learners will now be reacting to the finished product. Using one, or more, evaluation method listed in **Table 16-20**, we can provide data illustrating the degree of learning that occurred, the perceived usefulness and value of the training, the changes in trainees' attitudes and behaviors, and the effects on organizational performance.[66,67,72]

Facilitator and Trainee Handbooks

After the final user testing is completed and the training program is ready to move into full development and production, facilitator and trainee handbooks should be developed. There are many potential formats for these handbooks. Typically the facilitator handbook contains the following elements:

- a detailed outline of the instructional sequence,
- a description of the course and lesson goals and objectives,
- a narration of the visuals to be presented,
- the training timeframe,
- administration issues and guidelines,
- description of the group exercises,
- a list of the participants and facilitator materials,
- a list of reference materials,
- a description of how to set-up the training classroom, and
- a list and description of the evaluation instruments (see **Figure 16-12**).[18]

The trainee handbook typically contains all evaluation instruments, copies of the visuals, instructions for participating in the course, course goals and objectives, instructions for group exercises, copies of case studies, articles, and other reference materials.

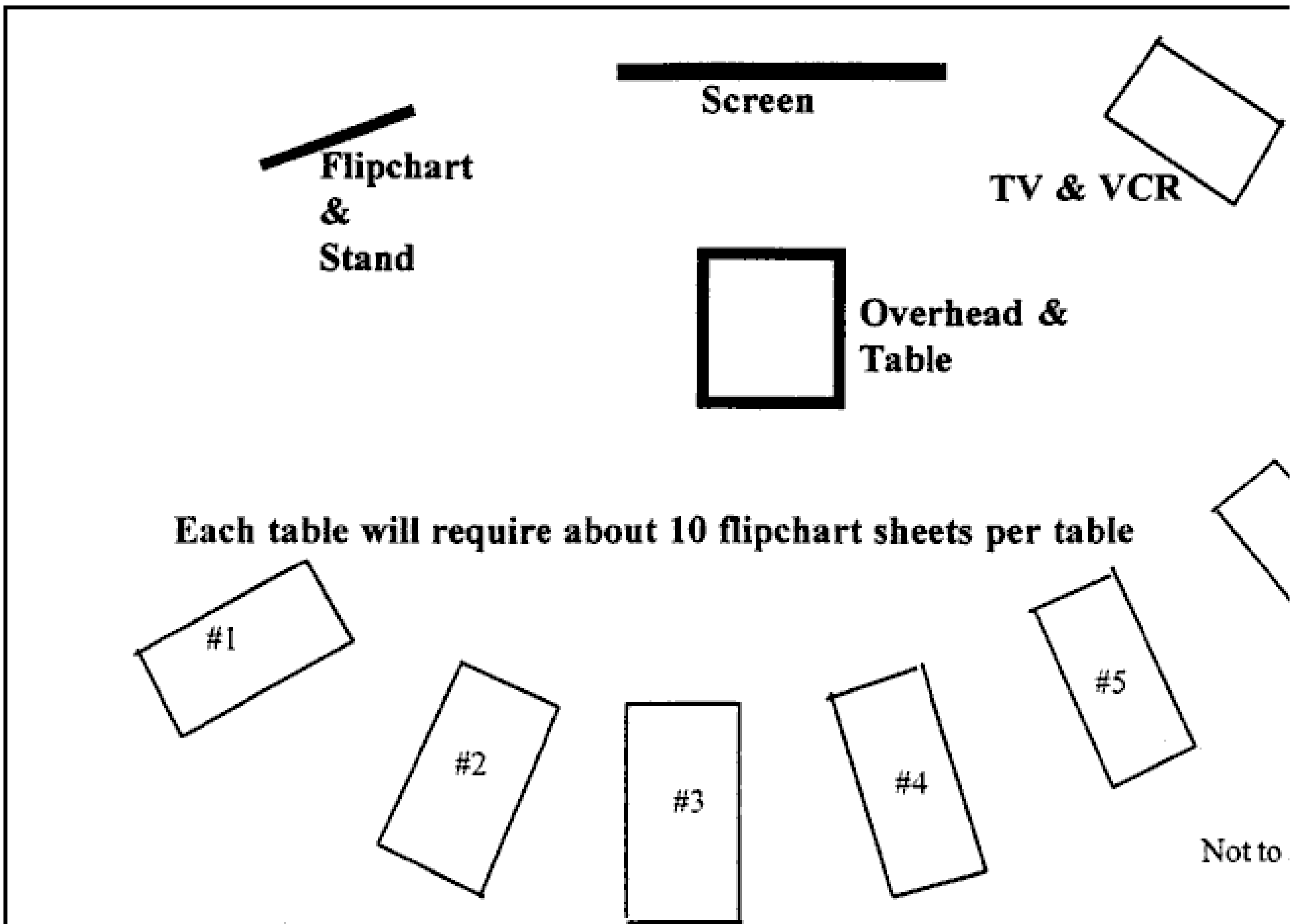


Table # 1: Names & Co.

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Table #2:

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Table #3:

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Table #4: Names & Co

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Table #5:

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Table #6:

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Figure 16-12. *Recommended MRM Training Room Layout*

Phase 4-Implementation

In this phase, the overall training implementation plan is developed and the training is actually conducted. If the training is delivered in stages, it is possible to conduct further formative evaluations and revise the training program and materials before full production and implementation. A spreadsheet can be created that includes the schedule for delivering the training. It is also possible to purchase various computer-based management programs that can provide a framework for structuring the training schedule.

Facilitators, training facilities, timing of the course delivery, number of trainees, geographical locations, and logistics need to be identified and included in the implementation schedule. The implementation schedule needs to ensure that all training materials are produced and sent to the training facilities. The tasks of maintaining training equipment, purchasing training materials, and administering the training program also need to be considered in this phase.

The tentative plans that were outlined in the development phase are reviewed at this time and revised as needed. An important program element that must be addressed during this phase is to gain (or re-confirm) the management commitment to deliver the training program and to provide the necessary resources to successfully implement the course.

Facilitator training

During the implementation phase, the facilitators must be formally trained to deliver the training program. It is possible that the facilitators are part of the design and development team and require only a minimal level of training. However, in many instances the facilitators or instructors will not have taken an active part in designing the training program and will need assistance in preparing to deliver it.

If they have been identified, potential facilitators can practice delivering the training lessons during the formative evaluation and user testing stages. In this way, immediate feedback can be provided to the instructors as part of the overall evaluation process. The trainees reaction to a facilitator's presentation style can be assessed during and after the training by using questionnaires, video-tape, interviews with the trainees, and/or feedback by other facilitators. Receiving immediate feedback will greatly enhance the learning process for the facilitators. Changes to the training materials and instructional sequence also can take place in these early training periods.

For **MRM** courses, it is important to have co-facilitators as they can provide subject matter experts with different perspectives. A high level of interaction is desirable among the course participants and the co-facilitators. Also, the facilitators can support one another when presenting the material, conducting group exercises, and providing maintenance examples and technical support. Together co-facilitators can form a dynamic team representing knowledge in more than one area of maintenance operations.

Some useful co-facilitating guidelines are listed below:

- Keep focused on the course topics.
- Prevent the class discussion from deteriorating into a "complaining session".
- When faced with a challenging question, refer to your co-facilitator or to the class. Generally, someone in the class will have the knowledge or expertise to help answer the question.
- Challenge the trainees to work hard on all group exercises, such as analyzing case studies and writing up and presenting their results.
- Ensure that each group of trainees presents their results has the opportunity to exchange ideas with their classmates.
- Post all group results on flip charts and mount them on the classroom walls. At the end of the course, it is good to refer to these results as evidence of the class's hard work and the large volume of information generated in the course. This shows the trainees how much they accomplished during the course and how they applied MRM concepts.

Figure 16-13 shows two co-facilitators delivering an **MRM** course.[28] The picture also shows the layout of the training room, how the trainees are seated for participation in group exercises, the visual aids hung on the walls around the training facility, and the set-up of the training media.

Figure 16-13. *Co-facilitators presenting an MRM training program.*

Phase 5-Evaluation

During this phase, we evaluate the effects of the **MRM** training program. Planning for evaluation should take place during the design phase. **Table 16-20** lists various methods for evaluating training courses.[66,67,72,73,74] There are several reasons why we evaluate the training program, including the following:[66,67,72,74]

- To determine if the training meets the objectives
- To determine if the entire training program its goals
- To provide feedback to the facilitators
- To provide feedback to the trainees
- To provide feedback to top managers and the organization as a whole
- To review and improve the training program

Evaluation processes

There are two types of evaluation -- formative and summative. We have discussed formative evaluation in the design and development phases. Basically, this involves prototyping and user testing during the formation of the **MRM** course. Evaluation instruments that can be used during the formative evaluation are given in **Table 16-20**. An example of a post-training, trainee reaction questionnaire is shown in **Table 16-24**.[44]

Examples of pre, post, and follow-up training questionnaires, which measure changes in learning, attitudes, behaviors, and organizational performance, are contained in published research results.[15]

Table 16-24. Example of a post-training, trainee questionnaire

MRM--II Team SA Training Experience and Evaluation

For each of the topic areas of training techniques listed below, please rate the value of this aspect of the training to you. Rate each item by choosing the number on the scale below which best describes your personal opinion and then write the number beside the item.

1	2	3	4	5
Waste of Time	Slightly Useful	Somewhat Useful	Very Useful	Extremely Useful

MRM Review and Background

____ Human Factors Elements

_____ SHELL Model

_____ "Link Busters"

_____ "Swiss Cheese" Model

Situation Awareness (SA)

____ Levels of SA

____ Consequences of Poor SA

____ "Loosing the Bubble"

VIDEOS:

____ Maintenance Video

GROUP EXERCISES:

____ SA problems and solutions within Tech Ops

____ Gaps between Maintenance Operations groups

____ **OVERALL,** how useful did you find the training?

Summative evaluation is conducted after the **MRM** training course has been developed, implemented, and delivered. Summative evaluation typically determines the extent to which the training program has been successful in meeting its established training, behavioral, and organizational objectives[73]. It also determines the value of the training program, and what modifications need to made to make it more effective.

Some type of trainee evaluation is generally performed immediately after they have completed the training course. This is often done with a test or questionnaire. Summative evaluation focuses directly on whether the **MRM** training program affects actual on-the-job performance and attitudes as intended. Testing someone immediately after training does not necessarily give us valid data concerning whether a person's job performance and attitude will change. Instead, we need to collect data that are directly relevant to changes in trainee behavior.

The evaluation process should measure the effects of training on the variables we have identified as being important. These will usually include some combination of trainee job or task performance, attitudes, and measures associated with overall error performance (e.g., ground damage, occupational injuries). Evaluation "criteria" are those variables that represent the specific factors course designers have targeted during the development process. These criteria are based on the training objectives and goals and are established in the needs assessment and design phases.

A summative evaluation should be conducted using the following general principles.[67,70,72,73]

- Conduct the evaluation in an environment that is as similar to the ultimate job environment as possible.
- Conduct the evaluation after a realistic period of time (preferably 2, 6 and 12 months following training).
- Conduct the evaluation based on the targeted job tasks and conditions.

Summative evaluation process

This process incorporates the use of several evaluation instruments (see **Table 16-20**) and multiple measures of training effectiveness. Providing a comprehensive and informative training evaluation is critical in measuring the value of the training. The summative evaluation process focuses primarily on the trainees' behavior, the success of the transfer of training, and the impact of training on organizational outcomes.

A five-step process can be used as the basis for evaluation.[70,71,75] **Table 16-25** relates this five-step process to the evaluation methods shown in **Table 16-20** and the types of data that can be collected.[66,67,71,72,73] Steps 1, 2, and 3 should be completed as part of the formative evaluation processes. These data are used in the summative evaluation process. However, summative evaluation focuses on behavioral and organizational variables.[70,71,72,73]

Table 16-25. Five-Step Evaluation Processes

Examples of evaluation measures

1. Pre-Training Baseline Assessment	1. Questions asked of trainees concerning the training objectives: (i.e., What are four human factors elements that impact performance?)
2. Trainee Reaction	2. Questions asked of trainees concerning usefulness, value and relevancy of the training. (i.e., How useful was the lesson on norms?) (Scale from 1-5; waste of time to extremely useful)
3. Learning	3. Questions asked of trainees same as pre-training questions: (i.e., What are three types of human error?)
4. Performance (behaviors)	4. Observations, Interviews and Behaviors; Questions can be asked of the trainee of their behavioral intentions: (i.e., How will you use this training on your job?; What changes have you made as a result of this training? Observations: Supervisor and Leads observe crews and rate them on a scale [1-5] as to when they use the newly acquired behavior.) (i.e., Crew members speak up when potentially unsafe situations develop)
5. Organizational Results	5. Organizational results: These are performance measures gathered at the unit and organizational level. (i.e., Aircraft safety [ground damage], Occupational Safety [injuries]; Dependability [on-time departures, on-time maintenance]; Efficiency; [contained overtime cost].)

The data collected during this evaluation process will determine the trainees' improvements in skills, knowledge, attitudes, and behaviors. Presenting these data to high-level managers can provide important justification and support for the training program. Results from the evaluation process will provide the information necessary to analyze the program's success over time and to revise the program as needed. These data will serve as a foundation for developing follow-up training programs.

The evaluation process reinforces the importance of **MRM** training by demonstrating its (hopefully) positive effects on individual, work unit, and organizational performance. There are several mechanisms that can be used to further reinforce MRM skills. These include writing articles in the company's maintenance operations newsletter regarding how individuals or teams have successfully used MRM principles. New processes or procedures developed by trainees as part of the MRM course might be implemented on the hangar floor.

Other activities that could occur as a result of **MRM** training include establishing an MRM or Human Factors working committee. This committee can focus on increasing safety and reducing maintenance errors using MRM and **HF** principles and methods. The strength of and continued commitment to MRM principles in the workplace depend on the existence of conditions that support and reinforce their use.

WHERE TO GET HELP

There are many sources for assistance with **MRM** programs, as well as other specific human factors and training issues. We have divided the resources in this section into two categories -- professional organizations and governmental entities. All of these groups focus their efforts in the areas of training and human factors. Many produce publications, videotapes, and training materials in the areas of human factors, training, aviation, and maintenance.

Professional Organizations and Research Sources

The American Society for Training and Development (ASTD) is the largest professional training organization in the United States. They produce many publications related to specific training issues and can recommend groups or individuals to help with particular training-related problems.

American Society for Training and Development
1640 King St.
Alexandria, VA 22213
Phone: (703) 683-8100
Fax: (703) 683-1523

The Human Factors and Ergonomics Society (HFES) can provide assistance on several levels. Generally, the HFES central office can provide a list of Technical Group contacts and a Directory of Consultants who work in a variety of aviation-maintenance-related areas. Within the HFES, many Technical Groups specialize in training issues and related aviation maintenance issues. These include the following: Aviation Systems Technical Group, Macroergonomics Technical Group, Naturalistic Decision Making Technical Group, Industrial Ergonomics Technical Group, Systems Design Technical Group, and Training Technical Group,

Human Factors and Ergonomics Society
PO Box 1369
Santa Monica, CA 90406
Phone: (310) 394-1811
Fax: (310) 394-2410
E-mail: hfes@compuserve.com
Web: http://hfes.org

The International Society for Performance Improvement is a professional training organization which focuses on performance improvement and training implementation processes. The society supports the performance technologist, training directors, instructional designers, and organizational development consultants who are dedicated to improving human performance in the workplace.

International Society for Performance Improvement
1300 L. Street, N.W.
Suite 1250

Washington DC 20005
Phone: (202) 408-7969
Email: info@ispi.org
Web site: www.ispi.org

An aviation-related organization that can provide materials on the area of Crew Resource Management is the Crew Systems Ergonomics Information Analysis Center (CSERIAC). The CSERIAC is a Department of Defense Information Analysis Center located at Wright-Patterson Air Force Base, Ohio. Managed by the University of Dayton Research institute, the CSERIAC will conduct detailed literature searches. It also produces a number of pre-researched reports, that are for sale.

CSERIAC Program Office
AL/CFH/CSERIAC Bldg. 248
2255 H Street
Wright-Patterson AFB, OH 45433
Phone: (513) 255-4842
Fax: (513) 255-4823

The International Association of Machinists & Aerospace Workers (IAM&AW) is the largest labor union representing **AMT**s. As an AMT labor organization, the IAM&AW has a special interest in reducing maintenance errors. Its representatives sit on many of the committees and subcommittees that are involved in various human factors initiatives.

IAM&AW
Air Transport Dept.
9000 Machinists Place
Upper Marlboro, MD 20772
Phone: (301) 967-4558
Fax: (301) 967-4591

The Maintenance and Ramp Safety Society consists of people in the aviation industry who are involved in maintenance and ramp issues. The Society develops training videos for aviation workers. These videos typically challenge viewers to recognize the links among various factors causing accidents. The videos then demonstrate the links and identify the safety nets that can help prevent a repeat of the accident. They also produce safety posters including "The Dirty Dozen," and "The Magnificent Seven."

Maintenance and Ramp Safety Society
5750 Cedarbridge Way
Richmond, British Columbia
V6X 2A7
Canada
Phone:(604) 207-9100
Fax: (604) 207-9101

E-mail: marss@marss.org

National and International Government Sources

The organizations listed below are national and international government groups that are involved in aviation regulations and legislation. Several of these organizations are investigating and discussing aviation-maintenance-related issues. These organizations are essential resources for helping the aviation community understand the most pressing regulatory issues.

The National Transportation Safety Board (NTSB) is an independent Federal agency. Its five Board Members are nominated by the President and confirmed by the U.S. Senate to serve 5-year terms. The NTSB has been charged by Congress to investigate every civil aviation accident in the United States. The NTSB also investigates significant accidents in the other modes of transportation -- railroad, highway, marine, and pipeline. The NTSB, through its fact-finding investigations, serves as the impetus for many human-factors-related initiatives in the aviation industry.

National Transportation Safety Board
490 L'Enfant Plaza, SW
Washington, DC 20594
Phone: (202) 314-6000
Web: http://www.ntsb.gov

The Air Transport Association (ATA) is an aviation industry consortium located in Washington, DC. The work of the ATA is typically accomplished using committees composed of aviation company employees serving as volunteers. The ATA has several active committees and sub-committees that are responsible for developing and reviewing human factors guidelines and training practices and standards, such as *ATA Specification 104 - Guidelines for Aircraft Maintenance Training*.

Air Transport Association of America
Engineering Department
1301 Pennsylvania Ave., NW
Washington, DC 20004
Phone: (202) 626-4000
Fax: (202) 626-4081
E-mail: ata@air-transport.com
Web site: http://www.air-transport.org

The International Air Transport Association (IATA) is an international aviation consortium with headquarters in Montreal, Canada. IATA manages much of the infrastructure for its airline members, including acting as a clearing house for ticket exchanges. However it is also known for its extensive list of consultants and training courses. Since it is an aviation industry organization, IATA is responsive to the needs of its members, especially for specific types of training.

International Air Transport Association
IATA Building
2000 Peel Street
Montreal, Quebec
Canada H3A 2R4
Phone: (514) 844-6311
Fax: (514) 844-5286
Web: http://www.iata.org

The International Civil Aviation Organization (ICAO) was founded in 1944 with the signing of the Convention on International Civil Aviation. It is a specialized agency of the United Nations. Among other activities, ICAO sets international standards and regulations in the air transport industry. The governing body of ICAO is the Council, which is elected by representatives from its 185 Contracting (i.e., member) States. Several relevant ICAO publications are listed in the **FURTHER READING** section.

International Civil Aviation Organization
999 University
Montreal, Quebec H3C 5H7
Canada
Phone: (514) 954-8219
Fax: (514) 954-6077
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The Canadian Department of Transportation, known as Transport Canada, is the Canadian counterpart of the U.S. Department of Transportation. Its Safety and Security Group is responsible for administering regulations and standards for civil aviation. We noted in this chapter that Gordon Dupont, who works in the Safety and Security Group, has been instrumental in identifying the "Dirty Dozen" causes of maintenance error. These form the basis of a human factors training program available through Transport Canada.

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FURTHER READING

The documents listed here provide detailed information related to the topics discussed in the chapter.

Cockpit/Crew Resource Management

Federal Aviation Administration (1992). *Crew Resource Management: An Introductory Handbook* (DOT/FAA/RD-92-26). Washington, DC: Author.

Wiener, E.L., Kanki, B.G., & Helmreich, R.L. (1985). *Cockpit Resource Management*. Orlando, FL: Academic Press.

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ICAO Documents

Human Factors Digest No. 12: Human Factors in Aircraft Maintenance & Inspection.

Human Factors Digest No. 2 - Flight Crew Training: Cockpit Resource Management

Circular 217 Line-Oriented Flight Training (LOFT)

Circular 247 Human factors, Management and Organization

Human Factors in Aircraft Maintenance & Inspection (Digest No. 12) gives a very good overview of the problems in aviation maintenance. It uses a few high profile accidents to illustrate its points and discusses the importance of looking past the obvious micro issues to organizational culture factors, which contribute to latent failures and overall systems problems. All of these **ICAO** documents are available from:

ICAO
Document Sales Unit
1000 Sherbrooke Street West, Suite 400
Montreal, Quebec
Canada H3A 2R2
Phone: (514) 954-8022
Fax: (514) 954-6769
E-mail: sales_unit@icao.org

Training

Goldstein, I.L. (1986). *Training in organizations: Needs assessment, development, and evaluation* (2nd Ed). Monterey, CA: Brooks/Cole.

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EXAMPLE SCENARIOS

The scenarios presented below represent typical **MRM** training-related tasks one can expect to encounter in the workplace. The purpose of including these scenarios in the *Guide* is to demonstrate how the authors foresee the document being used. For each scenario, we describe how the issues raised in the scenario can be resolved. There is usually more than one way to approach these issues, so the responses represent only one path that users of the *Guide* might take.

As a general rule, always start to look for information by using the Search function. There will be instances that you already know where required information is located. However, unless you frequently use specific sections of the *Guide*, you might miss information pertaining to the same issue located in more than one chapter. The Search will allow you to quickly search all chapters simultaneously.

Scenario 1 -Training Development

Your manager just participated in a new maintenance training course called "Human Factors and Maintenance Resource Management" at another company. He is enthusiastic about developing and delivering this kind of course for your maintenance operations personnel and has been discussing the idea with your Training department. An **MRM** design team is being formed and you've been appointed to the team.

In preparation for participating on the design team, you have been given an **MRM** training curriculum book and told to study how another company developed its MRM course. While studying the handbook, you recognize that the course was not developed by an interdisciplinary team representing **AMT**s, management, training and human factors experts. It's not apparent that the other company used any type of training model or approach. Also, you are familiar with several of the videos that were used in this MRM training course and you believe they are not appropriate for MRM training.

Issues

1. How will you ensure that the **MRM** design team represents the appropriate subject matter expertise and end user population?
2. With which training model should you become familiar so that you can propose a general design approach for developing a **MRM** course?
3. What issues should be considered when selecting the training media for an **MRM** course?

Responses

1. The **BACKGROUND** and **CONCEPTS** sections of the chapter stress the importance and benefits of active participation by **AMT**s, managers, inspectors, and human factors specialists. The experiences of other companies illustrate this essential component of successful **MRM** training programs. **Tables 16-3**, **-10**, **-11**, **-13**, and **-20** in the **GUIDELINES** section, lists the requirements for full participation in the development of an MRM training program.

2. We describe the instructional systems design (ISD) training development model in the

METHODS section. Details of the tasks and activities involved in using an ISD approach are given in the **GUIDELINES** section (see **Figures 16-3**, **16-4**, and **16-5** and **Tables 16-4** and **16-6**). These discussions of the ISD model should provide you with a general background for working with training and human factors professionals in developing an **MRM** training course. Also, in the **CONCEPTS** section, we discuss the issue of adult inquiry learning, which is important to incorporate into the design of the MRM training course. The **READER TASKS** section provides a description of the tasks a maintenance supervisor can expect to undertake when participating on the MRM design team.

3. **Table 16-16** provides media selection criteria that will help you specify appropriate training media. In the **METHODS** section, there is a discussion of the importance of selecting training technology and **media** that support the instructional objectives of the **MRM** training course. See also **Figures 16-8**, **-9**, and -10.

Scenario 2 - Facilitating an MRM Course

You have attended an **MRM** course that has been designed and developed by an internal team. Because you found the material to be very useful and informative, you have asked the MRM design team if you could become a co-facilitator for the course. They have accepted your offer and you are going to attend more MRM courses. They really don't have a "train the trainer" program so you will be learning on-the-job.

Issues

1. What types of learning styles should be of concern when co-facilitating the **MRM** course?
2. What are some effective training delivery mechanisms that you should learn in order to co-facilitate this course?
3. How should you arrange and set up a training facility?

Responses

1. In the **CONCEPTS** and **METHODS** sections, we discuss the instructional method of adult inquiry and the learning style of discovery learning. This type of learning style is active, with open-ended questions, problem solving activities, group exercises and other experiential exercises. Co-facilitators can enhance the effectiveness of this type of training by teaming to present the training materials and asking questions of the trainees. The dynamics between the co-facilitators is important. They can easily motivate the class by *facilitating* the learning process instead of *lecturing* to the students.

2. Actively presenting material and handling classroom dynamics are essential skills you must acquire to become a co-facilitator. **Tables 16-14**, **16-15**, and **16-16** in the GUIDELINES section list effective training delivery mechanisms, media handling and co-facilitation and

communication skills. Also in the GUIDELINES section, see the **Implementation subsection** on facilitator training.

In the CONCEPTS section, see the discussion on **active learning**. Practicing these skills with other experienced co-facilitators will greatly improve your classroom delivery skills. Spend some time at the end of each day discussing with your co-facilitator what happened during the class. What were some good points and some points for improvement? Also, what occurred while the trainees were performing the group exercises.

3. **Figures 16-12** and **16-13** illustrate how a training room should be arranged. **Table 16-17** lists the training facilities design factors that should be considered when selecting a training facility. Always ensure that all media technology works and backup supplies are available. Always get to the training room early. Test all media equipment. Ensure that all of your training supplies are arranged for the exercises and that supporting facilities are open and accessible.

Scenario 3 - Practicing MRM Skills

You have been asked by your supervisor to design some **MRM** activities that could be conducted during shift turnovers. Your supervisor wants to see more follow-up MRM activities to reinforce the newly-acquired MRM skills and to promote feedback. He has asked you because you have co-facilitated several MRM courses and now you are back on-line.

Issues

1. What type of **MRM** practice activities can you design to use during shift turnovers?
2. What type of reinforcement and feedback issues should you be concerned about?

Responses

1 .Several **MRM** activities are outlined in the CONCEPTS section on **Transfer of Training** and **Continuous Learning and Improvement**. We have included some MRM activities that have been created and used in other companies and discussed in the **BACKGROUND** section. What is important is to build on the experiences of **AMT**s within the company. In the **WHERE TO GET HELP** section, we list several WWW sites and governmental sources that can provide excellent case studies and aviation maintenance experiences demonstrating MRM and human factors issues.

2. In the CONCEPTS section, there is a discussion of the importance and benefits of providing **reinforcement** and **feedback** when learners return to the work site. The **CONCEPTS** section of this chapter provides an overview of important issues to consider: how, when and why feedback should be provided.

Scenario 4 - Managing an MRM Training Program

The Maintenance Operations Manager has asked you take a significant role in managing an **MRM** training program. He has specifically asked you to co-manage the program. You have been a member of the MRM design team for the past year and you have developed a working relationship with upper management. You will be representing the maintenance operations people in fulfilling this role.

Issues

1. What background information should you be concerned about when managing an **MRM** training program?
2. What types of tasks and activities can you expect to be involved in?

Responses

1. This type of assignment is characterized as project management role. **Figure 16-4** in the **GUIDELINES** section outlines the basic steps and processes of project management. Depending on how much time you have committed to this project, your expectations about your role could vary widely.

2. In the **METHODS** section, we describe the instructional systems design (ISD) model, which outlines the basic steps in developing a **MRM** training program. You could be managing specific activities in each phase of the development process or just managing one part of the program. For example, you might be responsible for scheduling the delivery of the training program, which could be a significant task. Another example of a discrete task is organizing the development of a videotape. For more help in a specific phase of the management process refer to the **WHERE TO GET HELP** section.

Scenario 5 - Evaluating & Selecting an MRM Training Course

Management has decided to contract a training firm to deliver an **MRM** course. You have been asked to be a member of the selection committee. You have some familiarity with what an MRM course should be like and what materials should be included, since you have attended your company's MRM course.

Issues

1. What issues and criteria should you be concerned about when you go through the selection process?
2. How will you evaluate the effectiveness of the vendors' **MRM** courses?

Responses

1. **Tables 16-7**, **16-8**, and **16-10** in the GUIDELINES section lists several questions and criteria that should be used when evaluating an **MRM** training course. Instructional design, development of instructional materials, and the background of the trainers are some areas that need to be covered. In the BACKGROUND section, **Figure 16-2** presents the historical development of MRM training. This can provide a benchmark for the development of a contract training program. Look in the **WHERE TO GET HELP** section for agencies and companies who can provide recommendations and background information on the contractor.

2. In the **METHODS** and **GUIDELINES** sections, we discuss the evaluation process for measuring the effectiveness a training program. The training vendors should be asked to describe how they measure the effectiveness of their training courses and to provide representative data showing these measures. Use **Tables 16-20**, **-24**, **-25** as an outline of the four levels of an evaluation process.

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