A MODEL FOR EVALUATION AND TRAINING IN AIRCREW COORDINATION AND COCKPIT RESOURCE MANAGEMENT

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To improve crew coordination in aviation operations, the Army has adopted an Aircrew Coordination Training (ACT) program. However, the Army does not have a reliable, objective set of metrics for assessing the extent of the resulting crew coordination. Consequently, ARIARDA and DRC developed measures of aircrew coordination to assist in evaluating the effectiveness of the Army ACT program. A rational approach to evaluation requires that assessment be structured and tied to well-defined objectives. The initial stages of the project were driven by the recognition of two crucial deficiencies. First, there was no fundamental conceptual framework for aircrew coordination articulated in the literature. Second, most ACT evaluation schemes were based on measuring attitude change, rather than attitudes and behavior. To remedy these deficiencies, a conceptual model of aircrew coordination was developed and coordination objectives were established. Based on this work, an aircrew coordination evaluation measurement suite was constructed to measure both attitudes and behaviors. This work will assist in moving ACT programs to a much sounder footing since many ACT courses have been criticized for being too "soft." The ARIARDA project, with a robust theoretical model and associated behavioral outcomes, will integrate ACT training and evaluation in the Army. Moreover, because the model is general, it can provide guidance to other agencies developing crew coordination training or evaluation.

Introduction

An Army Research Institute (ARI) analysis of Army aviation accidents indicated that crew coordination errors represent a major category of human error-induced accidents. To date, however, crew coordination issues have been addressed largely in anecdotal or qualitative terms. The Army lacks a reliable, objective, and quantitative set of metrics for assessing crew coordination.

To improve crew coordination in aviation system operations, the Army incorporated an Aircrew Coordination Training (ACT) segment into the Initial Entry Rotary Wing training program. Limited ACT is also provided to aviators in the field as part of continuation training.

ARIARDA tasked DRC to develop measures of aircrew coordination to assist the Army in evaluating the effectiveness of its ACT program.

Model Development

In a review of the literature, two crucial deficiencies became evident. First, there was no integrated conceptual framework for aircrew coordination articulated in the literature. Secondly, it was found that most ACT evaluation schemes were based exclusively on measuring attitude change. The Army is not only interested in changing (and measuring) attitudes toward aircrew coordination, it also recognizes the importance of training and measuring specific task skills, behaviors, and procedures related to aircrew coordination.

To remedy the above deficiencies, the following efforts were undertaken. To address the first deficiency, a conceptual framework was built to allow for effective evaluation of ACT. The framework was necessary since a rational evaluation approach requires that assessment be linked to desired learning objectives and behavioral outcomes. The effort

resulted in a Basic Model of operator behaviors (Figure 1). Then, Lauber's (1987) definition of Cockpit Resource Management (CRM, as aircrew coordination is called in the commercial world) was expanded to include additional elements which helped to define the "systems approach" being undertaken by ARIARDA (Figure 2). Third, crew coordination considerations were incorporated into the Basic Model to generate the Crew Coordination Model (CCM). An abbreviated version of the CCM is presented in Figure 3.

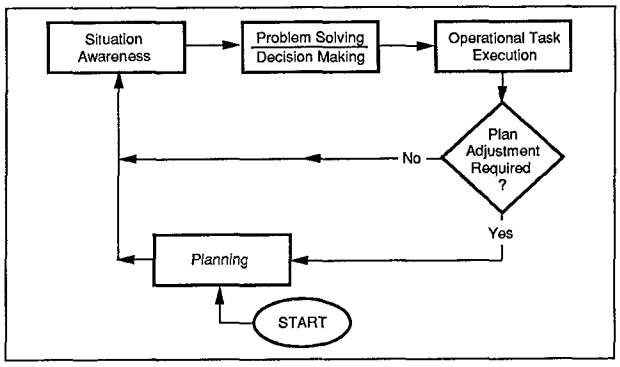

Figure 1. The Basic Model.

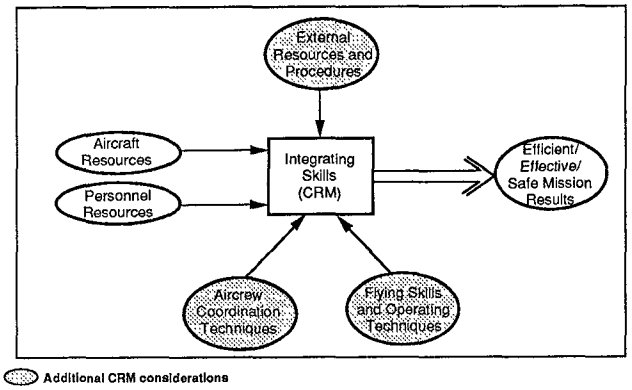

Figure 2. Extending the Model of Cockpit Resource Management.

Much of the past instruction in CRM/ACT was based on teaching Decision Making skills. The CCM substantially broadens the CRM/ACT perspective to include Planning, Situation Awareness, Problem Solving (Decision Making is treated as a subset of Problem Solving), Operational Task Execution, and Replanning, as necessary. Also, the CCM incorporates two other crucial considerations:

1. Recent research on Decision Making (e.g., Klein, 1989). Klein argues that in the past we have relied too heavily on teaching "analytical"

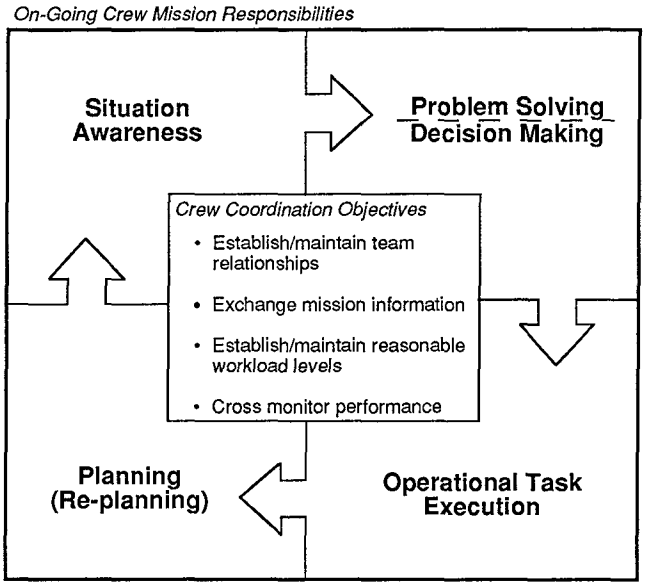

Figure 3. The Crew Coordination Model (CCM).

Decision Making processes and proposes a "recognitional model." The CCM accommodates alternative Decision Making methods.

2. The concept of task "coupling." Task coupling takes into account the environment in which an incident occurs, i.e., under forgiving or unforgiving circumstances, and whether there is little or much time to respond to a flight event. This issue is critical in considering Army aircrew coordination since a large percentage of Army flying is highly time-stressed (e.g., nap-of-the-earth flight), as compared to the commercial aviation sector.

The second deficiency (i.e., most current ACT evaluation schemes rely on measuring attitude change) was addressed by showing the transition from the old "Right Stuff" (Wolfe, 1979) beliefs and attitudes to the attitudinal and behavioral objectives essential to aircrew coordination (Table 1).

Instrument Development

Evaluation instruments were then designed in accordance with the conceptual framework and the set of aircrew coordination attitude and behavioral outcomes. The current measurement suite consists of three instruments: The Army Cockpit Management Attitudes Questionnaire, the Aircrew Coordination Evaluation Checklist, and revised Aircrew Training Manual tasks. The evaluation scheme is presented in Figure 4.

Table 1. Linkages Between Beliefs - Attitudes - Behaviors

Old Implicit Beliefs ("Pilots are perfect.")	New Explicit Beliefs Based on Lessons Learned ("Crewmember's capabilities are limited & fallible.")	Essential Attitudes That Must Be Adopted By Individual Crewmembers	Behavioral Objectives In Crew Coordination
• Beyond the pilot the rest of the crew is backup and basically unimportant to the mission	• The entire crew is critical to mission success	My fellow crewmembers are an important resource; I need to use them and treat them with respect (Values crew)	Establish and maintain interpersonal relationships to create and maintain a harmonious team atmosphere and to execute mission objectives (Establish/maintain team relationships)
• Pilots are infallible in their flying skills	• All crew members make mistakes • Crewmembers can catch other crewmembers' mistakes before they have serious consequences	Human errors are a fact of life, everyone makes them; they should be corrected with minimum disruption to ongoing tasks/ mission execution or to team relationships (Crew fallibility)	Check each other's actions for possible errors (Cross monitoring of crew performance)
• Pilots are aware of all available decision options	• A qualified crew will surface a greater range of decision options than the pilot alone will produce	I may have information which is important to another crewmember; I must take actions to ensure that he receives this information in a timely manner (Give information)	Establish and maintain the same mission plan and a common frame of reference within each crewmember in as much detail as possible (Establish/maintain common mission understanding)
• Pilots can collect and integrate all important decision information alone	• A more complete set of decision support information will be generated by the crew than by the pilot alone	Other crewmembers may provide important perspectives and information that I have not considered; I need to take actions to ensure the delivery of this information to the group (Get information)	Expose the decision-maker to the full range of action options available at each important decision point (Surface all decision options and information)
• Pilots operating alone make the best decisions	• On average, decisions which consider crew recommendations will be better than decisions made by the pilot alone		
• Pilots can handle all workload alone	• The quality of mission task performance is highest when the workload is effectively distributed across crewmembers • Crews can effectively distribute task execution responsibilities	Overloads increase the risk of errors and poor mission performance; providing support to overloaded crewmembers is essential to effective mission execution (Provide/Accept Help)	Allocate workload in a reasonable manner across crewmembers (Establish/maintain reasonable workload levels)

Army Cockpit Management Attitudes Questionnaire (Army CMAQ):

Attitude measures developed by NASA/UT (Helmreich, et.al. 1988) were refined and expanded. It was found that the military version of the NASA/UT Cockpit Management Attitudes Questionnaire (CMAQ) had several incompatibilities with Army leadership doctrine and command principles and did not address several attitude principles that ARIARDA identified as important. It was also evident (Helmreich, et.al, 1986) that several CMAQ items did not function well in differentiating among high and low CRM performers. Lastly, the NASA/UT 5-point Likert-type scale was expanded to a 7-point scale to better capture variability. The Army CMAQ was developed to measure the attitudes presented in the third column of Table 1. The number of items in the Army CMAQ and the attitude area they measure are presented in Table 2.

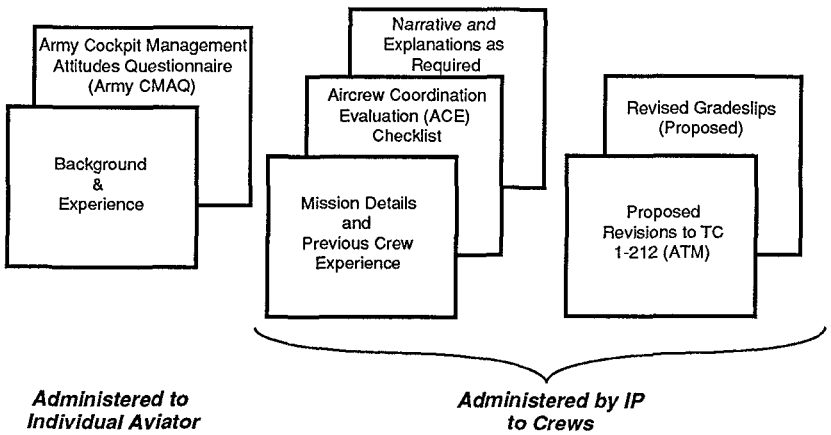

Figure 4. Measurement Administration System.

Table 2. Relationship Between Attitude Areas and Army CMAQ Items

Essential Crew Coordination Attitude	Source and Number of Items: NASA/UT CMAQ*	ARIARDA/DRC Additions	Total**
Values Crew	17	8	25
Crew Fallibility	12	8	20
Give Information	12	4	16
Get Information	8	4	12
Provide/Accept Help	2	6	8

* Items were obtained from several versions of the NASA/UT CMAQ. A number of these items were modified by ARIARDA/DRC for Army use.

** *The number of items in the current version of the Army CMAQ is 45.* However, some items relate to more than one attitude.

Aircrew Coordination Evaluation (ACE) Checklist:

The ACE Checklist was developed to measure behaviors. Again, a NASA/UT (Helmreich & Wilhelm, 1987) measure (specifically, the Line/LOFT Worksheet) was used as a starting point for instrument development. Several items were added to the NASA/UT scale, some items were substantially re-worded to better capture their intent, the 5-point scale was expanded to a 7-point scale, and each ACE dimension was behaviorally anchored at the 1, 4 and 7-level ratings. The relationship between NASA/UT's Line/LOFT Worksheet and the ACE Checklist is presented in Table 3. Table 3 also presents the relationship between the fourth column of Table 1 (behavioral objectives) and the ACE dimensions.

Table 3. Relationship of LINE/LOFT Worksheet, ACE Checklist and Aircrew Coordination Objectives

LINE/LOFT Worksheet Dimensions	ACE Checklist Dimensions	Aircrew Coordination Objectives: Mission Information Exchange	Workload Management	Cross Monitoring	Team Relations Development/ Maintenance	Global workload & Performance
1. Briefing thorough, establishes open communications, addresses coordination, planning, team creation, and anticipates problems	1. Thorough pre-flight mission plan developed	X	X	X	X	
2. Communications timely, relevant, complete, and verified	2. Statements/directives clear, timely, relevant, complete, and verified	X				
3. Inquiry/questionning practiced	3. Inquiry/questioning practiced	X				
4. Advocacy/assertion practiced	4. Advocacy/assertion practiced	X				
5. Decisions communicated and acknowledged	5. Decisions communicated and acknowledged	X				
	6. Actions communicated and acknowledged	X				
6. Crew self-critique of decisions and actions	7. Crew self-critique of decisions and actions			X		
7. Concern for accomplishment of tasks at hand	8. Crewmember actions mutually cross monitored			X		
8. Interpersonal relationships/group climate	9 Interpersonal relationships/group climate				X	
9. Overall vigilance	10. Aircraft, personnel and mission status reported	X				
11. Distractions avoided or prioritized	11. Distractions avoided or prioritized		X			
12. Workload distributed and communicated	12. Workload effectively distributed/redistributed		X			
10. Preparation and planning for inflight activities	13. Support information/actions sought from crew		X			
	14. Support information/actions offered by crew		X			
14. Over TECHNICAL proficiency	15. Overall technical proficiency					X
15. Overall CREW effectiveness	16. Overall crew effectiveness					X
13. Overall workload	17. Overall workload					X
16. Management of abnormal or emergency situation	18. Management of abnormal or emergency situation				X	
17. Conflict resolution	19. Conflict resolution				X	

Aircrew Training Manual (ATM) Task Revisions:

Selected ATM tasks were revised to reflect aircrew coordination behaviors. ATM Task 1071, Perform Aircrew Coordination, was completely rewritten. Fourteen other ATM tasks, involved in multiple Class A, B and C aviation accidents, were also revised to incorporate aircrew coordination considerations.

Implementation

The Army has begun implementation of the aircrew coordination model in two settings. First, an initial validation of the aircrew coordination evaluation instruments was conducted for a sample of 20 UH-60 Black Hawk helicopter crews during May 1990. Data from these tests are currently being analyzed and will permit various dimensions of aircrew coordination to be related to operational measures of mission performance. Based upon these results, an experimental ACT course will be tailored to the specific needs of Army rotary wing pilots. Full-scale testing of the prototype ACT course and a revised set of evaluation instruments is planned for late 1990.

The second area of implementation involves the use of the CCM to incorporate aircrew coordination considerations into the Army's accident investigation process. During the summer of 1990, the methodology is scheduled to be field tested during three investigations to validate the new procedures.

Discussion

The work presented here will assist in moving CRM/ACT programs to a much sounder footing. To date, many CRM/ACT courses have been criticized for being too "soft," or "touchy-feely." A coherent, conceptual model for CRM/ACT that can be used to guide implementation, training development, and evaluation has not been presented heretofore in the literature. The CCM will guide ACT training and evaluation in the Army and, because the model is general, it can provide guidance to other agencies developing crew training or evaluation, whether the focus is aviation, marine, or ground vehicles.

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