CHAPTER 3
LINE-ORIENTED HUMAN FACTORS TRAINING:MRM III

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3.1 INTRODUCTION

This report was created to help plot future directions for Maintenance Resource Management. Maintenance Resource Management (MRM) is a "general process for improving communication, effectiveness and safety in airline maintenance operations."[1] Much as crew resource management (CRM) was created to address safety and teamwork issues in the cockpit, FAA researchers, in conjunction with industry partners, developed MRM to address teamwork deficiencies within the hanger. By doing so, it is hoped that MRM will foster a culture of safety in all maintenance operations.

Although MRM is an outgrowth of CRM, differences between the two exist. Other than the obvious (training population, training context), other, more subtle differences affect the transition from CRM to MRM.[2] The purpose of this report is three-fold. First, both MRM and CRM are reviewed within the context of safety and training. Second, the similarities and the differences between CRM and MRM are highlighted. Third, recommendations for developing the next stage in MRM training, MRM III, are presented.

3.2 ACCIDENT CAUSATION

An "accident" as defined by the Random House Dictionary of the English language (2nd ed.) is "any event that happens unexpectedly without a deliberate plan or causes; by chance, fortune, or luck." However, most accidents rarely occur by chance at all, and their causes can be tracked.[3] Accidents are usually the result of an accumulation of factors whose results are seen in their consequences. These factors are numerous and range from the measured reliability, both on an individual and organizational level, of completing a task successfully to reliability's converse, the incidence of error present during task completion.

A widely accepted model of human error is Reason's classification of unsafe acts.[3] The defining characteristic of Reason's taxonomy involves the intentionality of the act or behavior which led to the mishap. Reason asserts that unsafe acts can be categorized as either intentional or unintentional. Unintentional actions are due to either memory failures or failures of attention.

In addition to the intentionality of the error actions, error may have differential effects, especially in a systemic analysis of mishaps and disasters. Reason distinguishes between two types of errors: 1) active errors, whose effects are felt immediately in a system, and 2) latent errors, whose effects may lie dormant until triggered later, usually by other mitigating factors.3 The presence of defenses or safeguards in a system can usually prevent the effects of latent errors from being felt by closing the "window of opportunity" during which an active failure may be committed.

Active errors are usually the result of "front-line" operators such as pilots, air traffic controllers, or anyone else with direct access to the dynamics of a system. Latent errors, on the other hand, are associated with those individuals separated by time and space from the consequences of the system. Examples include architects, hardware designers, and maintenance personnel. Differences between active and latent errors cannot be over emphasized; each type of error helps to shape the type of training required to correct them. Therefore, maintenance personnel may require more thorough human factors and operations training to account for their susceptibility to latent errors.

In an example specifically related to aircraft maintenance, Marx and Graeber categorized human error two ways.4 The first refers to an error which results in a discrepancy that was not present prior to initiating the maintenance task. Such an error is comparable to an error of commission. Examples of these error types include the incorrect installation of a unit or damaging a piece of equipment in the maintenance process. The second error category includes those errors in which damage results from the failure to detect aircraft degradation in a maintenance task. This is akin to an error of omission. An example of such an error could include the failure to notice a structural fatigue crack in a visual inspection. Though MRM does not address these particular error categories short of training AMTs to be aware of them, it is important to note that many researchers have studied, and continue to study, the role of the AMT in accident causation.

3.3 INSTRUCTION SYSTEMS DESIGN

Training is defined by Goldstein as the "systematic acquisition of skills, rules, concepts, or attitudes that result in improved performance in another environment", and is divided into three phases.5 The first is the *needs assessment phase*, a process of determining what "skills, rules, concepts, or attitudes" should be trained and whom should receive the training. The *training phase* which follows encompasses the selection and design of the actual training program and its implementation. Finally, the *evaluation phase* assesses a training program in order to judge its effectiveness or, in other words, test the notion that the training "resulted" in improved performance. Together, these phases embody the "systematic" process favored by most training theorists and practitioners. Though there are several models of training in the literature, Table 3.1 lays out the basic instructional design as proposed by Goldstein.

Table 3.1. Generic Instructional Design Methodology

Phase I: **Needs Assessment**	1. Conduct needs assessment. a. organizational analysis b. task analysis c. person analysis 2. Create instructional objectives.	
Phase II: **Training and Development**	1. Select/Design instructional programs. a. select/develop media 2. Deliver training.	Develop evaluation criteria (occurs concurrently).
Phase III: **Evaluation**	1. Test training effectiveness. a. trainee reaction b. trainee learning c. trainee behavior d. organizational effectiveness 2. Revise training if necessary.	Match evaluation criteria to instructional objectives through experimental design (occurs concurrently).

3.3.1 Training Evaluation

The final step in a training development program is the training evaluation. Evaluation, as defined by Goldstein5 is "the systematic collection of descriptive and judgmental information necessary to make effective training decisions related to the selection, adoption, value, and modification of various instructional activities." In short, the evaluation phase allows one to test if the training program is, first, beneficial and, second, has truly had the desired effect on trainees. This definition accounts for the dynamic nature of most training programs, allowing one to modify the evaluated course to achieve multiple instructional objectives. It is important to consider the evaluation stage of training *before* developing a final program. In most cases, the ability to evaluate properly a training program is driven by its initial structure. Therefore, a cursory discussion of training evaluation is presented.

Before choosing an evaluation technique, however, one must consider a variety of methodological and organizational constraints. From the methodological standpoint, just as criteria were developed for training to represent the desired job skills, criteria must also be developed to measure adequately a training program's success.[5] In order to achieve this, relevant criteria must be chosen that accurately reflect both the knowledge, skills and abilities (KSAs) developed during needs analysis *and* the objectives specified by the training program itself. For example, just because a trainee is able to demonstrate a new skill, such as the ability to use a new word processor, that does not ensure that the goal of the program, switching an entire office to a word processing standard, will be achieved. Thus, both goals are important for a full training evaluation.

Finally, four levels of evaluation criteria have been identified.[6] They are reaction, learning, behavior, and results. Reaction and learning refer to the extent that a trainee likes a program and learn relevant information from it, respectively. MRM III represents the final stage in the development of MRM training. Though reaction and learning-level criteria are important and can be measured, behavioral and performance-level criteria remain the primary focus of MRM III evaluation.

3.3.2 Safety Training

Training for enhancing safety has long been a practice in industry. Compliance with the Occupational Safety and Health Administration (OSHA) regulations has been the driving factor behind many of these safety training initiatives.[7] However, beyond this mere compliance, a safe workplace ensures uninterrupted and continuous operations, especially when reliability (e.g., smoothly running aircraft) is one of the workplace's main goals.[8] Therefore, safety training is well-known throughout industry.

One study that documents the impact of safety training on an organization was conducted by Komaki, Heinzmann, and Lawson.[9] The goal of this training program was to reduce the mishap rate in the vehicle maintenance division of a city's department of public works.

- Raters conducted a series of 165 observations, each lasting for a total of 60 minutes, over a 45-week period.
- "Safe" (e.g., wearing goggles) and "unsafe" (e.g., no goggles) behaviors were targeted.
- A multiple-baseline design was employed using five experimental conditions: baseline, training only, training with feedback 1, training only 2, and training with feedback 2.

The results indicate that training with feedback is the most effective at reducing accidents, though training by itself also helps to reduce unsafe behavior. The power of feedback is consistent with the definition of safety climate proposed by Zohar.[10] To review, safety climate relies on employee perceptions of how management prioritizes safety. Feedback from supervisors may provide salient examples to create a safety climate. Nevertheless, safety-related behaviors appear to be both trainable and beneficial to an organization.

Currently, a popular training method is on-the-job training (OJT), otherwise known as the "buddy" system.[8] However, anecdotal evidence indicates that the structure of such training in the hanger is mostly informal and depends heavily on the skills of the more experienced team member. In fact, most OJT programs in general are not planned and, as a result, do not work well.[5] In this sense, OJT has proven to be inadequate for teaching skills related to maintenance resource management.

3.3.3 Safety Training Evaluation

Because the focus of MRM training is on safety-related behavior, results-level measures can be difficult to obtain. Specifically, results-level measures of safety are best reflected by the number of mishaps occurring during maintenance activities. The success of MRM could then be measured in terms of the reduction of those mishaps. The general rarity of such phenomenon makes gathering enough data to perform significantly powerful statistical tests a lengthy process.[11] However, such data are typically collected in compliance with Occupational Safety and Health Administration (OSHA) regulations as well as for companies' own safety departments. Therefore, mishap data typically do exist. However, one should allow for enough time to collect an adequate amount of data in order to make generalizations about the effect of training on worker mishaps.

Nevertheless, other evaluation criteria exist that can be used to assess an MRM program. An alternative evaluation measure of safety-training involves the critical-incident method. The critical-incidents method involves the description of either observed unsafe acts or near-miss accidents that occur without observable or formally recorded consequences. This method of accident analysis is described in detail by Feggetter.[12] By looking at a system's potential for accidents, this method has two advantages over accident analysis. The first is that analyzing critical incidents allows an accident investigator to root out causal antecedents without further damage to the system. Secondly, because such incidents are more numerous than accidents (or reported accidents), it provides a rich source of data that accident reports may not have.[11]

Because of the greater proportion of critical incidents relative to actual accidents, statistical analysis has greater power and is able to be performed with greater precision. The critical-incidents method of accident investigation itself makes use of a variety of data collection techniques (e.g., questionnaires, interviews, behavioral observation), each with their advantages and disadvantages. (For a more complete review of this subject, see Feggetter.[11]) However, the critical-incidents method remains a vital tool both during the initial need analysis as well as in evaluating any behavioral changes after a training intervention has been implemented.

Behavioral-level criteria remain an attractive alternative to results-level measures. Though they often rely on the skill of those making the observations, large amounts of data can be collected over relatively (compared to results-level measures) short periods of time. In addition, tools such as behavioral observation scales can be utilized to create more systematic data.[13]

The preceding discussion presents some common evaluation methods. However, many other types exist. Among them are attitudinal, reaction, and learning measures. Behavioral criteria include job sampling measures and behavioral observations. The extent to which evaluation criteria are sufficiently relevant to both training program goals and training program contents determines their validity.[14] Due to the difficulties in making results-oriented evaluations, behavioral-level measures are emphasized and presented in the context of each specific plan. Nonetheless, we still advocate the use of performance-level evaluation criteria, in addition to behavioral measures, to assess the effectiveness of MRM III.

This chapter of the Phase Report serves primarily as a guide to help MRM trainers who may be shifting the development of their program from the needs assessment phase to that of training development. This chapter will serve as a primer that will ease the transition from determining what needs to be trained to how the training should be implemented. It will highlight the advantages and disadvantages of a series of training delivery systems and allow the trainer to choose the most appropriate plan for their particular situation.

3.4 TEAM COORDINATION AND SAFETY

Teams have become increasingly important to organizations in recent years. Because of such things as decentralization, employee empowerment, and the rising complexity of work, the role of teams and their component members has increased in number and the power they wield in organizations.[15] Yet, despite the increased visibility of teams in organizations, they remain difficult to define for most people. Some teams are temporary, such as a company softball team or a product-oriented team created solely for the purpose of achieving a single, short-term goal, while other teams are longer-lived and require a greater level of commitment from its members. Regardless of the nature of the team, every team is unique, each made up of its own set of components, experiences, and variables.[16] However, some commonalties do exist, or are assumed to exist among teams.

What is the nature of these commonalties? First, teams are defined as groups that consist of members who seek to complete a common goal, but contribute an individual set of knowledge, skills, and abilities that enable the team to advance through each of the subtasks that make up the common goal. However different these subtasks are, their integration leads to the completion of the final goal.[17]

Second, a review of the existing team literature by Cannon-Bowers, Tannenbaum, Salas, and Volpe has identified a core set of skill dimensions or behaviors common to most investigations.[18] Among these skill dimensions are coordination, communication, adaptability, shared situational awareness, leadership, performance monitoring, and interpersonal relations. These skills, at varying levels, are required to integrate a complex goal’s subtasks. Finally, in order to perform these behaviors in a team context, interdependence must exist between team members, adding yet another team-related constraint when examining the aforementioned behaviors.[17,19]

Hoffman and Stetzer performed a cross-level analysis of organizational and individual-level factors as antecedents of an accident.20 Using 222 individuals in 21 teams, group-level factors, such as communication and coordination, intention to approach others regarding unsafe behavior, and safety culture, using 21 teams and 222 individuals, were measured in an industrial setting. In addition, an individual-level variable, perceptions of role overload, was also measured. Results support Hoffman and Stetzer's hypothesis that both individual and group-level variables would be significantly associated with unsafe behavior, as measured through both self-assessments and the company's own accident database.

Despite Hoffman and Stetzer's success in demonstrating cross-level antecedents of mishaps, the environmental complexity that most teams were created to address tends to hamper efforts to derive generalized principles about teams.20 Therefore, closer examination and subsequent manipulation of any team must take into consideration that team's natural environment.19

Finally, team skill dimensions exist independently from what is known as "taskwork" skills, i.e., team skills are often times functionally different from the technical skills required to complete a task. Those who participate in team activities are often taught and are competent in the technical aspects of their work, but are often not trained to work as a team. In this case, the entire team's effectiveness is lost. AMTs are not an exception to this phenomenon. MRM seeks to address this discrepancy.

3.5 TEAM COORDINATION IN A MAINTENANCE ENVIRONMENT

Fuller et al., also proposed specific strategies for improving safety in ground handling operations.21 They contend that the "adaptability" of maintenance crewpersons must be trained to compensate for failures in a system. This assertion was again developed through the analysis of accident data. In their study of 580 accidents, Fuller et al., found that the majority of accidents were due to either behavioral (performance) failures, in which standard procedures were followed, but not done well, or because of a failure to follow proper procedure from the start. The authors conclude with a suggestion that training and safety programs should and could be more sophisticated than merely outcome-based incentive programs. They encourage a strategy that changes people's attitudes and establishes a sense of ownership of the trained behaviors.

Along with coordination and decision-making, another behavior identified as being necessary for a safe, "team-oriented" maintenance environment is assertive behavior.22 Not to be confused with aggressive behavior, Stelly and Taylor define assertive behavior by using a series of "rights" to which a team member is entitled. Some of these rights include the right to say "no," the right to express feelings and ideas, and the right to ask for information. It has been shown that teams in cooperation openly discuss opposing views, critical for making cooperative situations productive.23 Thus, assertiveness is a necessary skill for effective team behavior.

These and other ideas, all of which promote a team-orientation, make up the bulk of a training program Taylor and Roberston developed for Continental Airlines' technical operations.24 The airline named this program "Crew Coordination Concepts" (CCC). Evaluation of this program, with pre-test, post-test and follow-up measures, showed an increase in communication, "willingness to voice disagreement," "goal attainment with own and other groups," and other scales developed to reflect the targeted behaviors as well as attitudes regarding those same behaviors.

Performance measurement also indicate a significant drop in injuries, damages, and repair costs due to maintenance-caused ground damage. Finally, this airline company's program possesses high face validity and is widely accepted by technical operations. In short, these researchers demonstrated the validity of creating a team-orientation among groundcrew personnel by targeting the behaviors that specifically improve communication skills, such as assertive behavior.24

The benefits of planning before a task is undertaken are also emphasized in accident prevention.25 Planning is defined as evaluating a task at all levels and ensuring that the proper resources (e.g., the correct tools, adequate space, and clear and complete policies regarding the task) are allocated in order to complete the task safely and efficiently. Too often, a task is undertaken without making available the proper resources.

Planning and the ability to carry out a plan in a team context also depend on the ability of the team members to communicate with one another.18 Ferry defines communication as the transfer of information, verbal, written or otherwise.26 He goes on to state that communication deficiencies lie at the heart of many mishaps simply because of their role in disrupting plans. Consequently, it is safe to assume that the roles communication and coordination play in a safety-oriented, team context are highly important.

3.6 SUMMARY AND INDUSTRY EXPERIENCES

From the literature cited above, evidence has been found to support two assumptions:

- Assumption One: Team behavior is necessary in a complex environment, where safety and reducing maintenance-related errors are the prime goals. The aviation maintenance operations environment is one such place.
- Assumption Two: Specific behaviors are required for crew members to perform as a team. Among these behaviors are communication, assertiveness, planning, situation awareness, problem solving, and good decision making skills.

Displaying these and other team-oriented behaviors is necessary for coordination to occur among the many individuals who compose a typical maintenance crew. The remaining portion of the present needs analysis is designed to provide further support for these assumptions. By doing so, the specific team behaviors that can reduce maintenance error are identified and targeted for future MRM training.

3.7 CREW RESOURCE MANAGEMENT AND LINE-ORIENTED FLIGHT TRAINING

One of the most heavily and widely studied teams is air and cockpit crews.27 Previous research has demonstrated that aircrew accidents could be traced to human error on the part of the aircrew.28 Furthermore, it was determined that although each crew member possessed the necessary knowledge and skills for completing his or her job individually, the members of the crew lacked the coordination that characterizes team interdependence. These results became the basis for a systematic training program that identifies behaviors and teaches coordination among aircrew members. This intervention is commonly known as crew resource management (CRM).

CRM researchers identified basic skills necessary for coordination among aircrew members to occur. Among these behaviors are communication, situational awareness, decision-making, leadership, adaptation/flexibility, and assertiveness.29 Overall, studies of CRM-type programs demonstrate that training these specific behaviors has a positive effect on performance and performance-related attitudes.30

Because CRM has been identified as a skill set necessary for the safe operation of aircraft, the Federal Aviation Administration (FAA) has outlined CRM training for all multi-crew pilots.31 This training, as defined by the FAA, encompasses awareness training, practice, and continuous reinforcement. This is also the structure around which MRM was designed and implemented.

A review of the literature show a great deal of transfer of CRM-related behaviors and skills to MRM. Cannon-Bowers et al., conducted an extensive review of both theoretical and applied literature and summarized the behavioral skill dimensions that they found were common to almost all teams.18 Though they vary in skill labels used in each study, Cannon-Bowers et al., generated eight core skills common to almost all studies.18 These are listed below:

1. adaptability
2. shared situational awareness
3. performance monitoring and feedback
4. leadership/team management
5. interpersonal skills
6. coordination skills
7. communication skills
8. decision making skills

Both CRM and MRM are no exception to the list presented above. The following table is the result of additional reviews by these authors. Table 3.2 presents a series of behavioral skills common to both CRM and MRM training. Initial research into CRM first identified these specific skills.27,29,30,31,32,34 Follow-up research in the maintenance environment tested the validity, in terms of acceptance and effectiveness, of those skills for MRM.22,24,33,35,36

Table 3.2. Behavioral Team Skills Identified in CRM and MRM
Behavioral Team Skills
Communication & Decision Making • briefings • assertiveness • conflict resolution • communication
Team Building & Maintenance • leadership • team climate • interpersonal climate
Workload Management & (Team) Situational Awareness • preparation • planning • vigilance • workload management

To conclude, it must be noted that although team-related behavior and coordination remain the focus of both CRM and MRM, both programs encompass much more. Also included, though dependent on the syllabi of each specific program, are introduction to basic human factors concepts, training in human error recognition, and worker stress recognition and reduction among other things.

Line-Oriented Flight Training (LOFT) was a natural outgrowth of CRM research and training. LOFT is an application of CRM principles in a realistic, yet controlled cockpit environment. However, whereas previous simulator training focused primarily on individual, technical skills, LOFT scenarios are designed to include situations which require coordinated, team actions.[30] Taggart makes the analogy of a building; CRM is the foundation upon which the structure, namely LOFT, is built.[32]

In LOFT, trainees are placed in a simulated, though highly realistic environment, and are asked to react to a variety of pre-planned scenarios. Entire missions are run while mission variables, such as weather, "mechanical difficulties," etc., are systematically changed. This is done to facilitate the transfer of CRM concepts to the cockpit without placing trainees in a dangerous situation.30 In addition, LOFT also enables trainers to gauge the levels of a crew's technical knowledge as well as the level of transfer of CRM principles to the cockpit. Finally, a vital component of LOFT is the post-mission debrief, in which trainers evaluate and discuss trainees performances both individually and as a group.

Because coordination skill dimensions (or variations of those dimensions) such as communication, decision making, and pre-planning were found to be common to almost all investigations of team assessments, those dimensions appear to relate to the performance of maintenance personnel.18 Thus, as CRM applies to aircrew personnel, so too could programs be created to develop these skills for AMTs. This is the logic behind MRM I, II, and III.

3.8 AMT TEAM TRAINING

Gramopadhye, Ivaturi, Blackmon, and Kraus created a framework that incorporates team training into an aircraft maintenance environment.33 Based on previous task analysis of maintenance activities which show a high need for coordination,35 Gramopadhye et al.,33 list a series of factors relevant to teams. These factors were categorized in terms of organization, task, equipment, and the knowledge, skills and abilities of individuals.

Following this initial task analysis, Gramopadhye et al., proposed and evaluated a training program based on these factors.33 In this program, participants were taught either basic team training skills or placed in a control group. Their task consisted of the removal and installation of an aircraft engine, simulating a basic maintenance task. Pre- and post-test measures of performance and the perceptions of both trainees and instructors were taken. The results support the hypothesis that team-training 1) is possible in an aircraft maintenance environment, and 2) leads to increased performance. Although applied to a single task, the authors discuss how their results may be applied in a more general sense, emphasizing "coordination, communication, interpersonal, and leadership skills."33

Taylor and Robertson published a report that summarized three years of team-related training for maintenance personnel.24 Taylor and Robertson compared this training to crew resource management for maintenance personnel. Once again, CRM training encompassed many team-related concepts such as communication, situation awareness, assertiveness, teamwork, stress management, and leadership, among other things. As mentioned previously, CRM in aviation remains well-documented in the literature, but the focus has been primarily on cockpit training and aircrews. Although CRM programs have been in use for over a decade, its application for maintenance crews has been limited at best.34 This is unfortunate since many of the concepts addressed by CRM are crucial for a safe and productive maintenance environment. It is in this context that Taylor and Robertson introduced their training.24

An interdisciplinary design team assembled by a major airline identified what the training and learning objectives of the new MRM course were to encompass.24 These goals were to:

1. diagnose organizational norms regarding safety.
2. promote assertive behavior.
3. promote understanding of individual leadership styles.
4. teach stress management.
5. enhance decision-making skills.
6. enhance interpersonal skills.

To achieve these goals, a CRM program in use for training cockpit crews was adapted for use by maintenance personnel. This included attitudinal measures regarding the above behaviors as well as the program itself. The training method chosen by Taylor and Robertson was the lecture format. The instructional team consisted of lead and assistant supervisors in technical operations, trainers, human factors specialists and academic researchers.

The results of a multiple time-sampled design show considerable and significant improvement in the use of the five targeted behaviors as well as in those attitudes regarding their use. They also demonstrated stability 12 months after participation in the training program. Taylor and Robertson also show a strong relationship between performance and its related attitudes for each of the follow-up surveys.24 Performance was operationalized in terms of aircrafts' ground damage, lost time injury data, on time departures, delays from planned yet late maintenance, and the amount of overtime charged per week. The changes in attitudes demonstrated in these studies predicted improvement in performance and demonstrated a positive transfer from training to the job. This study laid the groundwork for future team-training programs and became the foundation upon which the resultant MRM initiative was built.

3.9 MAINTENANCE RESOURCE MANAGEMENT

Using a model derived from Reason, Wenner and Drury analyzed reports of preventable accidents among maintenance personnel.3,37 They discovered that a significant number of incidents were the result of poor communication, mostly between crews. The importance of teamwork has also been discussed by others.38,39 Wenner and Drury traced more incidents back to the lack of awareness of risks and hazards.37 In addition, they found that equipment inappropriately chosen to complete a task accounted for the greatest number of incidents.

These conclusions suggest that most crew members are knowledgeable about their tasks. Unfortunately, they operate under a large number of rules and procedures, and it may be difficult to be aware of all of them.37 Furthermore, these crew members are accountable to an airline's "on-time" policies. The large number of operating procedures coupled with the omnipresent scheduling pressure requires a certain flexibility in decision-making on the part of maintenance personnel.22 However, the extent to which most crew members, during initial training, are made formally aware of external pressures, such as scheduling pressure and other factors that may lead to error, is minimal. Wenner and Drury also contend that many unsafe procedures become routine when placed in this context and are even "taught" in lieu of proper procedures.37

To counter these failures, Wenner and Drury suggest changes in not only policy and procedure, but also in the introduction of interventions that go beyond the technique of "reprimand, motivate, and train."37 Instead, Wenner and Drury suggest that safety interventions must take into account factors typically not identified for change, and teach personnel to identify these factors themselves. These "hidden" factors, or latent errors, may be organization-level, such as insufficient shift rotation between crews, or workgroup-level, such as the perpetuation of a climate in which the productivity of the group takes precedence over its safety. The ability to identify the factors that lead to unsafe behavior becomes the impetus for changing them. MRM is the mechanism that enables airlines to make just such a change.

3.10 MRM I & II

MRM I and MRM II are the initial stages of AMT training in human factors. MRM I focuses primarily on teaching basic awareness of MRM-related skills. MRM II builds on this basic knowledge and introduces skill development in Team Situation Awareness.40 MRM II utilizes group exercises and participation to a much greater extent than MRM I. Knirk and Guftafson outlined the characteristics of specific training methods whose goals are to teach job skills, but whose focus is primarily on the cognitive level (i.e., thoughts, ideas, and attitudes).41 These training methods are presented in Table 3.3.

Table 3.3. Categories of Learning

Objective Categories	Examples of Individual Instruction	Examples of Small Group Training	Examples of Large Group Training
Cognitive (lower-order learning)	textbooks, workbooks, audio tapes, programmed materials	study groups, case studies	lectures, video tape, 16 mm film
Psychomotor (physical skills learning)	laboratory-directed practice	simulator/scenarios	demonstrations
Affective and cognitive (higher-order learning)	research fieldwork	discussion, simulation, gaming & scenarios, feedback training	on-site experiences

The model presented in Table 3.3 classifies learning into three categories: lower-order (cognitive) learning, psychomotor (physical) learning, and higher-order (affective and cognitive) learning. Because the goal of MRM I is that of "awareness" of human factors principles, it is characterized by lower-order learning.

Instructional techniques vary in their effectiveness; their effectiveness is also contingent upon the goals and constraints identified by the needs analysis. However, when asked to rate the effectiveness of different training methods, training directors rated "programmed instruction" and the "case study" methods as the most effective, respectively, in knowledge acquisition and lecture (with questions) as the least effective of nine identified training methods.42

However, of the instructional techniques identified, the lecture method is the most widely used.5 It is the most cost-effective training method. Despite criticisms about the passive role trainees play during a lecture, studies comparing the lecture method to the more sophisticated programmed instruction and teleconferencing methods show no differences in student achievement. There is, however, evidence of faster learning. This lack of differentiation among these training methods is especially true where the basic instructional task is the dissemination of information.7 Based on these criteria (low cost, lower-order learning), a lecture-based intervention was chosen over other training methods for MRM I.

The lecture method can be further augmented when used in conjunction with other methods. One such method that is easily incorporated into a classroom atmosphere is the case study method.7 The case study method is a paper simulation of certain organizational conditions. 5 In the classic case study method, a trainee is given a written report of an organization problem. The trainee then analyzes the problem and prepares a number of solutions. This portion of the case study is completed individually. Once the trainee has completed this section, he or she meets with a group that discusses each person's solutions. Critics of the case study method note its general lack of guided instruction.   However, when used as a part of a larger training program, these criticisms may not hold true. For example, trainees participating in a case study simulation, preceded by a lecture, may use the information gleaned from the lecture to help guide their analysis of the case study material. In this case, the role of instructor feedback is critical to the effectiveness of the case study method.

In this sense, the structure of the MRM II training program follows the classic case study design. Briefly, the structure chosen for MRM II is lecture and adult inquiry learning with an examination of mishap incidents. Analysis of these sample mishap incidents requires the application of skill and knowledge dimensions taught during the lecture portion of the program. The chosen instructional technique for MRM II is much more interactive than MRM I. MRM II exercises provide the opportunity to practice MRM skills and knowledge in an active manner, while instructor feedback reinforces their correct usage.   Therefore, it is expected that awareness of team behaviors will transfer to performance on the job.

It must be noted, however, that MRM II teaches more than just team coordination skills, although those remain a large part of the course. Whereas the tasks of an aircrew may be well-defined and the consequences of their actions immediate, the impact of maintenance personnel on public safety tends to fall in the domain of latent errors. Therefore, it is imperative that maintenance personnel be taught the processes that underlie the tendency to commit latent errors, even more than aircrew should be taught. As a result, AMTs should be taught the process behind maintenance operations, taking a systemic perspective, in addition to learning how to work as a team. This phenomenon has been termed Team Situation Awareness.40

Team Situation Awareness is defined as the degree to which all members of a team possess the situation awareness necessary to complete his or her responsibilities.40 The difficulty of maintaining this level of awareness is compounded by the presence of multiple team members and multiple teams. Examples include those personnel employed in different departments such as "stores" and line maintenance. When one or more team members (or teams) do not maintain the minimum level of situation awareness, information gaps occur. In this case, poor communication results and the organizational "mission" is compromised.

In order to maintain Team Situation Awareness, MRM II also teaches maintenance personnel how to view maintenance operations from a systemic perspective and to understand basic human factors issues as they apply to their work.[1] These topics are as important as teaching team coordination skills for establishing a good safety culture within the organization.

3.11 MRM III

What training format is suitable to enable trainees to implement actual MRM skills? Ideally, a full simulation, one which incorporates many if not all of the intricacies of the aviation maintenance environment, is the best format to learn interpersonal and teamwork skills.[43] However, the costs of creating a high-fidelity simulated environment, as well as the lack of organizational support for such a project, generally prohibit its construction. Despite these constraints, the purpose of this research is to create a plan that takes into account organizational limitations, yet is still capable of sufficiently training MRM skills in a simulated maintenance environment. To this end, a plan is proposed that focuses on these following MRM skills: task planning, coordination, teamwork, communication, assertiveness, decision making, and situation awareness. This next phase in training MRM is tentatively called MRM III. In addition, an emphasis on the systemic perspective regarding the AMT's role in maintenance processes will remain a general theme throughout MRM III.

3.11.1 Instructional Design Model

In designing the next phase of MRM training, we incorporated and built upon the results of those previous needs analyses. Specifically, MRM I and II were assessed and deficiencies in training MRM behaviors were identified. In addition, deficiencies in training evaluation were also noted.

After integrating and using the development of CRM and LOFT as reference points, several goals and objectives were identified. They are as follows:

1. Opportunities for additional skill practice and development must be created.
2. The integration of technical training with MRM skills is necessary.
3. The ability to assess directly the use of any overt MRM behaviors is required for evaluation.

These MRM training objectives served as the basis for designing an instructional strategy for MRM III.

3.11.2 Design

Several factors affect the design of a training program and what is ultimately chosen. Among these factors are the content of the training (i.e., “what” is being learned), the target training population (“who” is being taught), and the trainers themselves (“who” is teaching).[7] For MRM III, the content and the targets are pre-determined by MRM II, while the trainers remain each organization’s prerogative. Therefore, the development of MRM III must rely on other factors. Among these factors is an organization’s ability to create maintenance simulations economically. These same programs, however, must still provide trainees with the opportunity to practice and integrate MRM skills outside of the classroom environment. The next section discusses three specific training strategies that take these factors into consideration.

3.11.3 Simulation Fidelity

Simulations range in their degrees of fidelity i.e., how close to the real situation they seem to be. However, there are two types fidelity that exist in training simulations. These are *physical fidelity* and *psychological fidelity*.[5] Physical fidelity refers to the degree that real-world operational equipment is reproduced. This is the type fidelity that comes to mind when most people think about simulators and simulations. Examples of these include aircraft simulators for pilots. Psychological fidelity, on the other hand, refers to the degree to which training tasks reproduce actual behaviors or behavioral processes that will be used on the job.

Physical fidelity also varies from simulation to simulation. Pilots are trained in full machine simulators, replete with motion, that immerse the trainee in an environment that is very close to their actual workplace. On the other hand, many simulations exist that do not, on the surface, resemble the workplace environment at all. Simulations such as business games are examples of simulations with low physical fidelity. Briefly, business games are simulated environments in which participants compete based on the rules and objectives of the business setting chosen. In the course of the game, participants learn and apply information on the operation of the simulated business.[5] Other variations of business games include “in-basket exercises,” (though typically used for employee selection and assessment) and role-playing exercises.[6]

It is important to note, however, that even simulations with low physical fidelity maintain psychological fidelity by emphasizing the use of a behavioral skill, independent of its setting as long as the proper stimuli exist to elicit the desired responses. Caro presented a comparison between low and high fidelity cockpit simulators.[44] He found that precisely designed mockups which simulated the necessary cues and response opportunities of specific aircraft did not differ significantly from those trained in high fidelity simulators in the number of errors made when evaluated. It can be argued that a low physical fidelity, but precisely designed MRM simulation could achieve similar results.

Finally, a simulation may possess psychological fidelity without maintaining physical fidelity, but it may not have physical fidelity without maintaining psychological fidelity. *Psychological fidelity*, after all, is the primary goal of all simulations. For example, training a set of behavioral skills, even in a highly realistic environment, which would never be used would result in ineffective training. Therefore, maintaining psychological fidelity is also the primary goal of MRM III.

Table 3.4 shows the instructional strategies that follow, relative to their physical fidelity. As you review each proposed design in full, note that psychological fidelity, using and developing MRM skills, is maintained for all three types.

Table 3.4. The Physical Fidelity of Proposed Instructional Designs

Physical Fidelity	Proposed Instructional Design
High	Full Maintenance Simulations
Medium	Intelligent Tutoring Systems
Low	TQM-Based "MRM Teams"

3.11.4 Full Maintenance Simulations

One approach, and seemingly the most apparent, involves the recreation of the maintenance environment in a controlled setting of high physical fidelity. High fidelity simulations or "mockups" have proven to be effective in training not just task skills, but team skills as well.7 A training environment such as this would be directed by the MRM trainer/observer. This trainer is comparable to the check-airman who evaluates performance in LOFT scenarios. Check-airman possess great technical proficiency and are specially trained in CRM principles and philosophy.43 MRM III facilitators would be similarly equipped.

Specific maintenance tasks could be selected for use in MRM III. The validity of such maintenance simulations was demonstrated by Gramopadhye, et al.33 The task chosen for their study was the removal and installation of an aircraft engine. This task was analyzed and divided into specific component behaviors. In addition to evaluating teamwork skills, each task behaviors were evaluated for an assessment of technical proficiency. In these ways, this study is quite similar to LOFT. A variety of maintenance scenarios can be developed, simulated, and evaluated in a hanger environment, creating a training system comparable to LOFT. MRM III facilitators can vary situations by introducing common AMT challenges, such as lack of adequate parts or manpower.

3.11.4.1 Evaluation of Mockups

Evaluation of mockups occurs in much the same way as with LOFT. Facilitators would rate trainees according to their proficiency in using MRM skills on the job. Behavioral observation would provide the mechanism for evaluation in this context. Peer review can also be included as a second evaluation measure.33 Finally, videotaping these simulated maintenance tasks would provide more data for evaluation and feedback than naturalistic observation alone.43

3.11.4.2 Benefits of Mockups

The benefits of choosing such a task or another actual maintenance task in which to practice MRM skills is obvious. Using established maintenance tasks would have high fidelity and possess great saliency for an AMT. Use of such tasks would increase the probability of MRM being "bought into" and ease the transfer of MRM skills into the workplace. Indeed, after initial resistance, LOFT is widely accepted by most pilots.32

3.11.4.3 Issues to Consider

There are other issues to consider in instituting full maintenance simulations. First, by using specific maintenance tasks, the general ability of learned MRM skills may be limited in those scenarios not simulated. In other words, from avionics to airframe to powerplant maintenance, maintenance tasks contain a great deal of variability in the resources, tools, and context in which work is being performed. Given that there are a finite number of training hours and resources available, maintenance simulations must be equally limited. On the other hand, LOFT simulations, though varied, all occur in the same context -- that of the cockpit. As is the case, LOFT is continually challenged on a technological level by the wide variety of aircraft flown by today's pilots. These concerns may be unfounded, however, due to the generic teamwork quality of many of the MRM skills (coordination, communication, assertiveness, etc.) being taught. Because several of these skills are common to most teams regardless of context, transfer of MRM principles may occur despite the specificity of the training tasks.18

Another issue involving the implementation of full maintenance simulations involves the cost of such endeavors. Ideally, full maintenance scenarios would replicate a hanger and include all relevant materials and tools to maintain the highest degree of physical fidelity. Large organizations, such as aircraft manufacturers, that possess a surplus of both may be adequately equipped to handle such a situation. Indeed, Boeing has had such an operation in use for many years. The costs of simulating a maintenance task, however, may prove prohibitive to smaller organizations.

Added to the cost of instituting a high fidelity mockup is the cost of maintaining it. Should an aircraft change configurations or designs, the mockup would have to be similarly changed. This would require extra resources that smaller organizations may not have.

Finally, one must also recognize the role that training takes in the socialization of organizational newcomers. Gramopadhye, et al., found that control teams who did not receive formal team training still improved in coordination and performance, suggesting an intuitive use of team skills and influence from the organization.33 Nevertheless, though these skills may reflect teamwork in the most fundamental sense, they may also result in the perpetuation of "bad habits," such as failure to follow standard operating procedure.45 Using highly-realistic maintenance simulations within an established work environment may help perpetuate these work habits, unless they are closely monitored by a capable MRM III facilitator. In other words, poorly-trained or haphazardly-chosen trainers may actually socialize negative work norms into new employees, in much the same way as been documented during on-the-job training.46 As Byrnes and Black stated clearly:

> Ironically but understandably, check airmen taken as a group can be the most resistant to the personal change suggested by a comprehensive CRM training program. They are the 'top of the food chain' of the pilot group and as such tend to believe that the skills which brought recognizable success are adequate. As 'captain's captains' suggestions for change can be interpreted as criticism of past performance. Therefore, since CRM is all about changing attitudes, one must first clear this hurdle of defensiveness…47

Because of the "defensiveness" described above, a poorly trained MRM facilitator may actually reinforce a newcomer's skills, based on their own experiences, that are contrary to the philosophy of MRM. Therefore, because the quality derived from using fully-simulated maintenance tasks as the vehicle for MRM III relies entirely on the skill of the facilitator, proper selection and training of these personnel are paramount.

The importance of check-airmen and their impact on the resulting quality of LOFT simulations are well-documented.43 Butler observed great variation among check-airmen and a corresponding variation in students' ability to grasp and integrate CRM concepts as well. The combination of a poorly trained facilitator with the "common sense" quality of many MRM skills may undermine the goals of MRM as a whole. Yet, MRM facilitator issues are not limited solely to full-maintenance simulations. As will be seen, the quality of the MRM facilitator affects the effectiveness of each of the proposed MRM III plans. However, facilitator errors are more salient in the context of full maintenance simulations than in others.

3.4.11.4 The Use of Mockups

In what context would full maintenance scenarios be best? Apart from large, well-established organizations and airline companies, Gramopadhye, et al., suggest that airframe and powerplant (A&P) schools would provide the ideal context for such training.33 This training easily could be incorporated into school curricula. Because of the access to resources afforded most A&P schools, costs would not generally be prohibitive. The difficulty lies in training MRM-type skills within a particular learning window, specifically after a student gains technical proficiency but before work habits are established. This can be circumvented by the continuous training of MRM-type skills throughout an AMT's tenure. However, given that many work habits or "norms" are passed from senior, established workers to less-experienced workers, the socialization of habits opposed to MRM principles presents a challenge to designing an "on-going" MRM course. Companies should consider these pros and cons, it is up to each particular organization to assess how full maintenance simulations could be incorporated into their own training structure.

3.11.5 Intelligent Tutoring Systems

A second approach for constructing a training program and its delivery systems focuses on the cognitive processes through which individuals transfer learned skills into the workplace. These cognitive processes differ among experts and non-experts.48 Experts, for example, possess an extensive storehouse of knowledge and use that knowledge in unique ways based on previous experience. This ability to integrate knowledge and experience facilitates good decision making. Novices, on the other hand, possess a rudimentary knowledge of a system, and their understanding is less integrated than that of an expert. Clancy and Soloway present this as a model for computer-based training or, specifically, intelligent-tutoring systems (ITS).49

ITS not only contain a storehouse of specialized knowledge, they incorporate expert programs that approximate the decision making capabilities of human experts. In addition, ITS provide a tutoring model for students to guide them through these processes. Finally, ITS also possess full multi-media capabilities to demonstrate a variety of concepts through interactive audio and video, thereby giving any simulations presented in ITS added fidelity. For a more comprehensive discussion of ITS, see Norton.50

3.11.5.1 Evaluation of ITS

As with full maintenance scenarios, LOFT provides the template against which to structure ITS evaluation. Using behavioral observation, facilitators would rate MRM performance and provide feedback upon conclusion of each scenario. Furthermore, the ITS could maintain a database (using such criteria as "mistakes made," and time to elapsed between decisions, for example) of each group's progression over the course of time.

3.11.5.2 Benefits of ITS

All of the qualities of ITS make it an attractive alternative to full maintenance simulations for delivering MRM III. Although not as "realistic," i.e., possessing great physical fidelity, ITS is a satisfactory compromise between the benefits and criticisms of full maintenance scenarios. For example, ITS is much more cost effective, requiring only the purchase of computer hardware and the creation of relevant software. In fact, recent changes in FAA FAR Part 147 allows for the use of computer-based training for aviation maintenance.

ITS also avoids one of the downsides of full maintenance simulations by allowing for quick and relatively inexpensive maintenance and upgrading. A change in aircraft design would require only a change in software to maintain current. Costs, in this case, would be kept much lower than having to upgrade various types of hardware and/or the simulated mockup itself.

In addition to its low cost relative to creating full maintenance simulations, ITS is not location specific and can be instituted in a variety of locations. Finally, though the MRM III facilitator remains a vital component of training, the reliance upon the facilitator would be moderated by the ITS. In this way, the third criticism of full maintenance simulations is also addressed.

ITS training is already in use in aviation maintenance. One such example is the Environmental Control Systems (ECS) tutor. This program allows students to troubleshoot malfunctions of the air conditioning portion of the ECS through an interactive simulation of an aircraft's environmental control system. The student can ask for advice from the program at any time. Additionally, the system can detect if the student is encountering problems and may assist in helping to overcome them.

Though individually-based, such a framework can be modified to include other team members, and more complex maintenance scenarios. Maintenance variables, such as available resources, weather, etc., can also be easily manipulated. Similar to popular strategy-based computer games such as SimCity, such an ITS could prove to be extremely engaging as well.

3.11.5.3 Issues to Consider

Could ITS address an organization's propensity towards latent errors? The short answer is yes, but only if the ITS were designed to specifically tackle those issues. One possible strategy for addressing latent errors could be to introduce interactive, in-depth case study analyses of aircraft accidents via ITS. These analyses could be structured in two ways: the traditional, *post hoc* accident analysis or as a situational decision tree, in which the "actions" chosen by the trainees determine the next set of circumstances. Both strategies, used in conjunction with one another, could adequately convey a systems perspective of the maintenance process, thus training concepts that reinforce a culture of safety.

3.11.6 The Role of TQM in MRM

Though the heyday of quality circles seems to have past, many of the concepts taught and advocated in MRM training are similar to the principles of W. Edwards Deming's Total Quality Management (TQM) and quality circles, specifically. In fact, many of the initial MRM principles were derived from TQM.51 Therefore, a review of quality circles is included in this report and is suggested as another possible strategy to include within the proposed MRM III training program.

In short, a quality circle (QC) is a group of between 5 to 15 employees who meet on a regular basis to discuss issues of quality and other related problems.52 QCs address issues as varied as improving creativity to marketing to safety. The purpose of the typical QC is to create realistic and relevant solutions to workplace problems and suggest them to higher management. Though the term "quality circles" is the most widely used, organizations have been known to use other labels, such as "tiger teams" or "continuous improvement" teams.53 Each of these groups are formed to address specific issues, but they similar to QCs in structure and goals.

Adequate training, especially those focusing on problem-solving skills, is the foundation for the QC.51 Several researchers single out failure to train team participants adequately on interpersonal fundamentals, which are taught in MRM I and II, as the major cause for QC failure. In addition, management commitment is also necessary to ensure QC success. Management must enact the solutions suggested by the QC, lest members feel ineffectual.

The purpose of raising the issue of QCs is not to advocate their introduction into current organizations. That is beyond the scope of this report. However, a variegate of QCs can be incorporated into MRM III, and provide trainees with an opportunity to practice MRM skills as well as to apply them in a relevant, work-related context. (For lack of a more precise terminology, these modified QCs will herein be referred to as "MRM teams.") As an example, during MRM III training, students can be placed in teams comparable to existing workgroups. Afterwards, each team would be presented with a human factors-related safety problem and asked to generate solutions. These problems may be hypothetical or derived from the organization itself.

The methodology for creating these proposed MRM teams are most similar to implementing "continuous improvement" (CI) teams.53 CI teams address specific problems identified in an organization, though they are typically not formed in response to them. Because of this specificity, CI teams maintain a narrow focus, with the goals of the team limited only to solving a constrained set of problems. MRM teams would differ from CI teams in that they would be formed in conjunction with initial MRM training. Therefore, the difficulties facing most QC or CI teams (a previous lack of interpersonal skills training, the failure to demonstrate managerial commitment, minimal training in problem-solving, etc.) is negated by MRM I and II.52

3.11.6.1 Evaluation of MRM Teams

Evaluation of performance in MRM teams would once again fall on the MRM facilitator. The MRM facilitator would observe each problem-solving session and provide feedback to each group after a designated amount of time. Feedback would encompass observations related to MRM skills such as communication, assertiveness, decision making, and leadership. Although it is suggested that LOFT check-airmen remove themselves from group interactions until feedback is to be given, the danger of this strategy is the "gripe" session. Facilitators must be aware of these tendencies and address them before and during training.

3.11.6.2 Benefits of MRM Teams

There are several benefits to employing MRM teams in MRM III training. First, they allow a chance for AMTs to use MRM skills in an applied way and practice their skills. Although this benefit of MRM teams is similar to that of maintenance simulations, the difference lies in which MRM skills are emphasized. MRM teams would encourage AMTs to practice problem solving skills that tap the global, systemic perspective taught in MRM I and II. This could be analogous to "organizational situation awareness." The resulting interaction among team members would allow for team skills to be practiced as well.

Secondly, as is the case with ITS, MRM teams are transportable from location to location. They are easily instituted in a classroom environment. In this way, MRM teams are extremely cost-effective.

Finally, there is an added side benefit to incorporating MRM teams in MRM III training. Using MRM teams may provide an organization with solutions to real problems that plague them. These solutions would be created as a minimal cost to the organization, and may even help recoup costs of the initial training if a solution proves successful. In addition, if management were to institute changes based on the real suggestions generated in these sessions, it would demonstrate managerial commitment both to MRM training and to employees in general.

3.12 SUMMARY

Currently, MRM is still in the classroom stage and is being piloted in a host organization. Initial reaction to this pilot program has been positive. In response to industry interest in furthering MRM training, the purpose of this report was to chart possible future directions for MRM. Using LOFT as a model, the researchers propose a more immersive approach that builds upon previous MRM training. This proposed course has been named MRM III.

Three possible strategies have been outlined for use in MRM III: full maintenance simulations, intelligent tutoring systems, and modified "quality circles." Each strategy has its benefits and drawbacks, just a few of which have been outlined above. There are cautions against using one strategy in favor of another. Because of the different advantages and disadvantages to each strategy, an ideal MRM III program would incorporate all three. However, logistically speaking, this is unlikely at best. Therefore, it is up to individuals in each organization to assess their resources and determine whether they can support a program such as MRM III or, based upon needs analysis, if MRM is even necessary at all. However, considering the need for airlines to find new ways of doing business, the future of MRM remains bright indeed.

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