AN ASSESSMENT METHODOLOGY FOR TEAM COORDINATION IN COMBAT MISSION TRAINING

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ABSTRACT

A Team Mission Observation Tool (T-MOT) was developed to identify individual and team behavioral processes observed during a specialized, simulation-based program of Combat Mission Training (CMT) conducted for U.S. Air Force Special Operations Command (AFSOC) MC-130P Special Operations Forces (SOF) aircrew teams. The T-MOT, its foundations, development, and purpose are described. Measurement is accomplished within the T-MOT using behaviorally anchored rating scales and subject matter expert observations of key behaviors tied to a complex CMT scenario. The T-MOT supports recording and analysis of both individual and aircrew team behaviors within five Crew Resource Management (CRM) subprocesses (time management; tactics employment; function allocation; situation awareness; and command, control, and communications) across critical mission phases. Additionally, the T-MOT provides structure to direct observations of complex performances demonstrated during both mission preparation and mission execution. With this methodology, an internally consistent and reliable “record by exception” measurement philosophy for recording specific aircrew team mission behaviors demonstrated during CMT is provided.

The T-MOT is being used to address several research questions:

- Are team behaviors within one or more CRM subprocess areas related to overall mission performance?
- Which CRM subprocess areas have the greatest demonstrated impact on mission outcome?
- Is team performance related to mission outcome above the performance represented by each crew position?
- Do effective aircrew teams exhibit consistent sets of coordination behaviors that can be "captured" and designed into a CMT program?

With this assessment approach, team coordination process indices have been identified for emphasis using current CMT technologies; a schema for improving team coordination training within existing capabilities was identified; and CMT system effectiveness was assessed. Additionally, the T-MOT has demonstrated the potential to be expanded to other CMT environments with only modest modification, and can be viewed as the first step in the development of an overall team mission readiness assessment tool.

ABOUT THE AUTHORS

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INTRODUCTION

A great percentage of fatal aircraft incidents and accidents are attributable to human error caused by poor aircrew coordination. The perceived need to reduce human error in Crew Resource Management (CRM) training led to the development of a unique, mission-specific Combat Mission Training (CMT) program for USAF MC-130P (formerly HC-130P/N) Special Operations Forces (SOF) aircrews. This training is currently managed by the USAF's 58th Training Support Squadron (TRSS), and conducted by the Mission Training Support System (MTSS) at Kirtland AFB, NM.

CRM training serves as the foundation of CMT by: (a) identifying to SOF aircrews those behavioral skills that are critical to aircrew coordination in complex mission operations, and (b) developing strategies and procedures for training these skills. While the need for such training is widely accepted, data regarding an aircrew's coordination effectiveness in CMT is largely unavailable.

Both CRM and CMT are high-priority, annual training events for SOF aircrews. While some operational flying tasks are performed by only one individual, the vast majority of mission operations are performed by collective aircrew teams. A wide diversity of roles and responsibilities are present in a typical SOF MC-130P mission. The MC-130P mission crew consists of the aircraft commander (AC), co-pilot (CP), flight engineer (FE), left and right navigators (LN, RN), and communications system operator (CSO). In addition, there are other members of the combat mission team whose tactical actions directly affect the aircrew, such as any Special Forces "customers," or other Air Froce Special Operations (AFSOC) aircraft that will be participating in the mission (e.g., a helicopter that is to be refueled by an MC-130P). Besides the supporting and tactical players, the team also includes those individuals and functions who provide a command and control role, such as the command leadership and the airborne command, control and communication (ABCCC) aircraft. These teams must be trained to coordinate their specialized activities in order to produce effective decision-making and successful mission performance

The evaluability of CRM coordination subprocesses is increased when these have been defined in terms of tasks to be trained. A well-planned and conducted front-end analysis that establishes evaluation criteria contributes to the program's overall evaluability. CRM and CMT training programs have typically been designed without regard to such evaluation concerns due to the difficulty in establishing sensitive indices of crew mission performance (Silverman, Spiker, Tourville, Nullmeyer, 1996).

A major goal of our research program is the identification, measurement, validation, and eventual reinforcement of aircrew behaviors associated with combat mission readiness and effective mission performance. The specific purpose of this paper is to report on one component of our total assessment strategy. A Team-Mission Observation Tool (T-MOT) has been developed to determine an MC-130P aircrew team's coordination effectiveness. Two issues were applicable to the development of this methodology: 1) What are the relevant processes associated with effective team coordination in the SOF CMT program? and, 2) What specific evaluation components and associated behavioral criteria must be included in the T-MOT?

THE T-MOT AND ITS RELEVANT DOMAINS

To obtain background data on CRM, team processes, CMT concepts, and related research programs, relevant documents were acquired from a broad base of available sources, and were reviewed during the initial phases of the project. In particular, documents were collected relating to: (a) SOF concept of mission operations, (b) SOF service unit doctrinal statements, (c) specific SOF employment procedures, (d) SOF mission tactics, and (e) SOF training task and objectives documents. The relevant data were content-analyzed to provide a solid foundation for understanding SOF CMT and CRM issues.

Given our emphasis on CRM and team performance measurement, and our interest in the MC-130P weapon system, two regulatory requirements were of particular importance: (1) the mission definition portion of AFSOC Reg. 51-130 (1994), and (2) the Air Force Instruction for CRM Training - AFI 36-2243 (USAF, 1994). The first document outlines specific CMT tasks to be performed, and the second document provides guidance on methods that can be used to train and measure CRM task performance.

The AFSOCR 51-130 (Flying Training Regulation), served as a primary source by establishing which mission events are to be trained and whether these are being accomplished to a satisfactory extent. By identifying critical mission training events and success factors, this document formed the basis for, and established the validity of, the mission scenario that is used to conduct CMT in the MC-130P Weapon System Trainer (WST).

The AFI 36-2243 emerged as the second important document, establishing a requirement for Major Commands to measure CRM. The AFI specifies definite, albeit broad, boundaries around the content areas within which our own data collection efforts are formulated. The AFI is an essential element of CRM training, as it highlights, for example, the importance of situation awareness (SA) and mission planning in CRM, expands the scope of CRM concepts to the tactical environment, and permits over-the-shoulder observation as a legitimate data collection technique.

Finally, information from personnel who were experienced in SOF operations, mission execution, and training also served as data sources. Data were collected using informal interviews, observations of training events, and group discussion techniques. Besides providing information regarding SOF mission execution and training assessment issues, subject matter expert (SME) interviews provided clarification on issues not addressed in the doctrinal publications.

Mission Phases

The mission events identified by AFSOCR 51-130 formed the basis for categorizing five mission "phases," in which there are multiple situations where crewmembers would be expected to engage in specific CRM behaviors. These mission phases, and our description of their CMT objectives, follows:

The **Mission Preparation** (MP) phase entails conducting pre-mission planning and briefing activities that allow sufficient preparation of a comprehensive pre-mission execution plan. This plan will be prepared with considerations for a medium threat environment, all major mission events and activities, and mission operations procedural constraints.

The **Low-Level** (LL) tactical operations phase includes night vision device (NVD) low-level flight enroute to specific mission events, using proper tactical mission management procedures (altitude, airspeed, terrain masking, etc.) for a medium-threat environment.

An **Aerial Refueling** (AR) operations phase involves the successful conduct of tactical in-flight AR of (multiple) MH-53J Pave Low helicopters within prescribed time, course, and altitude constraints in a medium-threat environment.

The **AirDrop** (AD) operations phase involves conducting a personnel Computed-Air-Release-Point (CARP) airdrop within prescribed time, course, and altitude constraints in a medium-threat environment.

The **Infil/Exfil** (I/E) operations phase includes covert infiltration and/or exfiltration, at tactical landing sites for transload purposes, within prescribed time, course, and altitude constraints in a medium-threat environment.

CRM Subprocesses

We have chosen to define functional CRM subprocess areas based on considerations of specific aircrew tasks. This is in contrast to defining functional areas based on either global dimensions of performance (e.g., CRM meta-skills) or situation-specific considerations (e.g., critical behaviors). In particular, since our ultimate goal is to elucidate the coordination processes that contribute to effective aircrews and good team performance, we selected functional areas based on: (a) relevance to the SOF mission environment and previously reported operational problems, (b) appropriateness to the high levels of experience and motivation of most MC-130P aircrews, (c) applicability to CMT, and (d) amenability to measurement by outside observers. In addition, and where possible, we attempted to derive functional areas that tap the more global CRM dimensions identified by other researchers.

Based on these considerations, five functional coordination subprocess areas were identified. Our description of each CRM coordination subprocess and rationale for their selection follows. These areas are to be assessed during each of the five mission phases previously discussed.

In reviewing the scope and content of these areas, it is evident that some of the traditional dimensions of CRM, such as leadership, group cohesiveness, personalities, etc., have been omitted. We readily acknowledge that these five areas by no means encompass the entire content domain of what would properly be considered team coordination, and that other factors are worthy of study in their own right. However, our focus is on identifying CRM functional areas whose performance, we think, have the most direct links to the tactical CMT environment, training-related processes, and training interventions:

Situation Awareness (SA) entails maintaining an accurate mental picture of tactical mission events and objectives as they unfold over time and space. Emphasis and analysis are placed on three levels of SA (perception, integration, and generation: Endsley, 1995) and their impact on team coordination.

Function Allocation (FA) includes the division of crew responsibilities so that workload is distributed among the crew, avoiding redundant tasking, task overload, and crewmember disinterest or non-involvement. Tasks should be allocated in such a manner so that crewmembers are able to share information and coordinate responsibilities.

Tactics Employment (TE) includes all analytic and tactical activities necessary to avoid or minimize threat detection or exposure, and to successfully coordinate complex mission events and multiple mission objectives.

Time Management (TM) involves the ability of the combat mission team to employ and manage limited time resources, so that all tasks receive sufficient time to be performed correctly and critical tasks are not omitted.

Command Control, and Communications (C3) encompasses activities required to involve external parties in the mission; maintain communications with these external team members; monitor internal communications within the crew; and control of the sequence of mission events according to the mission execution plan.

T-MOT Content Identification

Preliminary evaluation criteria and the practical requirements for the assessment tool were established after observing a series of SOF CMT classes. The purpose was to collect CMT data during actual instruction through close-up observation of training and SOF mission execution. These observations allowed direct data collection from SOF crewmembers who had, during training, an opportunity to articulate their reasons behind the critical issues related to operational CMT concerns.

Content analyses were then performed on the compiled information to identify the major components and topics presented in the sets of data arising from the interviews and observations. The objective was to identify and classify the most frequently occurring issues, and to reconcile analytic, evaluative, or behavioral discrepancies and disagreements in information provided by individual experts.

Finally, the draft T-MOT was developed. An iterative sequence of identification, development, and refinement was used, wherein the logic and organization of the T-MOT were scrutinized for consistency, clarity, and coherence. Revisions were made based on review recommendations. As each iteration of the instrument was completed, it was compared with previous versions to ensure that all gaps in logic, flow, and content were addressed. SME reviews were used throughout, and formal summative reviews were conducted at each development milestone.

THE T-MOT APPROACH

The T-MOT approach has four distinguishing characteristics: (a) a focused perspective on key behaviors that are collectible, variable across aircrews, and operationally relevant; (b) a portable, multi-method and multi-measure mix of variables that captures complex cognitive processes; (c) a naturalistic observation-correlational design that takes full advantage of ongoing training systems, resources, and a readily available operational subject pool: and (d) a unique derivative of a Behaviorally Anchored Ratings Scale (BARS) approach, wherein explicit written descriptions of observed behaviors function as overt referents, and aid SME scoring decisions when determining a scale value.

Key Behaviors

Robust measures of team coordination are needed that must capture specific key behaviors which are collectible, variable across crews, and operationally relevant. In the CMT environment, the constraints of the training situation and the resources available must be considered. The T-MOT measures behaviors that we reasonably expect to occur on a regular basis. The behaviors selected for observation must also be variable across aircrews. Given the overarching objective of identifying effective SOF aircrews, behaviors that maximally differentiate strong from weak crews must be sought. Preliminary testing and SME interviews provided insights regarding the highest payoff areas (e.g., the five coordination subprocesses) and potential key behaviors on which to focus.

Next, the observed behaviors must be relevant to tactical mission operations. Operational realism was one of the primary considerations in selecting the five team coordination subprocesses for development in the T-MOT. Crewmembers often complain about the “soft” topics traditionally taught in CRM courses and their weak connection to the missions crews actually fly. The subprocesses identified in the T-MOT attempt to bring crew coordination training closer to the operational environment, and to include tactically relevant, behavioral indices of team coordination. These behaviors may then be folded back into training, providing crews with immediate and relevant feedback.

Multi-Measure, Multi-Method Approach

The study of team coordination is, by its very nature, a multi-faceted, multi-dimensional problem. Thus, a multi-measure, multi-method mix of variables is required to achieve a comprehensive, systematic investigation of the topic. As used in the T-MOT, this approach refers to the employment of a battery of objective (e.g., counts) and subjective (e.g., ratings) measures coupled with quantitative and qualitative methods of data analysis.

From an experimental perspective, this approach is appealing, as it permits researchers to tap cognitively complex processes that may otherwise be difficult to capture within a single index. Logistically, this approach has a robust appeal with regard to potentially devastating losses of partial data due to simulator malfunctions or subject-crew turbulence. In the T-MOT, team coordination processes are observed and rated by an SME across the five coordination subprocesses, across the five phases of flight, and across the six crewmembers. This is accomplished by using headsets to monitor live mission execution and, as discussed below, from over-the-shoulder observations during mission preparation.

Observation Procedures

An over-the-shoulder type, unstructured observation technique is advocated for CRM evaluation in the AFI 36-2243. This technique has been successfully employed in previous mission planning and mission rehearsal (Spiker & Nullmeyer, 1995a, 1995b) studies. There is no script for the observer, and the observer is free to record overt behaviors. Our measurement approach is to record "by exception," where the observer notes both individual crewmember and aircrew team behaviors and cognitions that seem unusually strong or weak, as compared to teams observed in the baseline period. With this approach, we intend to capture occurrences of effective or ineffective crew coordination behaviors demonstrated during CMT. Once collected, content analyses may be performed on the recorded behaviors to permit comparisons of frequency, quality, and/or intensity across teams. This qualitative analysis then supplements the quantitative analyses performed on the rating data.

For our initial research efforts, we have employed a naturalistic observation-correlational design rather than performing an explicit experimental manipulation. There are several reasons for this choice. First, this approach allows us to take advantage of ongoing CMT, using a high-workload combat mission scenario that is already in place. By working within the CMT community on a not-to-interfere basis, we have gained access to an experienced, inexpensive subject pool. Second, use of a naturalistic observation paradigm offers the advantages of true operational relevance (external validity) and clear-cut application of team mission coordination principles. Third, this approach allows us to immediately fold back the lessons learned into the training program, without the lag time often associated with laboratory research efforts.

Rating Procedures

Each crewmember's demonstrated behaviors across several coordination subprocess areas are individually rated by a trained observer, using a 1 (low) to 5 (high) Likert scale. The process of providing SME ratings for each crewmember across CRM functional subprocesses is repeated across each of the identified mission phases. This method of ratings assignment was developed for specific use within the T-MOT, to provide assessments across coordination areas, crewmember positions, and mission phases (see Figure 1). These techniques provide a circumscribed structure and rules under which observers assign numbers to an attribute. Unlike unstructured observations, this structured observation technique arms the observer with rules to record specific observations. The T-MOT employs this method as its primary technique to produce both quantitative and qualitative data regarding individual and team coordination.

In the T-MOT, rating assignments are supplemented by applying a unique derivative of the BARS approach to assess team coordination quality. After extensive testing and SME review and analysis, a series of referent descriptors for each mission phase and coordination subprocess area was developed. Specifically, the observer is prompted to circle either a "YES" or "NO" response to a descriptor question. This method then elicits a written rationale descriptor statement to promote "why" that item was circled. In reverse, these descriptive statements become the referent anchors of the particular rating awarded.

THE T-MOT METHOD

The following section illustrates the T-MOT method, along with sample descriptive data from observed MC-130P aircrews.

Figure 1 represents an example of SME ratings provided in the MP phase. Each of the matrix blocks describe an individual or crew rating received across each coordination subprocess. The norm rating for each of the matrix cells is considered to be a "3," and if any block is left blank, the assumed score is recorded as such. If a notable positive or negative event occurs, however, the corresponding block is scored appropriately. This strategy is used to score those "record by exception" key behaviors that occur in the particular mission phase. This methodology is repeated for each of the four remaining mission phases (i.e., LL, AR, AD, IE).

MISSION PREPARATION	AC	CP	LN	RN	FE	CSO	CREW
1. Situation Awareness (SA)	*4*	*4*	*5*	-	-	-	*4*
2. Function Allocation (FA)	-	*4*	-	*4*	*4*	*2*	-
3. Tactics Employment (TE)	*4*	-	*5*	*4*	*2*	*1*	*4*
4. Time Management (TM)	*5*	*4*	-	*4*	-	*2*	*4*
5. Command, Control, & Comm. (C3)	-	-	-	-	-	*4*	-

Figure 1. SME Ratings Matrix for the Mission Preparation (MP) Phase

Figure 2 describes how two crewmembers' observed social interaction patterns during MP may have caused problems in another crewmember's ability to perform necessary tasks (c). This item might help explain a lower individual or team SA score in one or more affected mission phases.

1.0 (SA) The AC will (typically) pay strict attention to overall mission preparation details (e.g., knowing everybody's job, and checking other crewmembers' work efforts).

a. Did the AC pay attention to detail? .... ***YES*** / NO
(Explain) *AC constantly checked other's work efforts, cross-referencing to own mission execution plan.*

b. Did the AC promote an environment for open "team" communications? .... ***YES*** / NO
(Explain) *AC periodically asked each CM to (summary) brief others on current efforts/status of tasks.*

c. Did non-operational factors (such as social interaction) interfere with any crewmember's time to perform necessary tasks? .... ***YES*** / NO
(Explain) *FE & CSO distracted others attention span on several occasions with jokes, detractors, etc.*

Figure 2. Mission Preparation (MP) Phase (Example)

Figure 3 represents a C3 measurement item scored during the LL tactical operations mission phase. This item describes an apparent observed strength on the part of the CSO to filter critical communications, that may have contributed to effective team coordination and task accomplishment.

2.0 (C3) CSO receives incoming (distracter) message. The crew should spend minimum time dealing with problem(including time for CSO to filter info.). There need not be an excessive amount of discussion about the problem's solution.

a. Was this event handled by one focal crewmember, or was a full-crew emphasis used? .... ***YES*** / NO
(Explain) *CSO received & processed the message so that "crew" were aware of entire situation & options.*

b. Did the CSO filter the message appropriately ? .... ***YES*** / NO
(Explain) *CSO requested and received clarifying information prior to passing message to crew for processing.*

c. Were reasonable options presented for dealing with the message? .... ***YES*** / NO
(Explain) *Crew was able to consider options/solutions because the CSO clearly filtered & relayed the SITREP.*

d. Was an appropriate decision (outcome) ultimately concluded? .... ***YES*** / NO
(Explain) *AC, with crew's concurrence, decided to continue mission. Requested CSO relay decision to C&C.*

Figure 3. Low-Level (LL) Tactical Operations (Example)

Figure 4 represents a TE measurement item, demonstrated during the AR operations mission phase. This item describes the occurrence of a key behavior that indicates weakness on the part of a RN, and which may have compromised effective team coordination and task accomplishment.

3.0 (TE) The AR should be completed early, so they can escape hostile airspace quicker. This also gives the crew additional flex time for later in the mission, when mission events get tight.

a. Did the crew exercise proper tactical refueling (phase) management procedures? .... ***YES*** / NO
(Explain) *LN and RN recognized hostile threat situation, modified refuel alt. to avoid/escape detection.*

b. ARCP ATA 02:35:25 . - Acceptable? .... YES / NO
(Explain) *RN distracted LN with target information, causing time control to suffer. LN recovered quickly.*

c. EAR Time 02:45.55 . - Acceptable? .... ***YES*** / NO
(Explain) *Time versus fuel transfer IAW Dash-1 specs. No delay caused by crew coordination issues.*

Figure 4. Aerial Refueling (AR) Operations (Example)

Figure 5 represents an FA measurement item during the AD operations mission phase. This item describes a possible strength on the part of the FE to prompt for checklist responses. It is reasonable to assume that this behavior may have contributed to effective team coordination and task accomplishment.

4.0 (FA) The LN and AC (combined) typically make the decision to command the AirDrop. A "blind" drop was specified in the mission planning phase - the crew will need to remember this point. Time compression, poor visibility, and mission environment may cloud their decision to drop (the DZ will likely not be visible until the final few second of the run-in procedure.

a. Was the final decision to AirDrop coordinated properly? .... ***YES*** / NO
(Explain) *All crewmembers verbally indicated to AC, with CP backup, that DZ was positively ID'd, and in sight.*

b. Were there any problems noted during the AirDrop (process)? .... ***YES*** / NO
(Explain) *Slow responses to multiple checklist items. Several FE prompts for responses. Operation completed.*

Figure 5. AirDrop (AD) Operations (Example)

Figure 6 represents an SA measurement item recorded during an IE operations mission phase. This item illustrates that a SA weakness exists on the part of the CP in incorrectly identifying the Landing Zone (LZ). This behavior may have compromised effective team coordination and task accomplishment.

5.0 (SA) The RN (FLIR, SCNS), AC (NVG Visual), LN (Radar, SCNS) will need to demonstrate a high level of effective coordination when working together to ID the airfield for the covert Infil operation. CP also needs to assist with high-precision chart interpretation, effective visual NVG scanning techniques, and efficient communications to other crewmembers.

a. Did the crew work together to ID the LZ airfield? .... ***YES*** / NO
(Explain) *The LN and RN confirmed to each other, then crew, that Nav systems were accurate, and LZ in sight .*

b. Did the crew have problems with the approach (process)? .... ***YES*** / NO
(Explain) *CP informed crew that LZ in sight (bad call), major (late) course corrections req'd. to compensate .*

Figure 6. Infil/Exfil (IE) Operations (Example)

Figure 7 represents an SA measurement item. This item illustrates the methodology for recording observed SA behaviors during, for example, the MP phase. This example portrays one crewmember's (RN) integration of "real world" aspects of the missions Area of Operations (AO) into the CMT scenario, possibly explaining the development or promotion of an overall enhanced team SA.

1.0 (SA) At least one crewmember's overall SA should be high, and an assessment of mission difficulty should be made based on (for example): marginal WX, threat saturation is high, large no. of mission events, etc.

a. Did any individual crewmember indicate an overall assessment of mission difficulty? .... ***YES*** / NO
(Explain) *RN indicated "...this mission is just like our everyday operations..." (He has operated in same AO) .*

b. Did crewmember(s) prepare for unexpected or contingency situations? .... ***YES*** / NO
(Explain) *RN added several "real world" aspects of INTEL & contingency plans to mission execution plan .*

Figure 7. Situation Awareness (SA) Functional CRM Subprocess Area (Example)

Figure 8 represents an FA measurement item, recorded during the MP phase. In this example, the AC appears to be the driving force in developing a task orientation to balancing and completing all mission preparation events. This demonstration of key leadership behavior may be illustrative of a higher level of FA, and effective team coordination.

2.0 (FA) Workload and/or task distribution should be clearly communicated and acknowledged by crewmembers.

a. Was the mission workload distribution clearly communicated and acknowledged? .... ***YES*** / NO
(Explain) *AC assigned primary task distribution for each CM, presented options to complete secondary tasks .*

b. Were secondary tasks prioritized so as to allow sufficient resources for primary tasks?.......... YES / ***NO***
(Explain) *Crew was unable to grasp secondary tasks due to intense workload - focus was on primary tasks only.*

c. Did non-operational factors (such as social interaction) interfere with any crewmember's abilities while performing necessary tasks? .... YES / ***NO***
(Explain) *This crew was totally task focused - NO social interaction observed (AC set example for crew) .*

Figure 8. Function Allocation (FA) Functional CRM Subprocess Area (Example)

Figure 9 represents a TE measurement item describing observed behaviors in the MP phase. In this example, the LN, RN, and CP developed a pragmatic tactics employment plan. This crew's use of assumptions and deception, for example, in their mission execution tactics is illustrative of an extremely higher level of TE and effective overall team coordination.

3.0 (TE) There are (typically) three tactical options to use in order to go undetected: Altitude, Airspeed, and Terrain.

a. Was a particular mix of tactics options considered? .... ***YES*** / NO
(Explain) *LN and CP developed an assumption that threat detection was 100% - opted for deception tactics .*

b. Did the crew change the tactics options as a function of difficulty in each mission phase? .... ***YES*** / NO
(Explain) *LN, RN developed an altitude masking, tactical LL altitudes, & deception tactics plans, as necessary .*

c. Was one option (e.g., speed) preferred over the others? .... ***YES*** / NO
(Explain) *Primary tactic was LL contour altitude masking using terrain and other cultural features .*

d. Did any crewmember periodically review or verify the status of the threat planning strategy? .... ***YES*** / NO
(Explain) *CP cross-checked, questioned, and referenced LN, RN during execution plan development .*

Figure 9. Tactics Employment (TE) Functional CRM Subprocess Area (Example)

Figure 10 illustrates the measurement of exceptional TM behaviors observed during MP. In this example, the AC negotiated a plan for the effective use of time, as a resource. Other crewmembers responded to the AC's plan in a positive manner, but the resultant effect appeared to be only partly successful. This may be illustrative of a higher level of TM, but not one that was a contributor to effective crew coordination.

4.0 (TM) An end-mission planning time should be indicated up front - most likely by an emergent "leader."

a. Did any crewmember indicate the need for an end-mission planning time? .... ***YES*** / NO
(Explain) *AC negotiated time reqd. to complete planning tasks, and established the mission briefings start time.*

b. Was that time noted by all other crewmembers? .... ***YES*** / NO
(Explain) *LN, RN indicated that "...if we're not done, we will continue working during the briefs..."*

c. Did any crewmember designate activities to establish a proper balance between their own authority, time available, and crewmember participation? .... YES / ***NO***
(Explain) *Each CM focused on own tasks, no observed willingness to help other's complete their tasks.*

d. Was adequate mission preparation time allocated for a comprehensive pre-mission briefing? .... YES / ***NO***
(Explain) *AC allowed brief start time to pass as not everyone was ready. Result - incomplete & hurried briefings.*

Figure 10. Time Management (TM) Functional CRM Subprocess Area (Example)

Figure 11 illustrates the measurement of C3 behaviors observed during the MP phase. In this example, the crew appeared to be unwilling to operate "out of their own box." They would not request specific external resources, nor were they willing to make mission assumptions. This may be illustrative of a lesser developed level of C3, and may possibly explain a lack of effective crew coordination.

5.0 (C3) Crew's willingness to challenge the system.

a. Do crewmembers request specific (Internal/External) resources they need? .... YES / ***NO***
(Explain) *Crew was unwilling to "operate outside of their own resources." No requests for other "players".*

b. Do crewmembers question/challenge assumptions (e.g., within frag, threat SITREP, etc.)? .... ***YES*** / NO
(Explain) *RN questions difficulty of AD operation, as tasked - Alternative suggestions offered to assure success.*

c. Do crewmembers ferret out needed materials and information from all sources? .... YES / ***NO***
(Explain) *Unless info was specified in FRAG, crew was unwilling to make assumptions, or request clarification.*

Figure 11. Command, Control, and Communications (C3) Functional CRM Subprocess Area (Example)

T-MOT APPLICATION

In our larger research program, the T-MOT supports two major areas of inquiry concerning team mission performance, coordination processes, and their relationships to each other:

Research Questions

One, does team coordination affect mission performance? Our primary research interest is to demonstrate a positive relationship between overall team coordination and tactical mission performance. While the unequivocal documentation of this linkage will provide a valuable addition to the team effectiveness literature, our conceptual approach permits us to scrutinize this relationship in further detail (Spiker, Tourville, Silverman, & Nullmeyer, in press). Once coordination-performance relationships have been identified, we intend to probe the data further, to determine whether effective aircrews exhibit a consistent set of behaviors that can be "captured" and provided as feedback during training.

One way to accomplish this is to compute "derived indices" from the key behaviors in the T-MOT checklist. For example, we might find that the most effective aircrews tend to exhibit some consistency in terms of: (a) having the AC serve as the leader (as opposed to some other crew position or none), (b) making effective use of the CP during mission preparation, or (c) early recognition by one or both navigators of problems in the designated control times, making the mission difficult.

Once these "derived indices" have been identified, a descriptive profile of a crew's relative standing on each index may be determined. For example, we might rank a crew either a 1, 2, or 3 on the AC index, depending on whether: the AC served as an effective leader (3), some other crewmember (e.g., LN or RN) was the leader (2), or there was no identified leader (1). Similar constructions are then developed for the other indices, yielding a crew descriptive profile, or vector, such as [3, 2, 3, 1, etc.], wherein the dimensionality of the vector would be determined by the number of "derived indices" that were identified.

Two, how do different crew positions affect team coordination and tactical mission performance? The T-MOT data matrix encompassing the five CRM functional subprocess areas and five SOF tactical mission phases may be expanded to isolate behaviors associated within the six individual crew positions. This would allow an assessment of the contributions of each crew position to overall team coordination and its component subprocesses, as well as overall team mission performance and its scenario elements. The expansion of this matrix would allow four additional questions to be addressed:

First, which crew positions have the strongest relationship to overall team coordination? While it is possible that all positions are equally vital in supporting the "emergence" of an effective team, the realities of operating the MC-130P may be such that some positions play a larger role than others. For example, we may expect to see that the AC, CSO, and two navigator positions (LN, RN), by virtue of their multiple tasking and extensive communications requirements, have a larger impact on team coordination ratings than do the FE or CP.

Second, an even more involved set of questions concerns the differential impact of crew position on specific team coordination areas. For example, a good LN may rate high on SA and TM, but TE, FA, and C3 may not be as important. On the other hand, a good CSO may rate high on TM and C3, but lower on TE, FA, and SA. While such determinations can become somewhat involved (i.e., six crew positions by five coordination areas), they hold considerable potential for helping to identify the content of future training interventions (e.g., specialized training workstations, communications checklists).

Third, do some crew positions play a larger role than others in overall team mission performance? Povenmire et al. (1989) observed that the squadron-provided rankings of B-52 crew mission performance were primarily influenced by the skill level of the Radar Navigator. Based on anecdotal accounts, a similar pattern may exist in MC–130P crews, with the LN's behavior being particularly central to mission performance.

Fourth, does the influence of specific crew positions vary when overall mission performance is divided into its specific scenario elements? For example, an AR operation is highly dependent on the ability of the FE to calculate fuel transfer and monitor systems (e.g., hoses) during transfer. At the same time, the CSO must send, receive, and transfer (secure) messages to C&C authorities, in order to coordinate the AR operation with the receiving party. Moreover, one must consider the additional labor of the pilots and the navigators required to ensure AR success. Despite this obvious team effort, it may be that the critical role of the CSO in coordinating this particular task is the most heavily weighted determinant of overall team AR performance.

Methodological Constraints

The T-MOT approach helps overcome five methodological constraints that plague traditional team studies: (a) small sample sizes, (b) simulator reliability, (c) scenario realism, (d) limited access to simulators, and (e) uncontrolled scenario variability.

Small Sample Size. Several factors can necessitate a small sample size when conducting team coordination research in realistic, operational settings. In our case, the small relative size of the SOF operational population is a major driver behind a small sample size. Researchers must accordingly develop their programs in conjunction with ongoing training and acquire subjects where available.

The analytic approach of the T-MOT to mitigate the risk of small samples is to look primarily for powerful effects rather than subtle ones. For example, in combination with crew-based measures of coordination process, the T-MOT supports collecting ratings and observations across all crew positions and several key dyads (FE and CSO) and triads (LN, RN, and AC). This enables additional comparisons, and in some cases, significantly increases the sample size.

Simulator Reliability. Whether conducting training or research in simulators, one obstacle that must eventually be confronted is simulator reliability. Advanced technology is not perfect, particularly as it involves complex computational systems.

The T-MOT uses two strategies to minimize the deleterious effects of simulator reliability. First, we monitor multiple phases of flight that involve elements having redundant tactical and technical significance. Within the simulator scenario, for example, there are multiple Infil/Exfils. If the simulator malfunctions during the course of training, we should collect information on at least one of these events. Second, since our data collection strategy covers the entire mission, from mission preparation through mission execution and debrief, we are guaranteed process data on every crew observed, even in the extreme case of the simulator not running at all.

Scenario Realism. This constraint poses a significant challenge to team performance measurement. Despite the high fidelity of the WST, aircrews often fail to treat simulator training with the same seriousness as they treat aircraft operations. This effect may even be compounded by instructors with similar views.

The T-MOT was designed with these factors in mind. We have limited the amount of direct aircrew input, and our observations are designed to be as unobtrusive as possible, so as to integrate smoothly with the normal flow of training events. To reduce the potential effects of instructor skepticism and variation, a researcher with high credibility among the aircrew due to previous experience serves as a participant-observer. He guides the introduction of the scenario to ensure its professional and realistic presentation, and often role-plays (along with instructors) responses and directives from other agencies that would be included if this were a “real world” mission.

Limited Access to Simulator. Due to limited available space in most WSTs, it is difficult for researchers to have direct access when making team coordination observations. Simulators are designed to match the aircraft cockpit which do not usually have additional seats for observers. The “extra” spaces that are provided in simulators usually accommodate instructors. Additionally, making over-the-shoulder observations while standing is not permitted in simulators with functioning motion systems due to safety concerns.

The T-MOT addresses this problem by focusing on those parts of the process that are reliably available, such as mission planning, briefings, and communication, during both mission preparation and execution. These are invaluable sources of data for which data may be consistently collected.

Uncontrolled Scenario Variability. Uncontrolled scenario variability is a natural characteristic of fluid training environments, where training events, training requirements, aircraft configurations, simulator capabilities, and instructors are constantly changing. To circumvent this issue for our research, an agreement was established for a "limited freeze" in the current scenario while data were collected. This agreement helps to ensure scenario stability across the observed crews, so that valid comparisons might be drawn. The previously mentioned participant-observer, and his acceptance by the instructors, also helped to remove some of the variability associated with scenario administration that can occur from instructor to instructor.

Despite these precautions, our simulator CMT scenario has, in fact, undergone several major modifications to the mission scope, concept, and definition. However, the T-MOT withstood each of these changes, requiring only minor modification to changing data formats. This is because the T-MOT approach is focused more on the specific scenario being flown, and less on particular events as they occur. The CMT scenario is not as highly scripted or controlled as in some approaches, but it is more appropriate in representing a fluid training environment where instructor turnover is high, training events change often, and mission events are unlikely to "freeze."

IMPLICATIONS

A desired goal of CMT is to produce lasting, positive behavioral change that results in improved team coordination effectiveness. Data generated from the T-MOT should further our understanding of those constituent subprocesses required for effective team coordination. The results of this investigation will produce data for CMT instructors and training developers to populate aircrew team coordination protocols and procedures with more focused, skill-oriented content. Interventions may then be developed to improve aircrew coordination subprocesses in task-specific situations where a high level of interdependency is required among members. We believe this approach will permit the T-MOT to be expanded to future distributed interactive simulation (DIS) environments where other agents provide stimulus events. Two impact areas are foreseen:

Application of the T-MOT to Other Domains. A recent study by Brannick, Prince, Prince, and Salas (1995) illustrated the Navy's similar view of relationships in team coordination processes. Consistent with the present approach, team coordination was considered to be a logical set of processes, and consistency among process raters in assigning coordination scores across mission scenarios was ably demonstrated. This consistency was taken as evidence for the quality of their rating methodology and the selection of concrete coordination behaviors for direct observation.

We similarly believe that the robustness and sensitivity embedded in the T-MOT's methodological strategy supports multi-service training or rehearsal applications. The T-MOT's flexible, real-time use of objective and subjective assessment indices may also be readily adapted to Distributed Mission Training (DMT) environments, such as those found in networked simulator mission training for joint SOF operations, AC-130U Gunship operations or multi-ship fighter operations.

Development of a Team Mission Readiness Assessment Tool (T-MRAT). The results of a study of CMT team coordination effectiveness within the confines of a WST should form an empirical foundation for development of a tool used to gauge an operational aircrew team's overall mission readiness prior to actual mission execution. The T-MRAT might be used for other purposes as well, including aircrew evaluation, crewmember evaluation, and instructional evaluation. The portable data collection methods used in this study will be specifically designed for expansion and incorporation into team effectiveness assessments during joint mission rehearsal exercises and other operational unit activities.

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