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A Pilot Study of Space/Missile Crews and Crew Resource Management

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A PILOT STUDY OF
SPACE/ MISSILE CREWS
AND
CREW RESOURCE MANAGEMENT

THESIS

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Thanks,

John E. Varljen

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Abstract

This study is a first step in formalizing CRM training as part of Undergraduate Space and Missile Training (USMT) and individual Unit Training thereby capitalizing on techniques already developed and in place for pilots. To facilitate the integration of CRM into Space/ Missile Crew Training, a tool must be created to measure CRM concepts and test their relationships with individual and group performance. We evaluated the usefulness of two modified versions of existing CRM measures for use by USMT, Unit and Guardian Challenge instructors or evaluators. Because the attitudes measure is easier to implement, this study analyzes the use of an established flight crew attitude measure, the Cockpit Management Attitudes Questionnaire (CMAQ) [Gregorich, 1990], to determine if it can be used as an indicator of overall Space Operations crew performance. This study also tests a modified version of the Air Force Mobility Command AMC Form 128, March 1995. We conducted the study in two phases. The first phase dealt only with Space Operations crews. The second phase dealt with the participants of the Guardian Challenge Competition.

Phase 1 correlations between an individual's self assessed attitude and that individual's rating by his superior show that Assertiveness with Cronbach's alphas of .61 and .66 on each questionnaire respectively, and a correlation of .204 (significant to .04, 2-tailed) is the only reliably measured attitude related to performance.

Also, phase 1 showed that graduates of Undergraduate Space and Missile Training consistently had better CRM related attitudes and were rated higher in the seven Form 128 areas than crewmen who did not attend USMT.

Phase 2 results were unexpected but extremely consistent. The higher a crew's score in Guardian Challenge, the worse the crew rated itself at the group level in CRM attitudes.

Generally, the data collected seem to indicate that beyond using Assertiveness, attitude measures are a poor indicator of whether or not an individual crewman will successfully utilize CRM. Therefore, attitude measurement is a poor performance indicator in the Space/Missile Operations environment. Stated another way, the CMAQ does not translate well into Space/Missile Operations and should not be used as an assessment tool by instructors. The Form 128 may still serve as a guide for designing a CRM evaluation sheet for Space/Missile crews, but the sheet does not seem well suited as, or easily converted into a self-assessment sheet to be used by individuals.

Overall, the Air Force needs to train young enlisted Space Operations crewmen to be more assertive with senior enlisted and officers.

A PILOT STUDY OF SPACE/ MISSILE CREWS AND

CREW RESOURCE MANAGEMENT

I. Introduction

General Issue

As technological complexity increases, critical tasks are more likely to be accomplished by teams. Teams, of specialists with different responsibilities and expertise, routinely work together to perform surgery, operate nuclear reactors, fly airplanes, and control spacecraft in orbit. In each of these professions, errors may have life or death consequences. Each profession is also characterized by advanced technology, a rapid operational pace, and complexity that exceeds individual capacities. One of the most difficult problems facing organizations that make use of complex technologies is ensuring that specialists communicate and coordinate their activities effectively with other team members. Crew Resource Management (CRM) is one approach addressing this problem. CRM has been successfully applied to several high technology professions (i.e. Airline/military pilots, merchant mariners, nuclear power plant operators), but to date no attempt has been made to adapt CRM for use by Space/ Missile Operators. This study is the first step towards introducing CRM techniques to the Space/ Missile Operations profession.

Background

Crew Resource Management began in the early 1980's as Cockpit Resource Management. NASA and several airlines began a study to determine why "good" pilots sometimes crash "good" airplanes. CRM originally focused on improving the way airline flight crews interact with their environment, their machinery and most importantly with other flight crew members. These studies developed into several training programs such as NASA's Line Oriented Flight Training Program (LOFT) [Helmreich, 1990] or the former Strategic Air Command's Mission Oriented Simulator Training (MOST) [Wiener,1993]. These programs appear successful in improving the overall performance of these flight crews in simulators [Helmreich, 1990] and in reducing errors during actual missions [Bates, 1997]. As a result, researchers have become interested in expanding the use of CRM to other crews operating complex equipment in high stakes and therefore high stress environments. For example, recent studies of CRM have examined the interactions of surgical teams within operating rooms [Helmreich, 1997].

Flying mutli-pilot aircraft shares many characteristics with Space/ Missile Operations. Both professions involve the control of high-technology, highly-automated machines that if operated improperly can lead to massive loss of life and property. Because of these consequences, each profession induces a tremendous amount of stress upon teams. Each of these systems is controlled by teams who interpret and react to possibly erroneous and conflicting information provided by remote sensors. One might mistakenly point out one key difference between pilots and space operators: unlike space operators, pilots are aboard their craft and therefore can use their senses to "feel" what the aircraft is doing. As anyone who has ever flown an aircraft in instrument conditions can tell you, the aircraft's instruments are the only reliable indicators of an aircraft's attitude and even its speed.

Also, in both professions, different team-members are provided with different pieces of a puzzle that they must communicate to the rest of their crew. For instance, it is common practice in multi-pilot aircraft for one pilot to fly the aircraft while the other pilot operates the radios. Often the flying pilot can become distracted by the flying task and does not hear instructions from ground controllers. The non-flying pilot then must communicate the controller's instructions to the flying pilot. Similarly, the Space Operator controlling a satellite is rarely the one maintaining the communications links between his control center and his remote antenna. If this link fails or is about to be moved beyond its limits of travel, the Ground System Operator is responsible for communicating this information to the Space Operator to prevent him from missing critical commands. In both cases, the quality of this communication, and assertiveness of the communicator can have drastic effects on the pilot or operator's overall Situational Awareness. In either case, a lack of Situational Awareness could lead to either a crashed airplane or a 'dead' satellite.

Currently, there are two philosophies on how to effectively measure a crew's use of CRM concepts. Both philosophies attempt to use some measure of crew or individual CRM effectiveness as a predictor of overall job performance. The first philosophy is based upon the influence of attitudes on individual behaviors as asserted by Ajzen and Fishbein's model [1975]. Attitudes are easily measured using surveys and if the Fishbein model works well in this context, the attitudes indicated by the survey results should give some indication of how well a crewman performs in terms of CRM. This is the basic philosophy espoused by Gregorich, et al [1990] in *The Structure of Cockpit Management Attitudes.* Gregorich, et al. believe that if individual attitudes about CRM are accurately measured, these measurements should accurately predict an individual pilot's behaviors and therefore his overall performance as a crewmember. The other philosophy is held by the research teams working for the U.S. Air Force's Armstrong Laboratory. They state that "the assumption that attitudes directly influence behaviors is questionable… As a result, requirements for measuring CRM skills and behaviors have emerged" [Murray, et al. 1995] Essentially, the Armstrong researchers believe in the development of a Critical Incidents Approach to measuring CRM. Summarizing, operators are asked to tell "war-stories". These stories are then distilled into basic critical behaviors that are ranked by the operators as being good or bad for CRM. These behaviors are then used by evaluators to rate crews on how well they perform CRM. Each crew's rating in CRM is then compared to their overall rating to identify which CRM behaviors promote high overall crew performance.

Of the two philosophies, the Attitudes approach by far requires the least expenditure of resources to implement since surveys used to measure attitudes exist and have the potential to be applied across a wide range of specialties. The Critical Incidents approach, on the other hand, requires a great deal of cooperation and time from the operators to be measured, just to create the basic criterion. The other disadvantage is that this method has to be recreated for each system type. In other words, the criteria setup to judge the CRM effectiveness of a bomber crew may not be applicable to a satellite operations crew.

Problem Statement

To facilitate the integration of CRM into Space/ Missile Crew Training, a tool must be created to measure CRM concepts and test their relationships with individual and group performance. Because the attitudes measure is easier to implement, this study analyzes the use of an established attitude measure, the Cockpit Management Attitudes

Questionnaire (CMAQ) [Gregorich, 1990], to determine if it can be used as an indicator of overall Space Operations crew performance. This study also tests a modified version of the Air Force Mobility Command AMC Form 128, March 1995.

Research Objectives

The overarching objective of this study is the prevention of the catastrophic loss of an American space or nuclear asset due to human error. This goal is best accomplished by assisting Air Force Space Command efforts to improve crew communication and coordination. This study is a first step in formalizing CRM training as part of Undergraduate Space and Missile Training (USMT) and individual Unit Training thereby capitalizing on techniques already developed and in place for pilots. This study evaluates the usefulness of two modified versions of existing CRM measures for use by USMT, Unit and Guardian Challenge instructors or evaluators.

II. Literature Review

Measuring Team Performance

The first step in studying crews is to determine the type of team/ crew to be studied. According to Brannick, et al. [1997], their are four basic types of teams: *Pooled/ Additive, Sequential, Reciprocal, and Intensive*. Brannick describes a *Pooled / Additive* team as the most basic form of team. *Pooled/ Additive* teams accomplish work independently, but their group effect is measured. For instance, the members of a janitorial team work independently to clean a building. Each member's efforts are performed independently of the rest of the team's. *Sequential* teams are best described by an assembly line. Each member's actions begin when the previous person is finished. Again, each member's individual tasks are independent of the previous members. *Reciprocal* teams are a permutation of *sequential* teams. *Reciprocal* teams are best described by an assembly line where the product is moved predictably back and forth between several members until the task is completed. The *Intensive* team, on the other hand has no set sequence of predictable events. Each member participates as they are needed and are what Schmitt, et al. [1991] referred to as *fate interdependent*. Generally, every task requires the participation of several team members to be accomplished. *Intensive* teams best describe the activities of Operating Room staffs [Brannick, et al., 1997] or flight crews. Like an Operating Room team, Space Operations crews are an *Intensive* team arrangement. Both types of teams require a "mutual situational awareness, where team members are able to predict, adapt, and coordinate with one another successfully, even under stressful or novel conditions" [Brannick, et al., 1997].

The second step is the identification of *critical levers* [Brannick, et al., 1997]. "Critical levers [are] the most important factors or work processes that underlie a particular team's performance" [Brannick, et al., 1997]. The *critical levers* measured by the current study are collectively known as Crew Resource Management.

The third step to studying crews is to link the *critical levers* to a measurement strategy [Brannick, et al., 1997]. Researchers need to choose their "source of information" and their "method of measurement" [Brannick et al. 1997]. "Sources may be either incumbents … or observers of some sort. The most common source …has been [the] team members themselves" [Brannick, et al., 1997]. Team members are best positioned to understand the nuances of subtle communication cues and how these interactions affect a given task.

The last step is the measurement and aggregation of team results. "Data on team … communication, and coordination… are often collected through members' ratings. These scores … are typically then aggregated …to form a single [team] score" [Brannick et al., 1997].

Introduction to CRM

"CRM includes optimizing not only the person-machine interface and the acquisition of timely, appropriate information, but also interpersonal activities including leadership, effective team formation and maintenance, problem-solving, decision making, and maintaining situational awareness" [Wiener,1993:4]. Succinctly, CRM is the use of all available resources to get the job done safely and effectively.

CRM and *Critical Levers*

CRM consists of several of what Brannick calls *critical levers*. Various authors have distilled CRM into different, but generally similar skill areas or *critical levers*. NASA has performed most of its work in seven areas: Communication, Situational Awareness, Problem solving/ Decision Making/ Judgement, Leadership/ Followership, Stress Management , Self and Peer Critiquing, and Interpersonal Skills [Orlady, et al., 1987]. Gregorich, et al. [1990] chose to focus on measuring three areas they believed were key to CRM: Communication and Coordination, Command Responsibility, and the Recognition of Stressor Effects. More recent work with MC-130P aircrews by Armstrong Laboratory divided CRM into four areas: Function Allocation (division of labor), Tactics Employment, Situation Awareness, Command/ Control/ Communications, and Time Management [Silverman, et al., 1998]. Each of these research groups focused on what can be called the core constructs of CRM: Communication and Command and what most researchers identify as crew and individual Situational Awareness. The rest of the areas measured by researchers are guided by the seven factors identified in the original NASA research.

CRM and Individual Attitudes

Two key aspects of CRM are an operator's attitude about CRM constructs and how those attitudes are related to individual and team performance. Traditional CRM research on pilots has taken a two-pronged approach patterned after Helmreich, et al's [1990] work. The first step is to measure the attitudes of the pilots using a survey such as the CMAQ. The second step is to measure their performance/behaviors during actual flight, or during intense sessions in a realistic flight simulator. The simulator is essential since this is the crucible where pilots: 1. demonstrate the application of CRM, 2. their performance can be efficiently graded by instructors, and 3. where a pilot's failure does not precipitate loss of life. The simulator is also a more accurate measuring device since the scenario can be controlled by the rater/observer and pilot performance on the same tasks can be accurately compared. Lastly, researchers correlate the attitudes with the behaviors observed in the simulators. Significant correlations give evidence that the positive CRM attitudes are associated with good performance [Helmreich, 1990].

History of the Cockpit Management Attitudes Questionnaire (CMAQ)

The questionnaire used in this study is adapted from Gregorich, Helmreich and Wilhelm's [1990] CMAQ. The CMAQ consists of 25 items. Using a factor analysis with an oblique rotation, Gregorich et al. [1990] identified three CRM factors: Communication and Coordination, Command Responsibility and the Recognition of Stressor Effects. A fourth factor known as Avoidance of Interpersonal Conflict was shown to be inconsistent among the pilots used in the survey. Also, of the 25 questions, 19 proved to be consistent identifiers of the three key factors listed above.

Air Mobility Command Crew Resource Management Assessment Sheet

The Air Mobility Command Crew Resource Management Assessment Sheet is also called the AMC Form 128 (Form 128 for short) and has been in use in its present form since March 1995. The Form 128 is used by AMC instructors as a rating sheet to grade flight crews on their use of CRM.

The Form 128 was used by this study in addition to the CMAQ since it covers many of the CRM topics omitted by the circa 1990 CMAQ. Consisting of 29 basic items, the Form 128 provides evaluators guidance in rating aircrews on Group Dynamics, Effective Communications, Assertiveness, Decision Making, Stress Management, Mishap Prevention and Overall Observations at the crew or individual level. The Form 128 is also similar to the Line/ LOS Checklist for Check Pilots developed by the University of Texas Crew Research Project [Wilhelm, 1996]. The Form 128 was chosen for this study because it is general enough to be easily adapted to Space/ Missile Operations in a military environment.

Space and Missile Crews

The size, training and make up of space operations crews vary as greatly as their spacecraft's/ weapon systems' missions. There are three basic types of Space and Missile crews: Space Operations, Space Lift, and Missile Operations

Space Operations Crews

For the most part, space operations crews remotely control satellites from ground control centers. Crew sizes range from 4 up to as many as 13 crewman depending on the system they operate. Crew shifts vary from 8 hours to 12+ hours on a rotating shift basis. Some crews work six days on with three to four days off before changing shifts while others change shifts every three days. These cycles vary greatly between different squadrons and change as often as the squadrons change commanders.

The crews are generally made up of a Crew Commander, Crew Chief, Satellite Systems Operator, Payload Specialist, Bus Specialist and a Ground System Operator. The Commander and the two specialists are usually manned by junior officers. The Crew Chief is senior enlisted while the two operators are junior enlisted men.

Space Operations crews control satellites ranging in value from $35 million to $1 billion and upload and download data and position and reposition satellites used for navigation, communication, missile detection and early warning, and weather prediction for both civilian and military users.

Space Operations Training. Space Operations officers attend Undergraduate Space and Missile Training (USMT) at Vandenberg AFB, CA with the exception of degreed Aero/ Astronautical Engineers or Electrical Engineers assigned to squadron engineering positions. The Engineers report directly to system specific schools. The enlisted men attend a Space Operations Technical School also at Vandenberg. After graduation, each group attends a system specific school and squadron training to teach them their specific duties.

Daily Space Operations. Generally the satellites fly on automatic pilot. The crews are responsible for monitoring the automated systems and for reprogramming the payload computers (uploads). Each unit uses a worldwide network of ground antennas (10m to 30m parabolic antennas) to monitor and command its satellites. These antennas are a shared resource making resource scheduling between units a difficult task. Occasionally, the satellites require orbital corrections to keep them in place over the planet. These corrections are planning intensive and if done improperly can result in the loss of a satellite. Also, solar flares and high energy storms can cause automatic systems on the satellites to fail causing the crew to scramble for ground resources to get in contact with the satellite, figure out what failed, and bypass the failed systems before the satellite runs out of electricity: effectively "dying" in space.

Space Lift Crews

Space Lift Crews launch rockets into space. These rockets cost between $30 million to $300 million excluding the cost of their payload. The crews generally consist of Air Force Launch Control, Assistant Launch Control, Bus Operations Control, Spacecraft Operations Control, Upper-Stage Operations Control and a Range Control Officer. Each of these positions is manned by an officer. Some launch systems have larger crews than others. Most systems use civilian contractors to back-up each of these positions.

Space Lift Training. Space Lift Officers undergo the same basic stages of training as Space Operations crews. However, due to the "one-shot" nature of their business, they spend the majority of their time rehearsing for launches. These rehearsals are performed on the actual launch equipment using a combination of tape playbacks and 'paper inputs'. A tape playback is basically a recording of a previous launch's telemetry that is fed back into the crews control stations. Situations (anomalies) are introduced into the scenario by 'paper inputs' handed to controllers by instructors/ evaluators. In this way, launch crews are taught how to reason their way through an emergency and practice coordination between the positions.

Daily Space Lift Operations. The majority of a Space Lift officer's time is spent planning and training for the next launch. Some units launch monthly while others launch once every six months. This study focuses on the activities of Space Lift crews during a countdown/ launch operation.

Space lift crews perform the last minute system checks necessary to launch a rocket into space. They utilize a large script sometimes called the "Countdown Manual-

Launch Activities". This script provides the exact sequence to configure the range, Launch Facility, and Space Lift vehicle for launch. Essentially, anyone who has watched NASA television, or even seen the film *Apollo 13*, has a basic understanding of how a Space Lift crew works.

As a rule, launch vehicles can not be turned off once they have ignited. This fact when added to the counteracting pressure to launch on schedule, places tremendous stress and responsibility on Space Lift crews to perform perfectly, every time.

Missile Operations Crews

Missile Operations Crews consist of a Crew Commander and a Deputy Commander. They are both officers and generally work 24 hour shifts in their underground Launch Control Centers (LCC). However, their shifts actually begin long before they arrive at the LCC.

Daily Missile Operations. First they report to their base to be briefed by their unit. Then they travel as much as 100 miles to their LCC. Then their 24 hour shift officially begins. Their daily responsibilities include managing message traffic from their command post and overseeing security and maintenance of their flight of intercontinental ballistic missiles (ICBMs). Should the final order come, missile crews are charged with programming targets into the missiles and launching multiple nuclear warheads.

Missile Operations Training. Missile crews go through the same basic training sequence as space operations crews. Missile crews first attend USMT. Then they attend a Combat Crew Training squadron at Vandenberg for system-specific training. Lastly, they attend unit specific training.

Guardian Challenge

Guardian Challenge is a yearly competition for Air Force Space/ Missile crews. Every operations squadron in Air Force Space Command puts forth one crew to compete against other units in their Wing. The finalists from each Wing compete in late April or early May every year. Units compete in one of three categories: Space Operations, Space Lift or Missile Operations.

Space Operations and Space Lift crews compete at their home base and are rated by their unit standardization and evaluation sections (DOV). The use of unit raters is unavoidable due to the specific training required to operate each system. However, the raters are considered 'trusted agents' and risk serious censure if they were to provide an unrealistic scenario to their crews. Also, the crews usually compete on actual equipment since Space Operators have no effective simulation capability.

Unlike Space and Space Lift Crews, Missile Crews actually travel to Vandenberg AFB and compete in very realistic LCC simulators. They are rated by Guardian Challenge evaluators. Therefore, of the three types of crews competing at Guardian Challenge, Missile crews have the most standardized and realistic scenarios.

However, all scenarios created by the various evaluation teams undergo central review to ensure they are somewhat standardized for difficulty.

Crew and Individual Performance Measurement

The most difficult aspect of any team oriented study is deciding how to measure the individual contributions of crewmembers that improve overall team performance.

CRM researchers appear to be split on whether CRM should be measured at the individual level as proposed by Gregorich, et al. [1990] or at the team level as proposed by Murray, et al. [1995]. The key to this debate is driven by how a researcher chooses to measure performance. In order to capitalize upon the strengths of either approach, we conducted our study in two Phases. The first Phase addresses the individual's contribution to CRM. To do this we paired the individual responses of crewman to their individual performance in CRM as rated by their direct superiors. Since their superiors interact daily with these individuals in the crew environment, we believe the raters provided us with a more accurate overall assessment than could be devised by a team of researchers.

To address that part of the CRM community that believes in measuring teams as a whole, we capitalized on the Guardian Challenge competition. In a "situation of ... task interdependency" such as a team competition, research into the "contributions of individuals would be inappropriate" [Schmitt, et al., 1991]. By utilizing the same measuring instrument as Phase 1, and aggregating the responses into a team response [Brannick, et al., 1997], we believe we were able to estimate the overall CRM attitude of a given crew. This aggregate could then be compared against the crews overall competition rating to determine which attitudes seemed to actually improve crew performance.

III. Phase 1: Space Operations Crews Methodology and Results

We conducted the study in two phases. The first phase dealt only with Space Operations crews. The second phase dealt with the participants of the Guardian Challenge Competition.

Phase 1 Experimental Goals

The basic goal of Phase 1 was to identify those attitudes held by Space Operators that correspond to their overall effectiveness/ performance as judged by their superiors/ raters.

Phase 1 Experimental Design

The experiment consisted of surveying space operators to measure individual attitudes and perceptions about CRM related constructs and comparing these with individual ratings provided by each operators superior to assess individual performance. The results of these two surveys were then compared to identify if any of the CRM attitudes or perceptions measured by the flying community are useful for predicting performance in the space community.

Phase 1 Experimental Instruments

Space Operations Crew Resource Management Questionnaire

The first step in the experiment was to measure each crewman's attitude about different aspects of CRM in the same way as Gregorich, et al. [1990] did. To do this we developed the Space Operations Crew Resource Management Questionnaire (SOCRMQ) which can be found in Appendix A. It consisted of 75 items presented in a 5 point Likert scale format and divided into three parts: background, modified CMAQ, modified Form

128. The 11 background items gathered general information about an individuals rank, time in service, time in position and education.

The next 25 items were adapted from the 1990 CMAQ and were slightly modified to be applicable to the Space Operations environment. For example, terms such as Captain or flight deck were replaced by Flight Commander (now Crew Commander) and Operations Floor respectively. Great care was taken to preserve the concept of each question while providing a simple translation between flight terminology and space terminology. Two items were added to the end of the CMAQ addressing checklist discipline and the pre-satellite-contact (pre-pass) briefing.

The AMC Form 128 underwent a more dramatic change. The Form 128 is designed as a rating sheet. This format was restructured from a 7 subject area, 28 item rating sheet, into a 7 subject area, 34 item questionnaire. The increase in the number of items is due to the rating sheet's use of multiple questions in many of its rating items. These questions were broken out into separate items. Again, great care was taken to minimize changes to the items. For the most part, the items were transitioned verbatim making translation changes where needed (i.e. Captain to Commander). The seven subject areas were Group Dynamics, Effective Communications, Assertiveness, Decision Making, Stress Management, Mishap Prevention and Overall Observations. Each of these areas easily transferred into the Space Operations environment except Mishap Prevention.

On the Form 128, Mishap Prevention is a combination of Situational Awareness and the management of aircraft automated systems. Generally, pilots are taught to disengage automated systems if the system produces inputs contradictory to the pilot's wishes. Satellites can not be hand flown so it is impossible to disconnect these types of systems. These items were modified slightly from their original wording in an attempt to make them more compatible with satellite operation.

Lastly, there are five questions pertaining to spending off-duty time with fellow crewmembers, original certification level, most recent re-certification level and whether or not the operator had ever caused a real-world critical error.

The Form 128 portion of the SOCRMQ (ratee) measures individual perceptions about the performance of that individual's crew with respect to CRM.

Space Operations Rater's Crew Resource Management Questionnaire

The second step in Phase 1 was to document how each supervisor/rater rated the effectiveness of each crewman in CRM terms. To do this, we developed the Space Operations Rater's Crew Resource Management Questionnaire (SORCRMQ) which can be found in Appendix B. The Rater's Questionnaire is drawn directly from the AMC Form 128. Several questions pertaining to the use of automated systems were omitted for the reasons stated above. Again, the form was modified to use a Likert 5 point scale and was translated to space operations terminology.

Phase 1 Experiment

The SOCRMQ (ratee) were distributed to every Space Operator currently assigned to a crew in the chosen Group at a chosen Air Force Base. Due to Air Force Regulations, participation in this study was strictly voluntary and if desired, anonymous.

Simultaneously, the SORCRMQ (rater) was distributed to every Crew Commander and the squadron Director of Operations (DO). The Crew Commanders rated every person on their crew and each squadron's DO rated the Crew Commanders. The surveys were individually sealed by each participant and returned.

Upon receipt of the data, we matched ratings to individuals using names (if provided) or Squadron, Flight, Position and Rank. The latter method proving very reliable when individuals chose to withhold their names. We then loaded the data into the SPSS version 8.0 statistical program for analysis.

Initially, we ran a reliability analysis on the CMAQ portion of the SOCRMQ survey using the item groupings identified in Gregorich, et al's *The Structure of Cockpit Management Attitudes* [1990]. The reliabilities obtained were deemed too low with Cronbach Alphas of .51 for Communication and Coordination, .26 for Command Responsibility, and .28 for Recognition of Stressor Effects. Clearly, a different construct was at work. We ran a Factor Analysis using Principal Axis Factoring and rotated using Oblimin with Kaiser Normalization similar to the method used by Gregorich, et al. [1990] when they originally developed the CMAQ. This method created three new factors: Coordination & Communication ($\alpha = .58$), Monitoring ($\alpha = .47$) and Briefings ($\alpha = .56$). These reliabilities are in line with Gregorich's work.

We then broke down the AMC Form 128 portion of the SOCRMQ into the seven Form 128 areas: Group Dynamics, Communication, Assertiveness, Decision Making, Stress Management, Mishap Prevention, and an Overall rating. The reliabilities for these areas were decent with the exception of Communication. They were $\alpha = .72, .49, .66, .63, .78, .76$ and $.71$ respectively. Communication was dropped from any further analysis due to its low reliability of $\alpha = .49$.

The SORCRMQ was analyzed in a similar fashion. Again we performed a Factor Analysis and obtained three new Factors. The first factor dealt with how well a crewman actively works to avoid overloading himself. This factor became known as Overload and had a reliability of $\alpha = .88$. The second factor dealt with how well a crewman communicated his workload to other crewmen. This factor became known as Workload and had a reliability of $\alpha = .81$. The last factor was Communication and it had a reliability of $\alpha = .73$. Like the SOCRMQ, we divided the SORCRMQ into the seven areas defined by the From 128. These areas and corresponding reliabilities were Group Dynamics ($\alpha = .61$), Communication ($\alpha = .62$), Assertiveness ($\alpha = .61$), Decision Making ($\alpha = .52$), Stress Management ($\alpha = .83$), Mishap Prevention ($\alpha = .58$) and an Overall rating ($\alpha = .74$).

Due to the great variability in how Crew Commanders rated individuals, every rating area was normalized to every rater using a standard Z distribution formula arbitrarily centered on 50 and multiplying the z-score by 10 for readability:

$$X := 50 + 10 \cdot \frac{(x - \mu)}{\sigma}$$

Where x is the raw sum of every item per area, μ is the average of this score for a given rater and σ is the standard deviation of the raw score for any given rater. Therefore X is the normalized score. The standardized ratings are all prefaced with an 's' in the results section to delineate them from raw scores. The basic assumption of this application of standardization is that every crew is equally blessed with good performers and bad performers. This is a good assumption since squadrons can not pick and choose who is assigned to them via the Air Force Personnel Center (AFPC).

Phase 1 Results

In all, 20 crews were surveyed with 132 out of an approximate population of 160 crewmen or 82.5% responding. In addition 25 raters were surveyed (20 Crew Commanders + 5 DO's) with 20 or 80% responding. Between these two groups, we received attitude measures and performance ratings for 102 or 64% of the crewmen. Since some crewmen did not answer every question, some items had a lower response rate with the lowest rate being 59%. Thus, since at minimum 59% of the Space Operations population responded, these results provide a strong indication of which individual CRM attitudes affect performance. Also, due to the high response rate, we chose not to perform a Bonferroni analysis.

A Pearson Correlation of the seven Form 128 divisions between the SOCRMQ and the standardized SORCRMQ sans Communication yielded two significant correlations. First, Assertiveness had a .204 correlation (significant to .04, 2-tailed) between the two surveys. Second, the Mishap Prevention attitude (SOCRMQ) and Stress Management performance (SORCRMQ) had a correlation of .173 (significant to .08, 2-tailed).

Table 1. Phase 1 Results

		SGRPDYN	SCOMEFF	SASSERT	SDECMAK	SSTRESS	SMISHAP	SOVERALL
COORD	Pearson Correlation	.071	.044	.028	-.003	.001	.049	.006
	Sig. (2-tailed)	.473	.657	.782	.973	.993	.622	.954
	N	103	103	103	103	103	103	98
MONITOR	Pearson Correlation	-.048	.004	.000	.040	.002	.096	-.029
	Sig. (2-tailed)	.630	.969	.998	.687	.985	.334	.778
	N	103	103	103	103	103	103	98
BRIEF	Pearson Correlation	-.135	-.057	.056	-.134	-.070	-.074	-.084
	Sig. (2-tailed)	.175	.566	.573	.180	.482	.459	.415
	N	102	102	102	102	102	102	97
GRPDYN	Pearson Correlation	.135	.103	.119	.062	.119	.027	-.002
	Sig. (2-tailed)	.176	.301	.233	.536	.234	.788	.982
	N	102	102	102	102	102	102	97
ASSERT	Pearson Correlation	.093	.100	.204	.007	.023	.145	.064
	Sig. (2-tailed)	.355	.322	.041	.944	.823	.149	.535
	N	101	101	101	101	101	101	96
DECMAK	Pearson Correlation	.103	.046	.126	.015	.056	.025	.001
	Sig. (2-tailed)	.301	.649	.206	.882	.578	.806	.993
	N	102	102	102	102	102	102	97
STRESMGT	Pearson Correlation	.111	.066	.129	.017	.062	.042	.111
	Sig. (2-tailed)	.266	.512	.195	.862	.534	.675	.280
	N	102	102	102	102	102	102	97
MISHAP	Pearson Correlation	.010	-.028	-.032	-.031	.173	-.005	.038
	Sig. (2-tailed)	.924	.786	.756	.761	.086	.964	.713
	N	99	99	99	99	99	99	95
OVERALL	Pearson Correlation	.058	-.034	.015	-.078	-.001	.005	-.048
	Sig. (2-tailed)	.562	.737	.882	.441	.989	.962	.641
	N	101	101	101	101	101	101	96
OFFDUTY	Pearson Correlation	.114	.058	.074	.001	.078	-.029	-.035
	Sig. (2-tailed)	.260	.566	.462	.993	.442	.773	.736
	N	100	100	100	100	100	100	95

Correlations between the three performance factors derived from a factor analysis of the SORCRMQ and the seven Form 128 areas of the SOCRMQ were not significant.

Correlations between the three attitude factors derived from factor analysis of the SOCRMQ and the seven Form 128 areas of the SORCMQ were also not significant.

We also investigated the correlation between the backgrounds of each of the crewmen and their performance ratings. This analysis yielded several fascinating points. First and foremost, graduates of Undergraduate Space and Missile Training consistently had better CRM related attitudes and were rated higher in the seven Form 128 areas than crewmen who did not attend USMT.

Table 2. USMT Attendance and CRM Ratings

		GRPDYN	ASSERT	DECMAK	STRESMGT	MISHAP	OVERALL	OFFDUTY
USMT	Pearson Correlation	.285	.308	.245	.151	.168	.240	.045
	Sig. (2-tailed)	.002	.001	.008	.110	.079	.010	.637
	N	113	113	114	114	110	113	112

For those crewmen who did not attend USMT (this includes all the enlisted crewmen), time in service or rank greatly affected their ratings in all of the Form 128 areas except the overall rating. Correlations between education and ratings in the Form 128 areas confirm the findings with the USMT and the Time in Service / Rank variables.

Phase 1 Discussion

The Mishap Prevention attitude (SOCRMQ) and Stress Management performance (SORCRMQ) had a correlation of .173 (significant to .086, 2-tailed). Stress Management is a key element in Situational Awareness which in turn is a key element in Mishap Prevention. Also, Stress Management is also a function of Workload which is clearly a function of whether or not Automated Systems (part of Mishap Prevention) are understood and being used properly. However, as can be seen by the amount of narration necessary to describe these relationships, this is not an easily defined construct that may not prove reliable in practice.

Considering graduates of USMT are all officers, and officers are for the most part better educated than the enlisted force, the USMT variable may not mean that USMT as a program does a better job of training CRM concepts than the all enlisted Technical School does. Indeed, the only real conclusion is that officers seem to receive better team oriented training than enlisted members do. This statement ties together the correlations seen between USMT and the Form 128 areas and the correlations between Education and the Form 128 areas.

The longer enlisted men spend in the military and the higher their rank, the better they are rated in the Form 128 areas. This seems to indicate that enlisted crewmen eventually learn how to operate in a team as they spend more time in the service. Interestingly enough, time in space operations and time in position do not affect a crewman's (officer or enlisted) performance in the Form 128 areas.

Correlations between the SOCRMQ (attitude) and the SORCRMQ (performance) show that Assertiveness with Cronbach's alphas of .61 and .66 on each questionnaire respectively, and a correlation of .204 (significant to .04, 2-tailed) is the only reliably measured attitude related to performance.

IV. Phase 2: Guardian Challenge Crews Methodology and Results

Phase 2 Experimental Goals

The goal of Phase 2 was to identify those attitudes and perceptions held by Guardian Challenge crews that correspond to their overall effectiveness/performance as judged by Guardian Challenge evaluators. Again Phase 2 is designed to capture group-level effects.

Phase 2 Experimental Design

We used a survey to measure the CRM related attitudes of Guardian Challenge crews, aggregated individual self-ratings into a team rating, and compared these attitude ratings with their scores from the competition. Since the Guardian Challenge competition is clearly defined as *fate* or *task interdependent*, the aggregated rating provided an "effectiveness measure… taken at the group level" as recommended by Schmitt, et al. [1991].

Phase 2 Experimental Instruments

The Space Operations Crew Resource Management Questionnaire was translated for use by Space Lift and Missile crews. Primarily, changes were made to the 11 background questions to account for the different unit and crew position designations. Changes to the actual attitude survey items were cosmetic (Flight Commander to AFLC or Satellite to Launch Vehicle). Some questions did not translate well between the three operations fields so no attempt was made to modify them and crews were instructed to ignore any question that they did not believe applied to them. For instance, item 24 states that "Even when fatigued, I perform effectively during spacecraft maneuvers." This question clearly does not translate to the Missile crews since if their spacecraft were maneuvering, very few of us would be left alive to interpret the results of this study. We opted to leave the questions in place so as not to bias the results between the surveys by risking the insertion of new concepts. The two new surveys were called the Space Operation Crew Resource Management Questionnaire (Launch), and the Missile Operations Crew Resource Management Questionnaire.

Phase 2 Experiment

The SOCRMQ was mailed or faxed to each of the Guardian Challenge crews. Of the nine participating Groups only one Group chose not to participate in the study. Of the approximately 50 participating crewmen, nine crewmen chose not to respond including the entire non-participating Group. Again, this yields a respectable 82% response rate. These data were then entered into SPSS version 8.0 with the addition of each crew's 2041 Score (competition score) available on the internet at:

www.vafb.af/mil/gc98/scores/98scores/98spce.html

The scores are presented as both total scores or a percentage of the total possible points. We used the percentage score since this number can be treated as a normalized score between the Space Operations, Space Lift and Missile Operations crews.

We created parameters from the Form 128 areas (Group Dynamics, Communication, Assertiveness, Decision Making, Stress Management, Mishap Prevention, and Overall), three parameters from the Factor Analysis of the SOCRMQ from Phase 1 (Briefing, Coordination and Monitoring) and also calculated the Offduty parameter. These parameters from each crewman were aggregated into team ratings for each area [Brannick, et al., 1997:212] and then correlated against each team's competition (2041) score.

Phase 2 Results

The results were unexpected but extremely consistent. The higher a crew's score in Guardian Challenge, the worse the crew rated itself in CRM attitudes. To ensure there was no clerical error, the raw data from the highest scoring crew and the lowest scoring crew were compared by hand and they confirm the findings in Table 3.

Table 3. Phase 2 Results

		COORD	MONITOR	BRIEF	GRPDYN	COMM	ASSERT	DECMAK	STRESS	MISHAP	OVERALL	OFFDUTY
SCORE	Pearson Correlation	-.439	-.708	-.811	-.829	-.846	-.620	-.610	-.896	-.544	-.695	-.603
	Sig. (2-tailed)	.102	.016	.007	.005	.002	.037	.040	.001	.103	.028	.043
	N	10	9	8	8	9	9	9	9	7	8	9

As an additional check of the results, the GC data was further divided into Space, Launch and Missile operations. Clearly, statistical significance was eliminated due to the reduced sample size. However, Space Crews and Missile Crews both still showed the negative correlations while Launch Crews showed no substantial correlations.

Phase 2 Discussion

The consistent negative correlation should not be interpreted as meaning the worse a crew is at CRM the better it does in competition. Rather, we believe the results indicate that a crew that can accurately identify its own weaknesses in CRM and attempts to compensate for these weaknesses will perform well in competition. In other words, for CRM to properly work, crews must understand and hold themselves to a higher standard in each of the measured CRM areas. Ultimately, the best crews never believe they perform CRM well and continuously strive to do better. On the other hand, crews that do not understand CRM tend to rate themselves high and perform low.

Another possible explanation for the Phase 2 outcome is simply that the Guardian Challenge competition is an unrealistic environment for measuring CRM performance. Ultimately, we do not believe this to be true since the Guardian Challenge (GC) scenarios are generated by each participating unit's Standardization and Evaluation (DOV) section and are submitted for a common GC committee approval. Also, GC is the only environment that allows for a substantial amount of crews to be tested at any one time. One possible future improvement may be to use the results of the Guardian Challenge preliminary competitions. This would nearly triple the number of participating crews.

V. Conclusion

Implications for Researchers

This pilot study offers a first look at the application of CRM to the Space/Missile Operations arena. Generally, the data collected seem to indicate that beyond using Assertiveness, attitude measures are a poor indicator of whether or not an individual crewman will successfully utilize CRM. Therefore, attitude measurement is a poor performance indicator in the Space/Missile Operations environment. Stated another way, the CMAQ does not translate well into Space/Missile Operations and should not be used as an assessment tool by instructors. The Form 128 may still serve as a guide for designing a CRM evaluation sheet for Space/Missile crews, but the sheet does not seem well suited as, or easily converted into a self-assessment sheet to be used by individuals.

Implications for Space Operations Training

The revelations about the differences between officer and enlisted member Assertiveness are interesting in themselves. The Air Force needs to do a better job of training young enlisted men to serve on crews with senior enlisted and officers. In each of the units surveyed for Phase 1, the junior enlisted crewmen are the ones who actually contact and command the satellites. Officers and senior enlisted crewmen serve in an 'advisory role' to the junior enlisted. It would be very unfortunate and extremely expensive to loose a satellite because a junior enlisted crewman (or any crewman for that matter) was afraid to contradict a senior officer who misunderstands a situation and requests an improper command be sent to a satellite.

Recommended Further Study

Beyond expanding this study into the Guardian Challenge preliminary competition mentioned earlier, another interesting investigation would be to validate the AMC Form 128, or its recent successor, AF Form 4031 (CRM Skills Training/ Evaluation Form) as a rating sheet for Space/Missile Operations. This could be accomplished by exposing every crew in each squadron to a Guardian Challenge like scenario as part of monthly recurring or quarterly recurring training. At the same time, independent evaluators could then rate each crew's CRM using one of the aforementioned sheets. The rank order of each crew's performance during the evaluation could then be compared against their CRM ratings.

Another outcome of this study is further confirmation of Murray, Weeks and Siem's [1995] and later Silverman, Spiker, Tourville and Nullmeyer's [1998] Critical Incidents approach to measuring CRM performance. The key to each of these studies' success is the utilization of subject matter experts to create a construct of favorable mission/system specific CRM behaviors. Assessment sheets are then created using these core behaviors. These assessment sheets are used by evaluators during simulator/operational scenarios to create a realistic model of good, system specific CRM behaviors. This method is proving to be far more reliable than attitude measures as a predictor of good performance.

APPENDIX A:

Space Operations Crew Resource Management Questionnaire

SPACE OPERATIONS
CREW RESOURCE MANAGEMENT
QUESTIONNAIRE

Department of the Air Force
Air University (AETC)
Air Force Institute of Technology

Information
About this Research Study

Thank you for agreeing to participate in this research study. Your work experience can make an important contribution to the goals of this study.

Description of the study: The goal of this study is to establish a baseline for Crew Resource Management (CRM) attitudes and behaviors in Space Operations. To accomplish this, we have adapted three CRM Attitude and Behavior surveys used by Air Mobility Command and NASA to measure the performance of flight crews.

How your responses will be used: The information you provide will be correlated against performance measures provided to us by your raters in strict confidentiality.

Confidentiality of your responses: This information is being collected for research purposes only. NO ONE in your unit, base, or MAJCOM will EVER see your individual responses.

PRIVACY ACT STATEMENT

In accordance with AFR 12-35, paragraph 8, the following information is provided as required by the Privacy Act of 1974.
Authority: 10 U.S.C. 8012, Secretary of the Air Force; powers and duties; delegation by; implemented by AFR 30-23, Air Force Personnel Survey Program.

Purpose: To improve the quality of training given to Space Operations crews.

Routine Use: Future 50th SPW instructors can draw upon training techniques proven to improve effective cockpit crew operations to better train space operations crews. Data will be grouped prior to analysis. No analysis of individual responses will be conducted and ONLY members of the research team will be permitted to access the raw data. Reports summarizing trends in crews may be published. *No crew or squadron will be identified to anyone outside of the research team.*

Participation: Participation is VOLUNTARY. No adverse action will be taken against any member who does not participate in this survey or who does not complete any part of this survey.

Contact Information

If you have any questions, please feel free to contact me:

Capt John Varljen
AFIT/ LAL
2950 P Street
Wright-Patterson AFB, OH 45433-7765

email: jvarljen@afit.af.mil
comm: (937) 879 1018

Please write in your name and fill in the appropriate bubbles on the computer answer sheet. Then answer the following questions, filling in the appropriate bubbles on the answer sheet.

1. Current Squadron
    1. 1 SOPS
    2. 2 SOPS
    3. 3 SOPS
    4. 4 SOPS
    5. 5 SOPS

2. Current Crew
    1. Alpha
    2. Bravo
    3. Charlie
    4. Delta
    5. Echo

3. Current Position (note: if you are a DCMDR, mark 1)
    1. FCMDR/ Crew Chief
    2. SSO
    3. Payload Specialist
    4. Bus Specialist
    5. GSO/GC

4. Time in the military
    1. 1-2 yrs
    2. 3-4 yrs
    3. 5-8 yrs
    4. 9-12 yrs
    5. over 12 yrs

5. Time in Space Operations
    1. 0-6 months
    2. 7-12 months
    3. 13-18 months
    4. 19-24 months
    5. 25+ months

6. Time in Current Position
    1. 0-6 months
    2. 7-12 months
    3. 13-18 months
    4. 19-24 months
    5. 25+ months

7. Rank (If you are an officer, please skip to the next question).
    1. E1-E3
    2. E4
    3. E5
    4. E6
    5. E7-E9

8. Rank (Please skip if enlisted)
    1. O1
    2. O2
    3. O3
    4. O4
    5. O5

9. Did you attend (please respond to most recent of the following)
    1. USMT
    2. UMT
    3. UST
    4. 277x0 Tech School
    5. Other

10. Gender
    1. Male
    2. Female

11. Education
    1. High School
    2. Some College
    3. Bachelor's Degree
    4. Master's Degree
    5. Doctorate

Please use this scale to answer the questions in this section. Record your responses on the computer answer sheet.

Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1	2	3	4	5

12. Crew members should avoid disagreeing with others because conflicts create tension and reduce crew effectiveness.

13. Crew members should feel obligated to mention their own psychological stress or physical problems to other crew personnel before or during a shift.

14. It is important to avoid negative comments about the procedures and techniques of other crew members.

15. Flight Commanders should not dictate operations procedures to their crews.

16. Casual, social conversation on the operations floor during periods of low workload can improve crew coordination.

17. Each crew member should monitor other crew members for signs of stress or fatigue and should discuss the situation with the crew member.

18. Good communications and crew coordination are as important as technical proficiency for space vehicle safety.

19. Operators should be aware of and sensitive to the personal problems of other crew members.

20. The Flight Commander should take over a satellite pass in emergency or non-standard situations.

21. The SOO/SSO/PC (pass controller) should verbalize plans for procedures or maneuvers and should be sure that the information is understood and acknowledged by the other crew members.

22. Crew members should not question the decisions of the Flight Commander except when they threaten space vehicle safety.

23. Crew members should alert others to their actual or potential work overloads.

24. Even when fatigued, I perform effectively during critical spacecraft maneuvers.

Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1	2	3	4	5

25. Flight Commanders should encourage crew members to question procedures during normal operations and emergencies.

26. There are no circumstances when the Crew Chief (except FCMDR's total incapacitation) should take command of the flight.

27. A debriefing and critique of procedures and decisions after each shift is an important part of developing and maintaining effective crew coordination.

28. My performance is not adversely affected by working with an inexperienced or less capable crew member.

29. Overall, successful operations floor management is primarily a function of the Flight Commander's operations proficiency.

30. Training is one of the Flight Commander's most important responsibilities.

31. Because individuals function less effectively under high stress, good crew coordination is more important in emergency and abnormal situations.

32. The crew changeover briefing is important for vehicle safety and for effective crew management.

33. Effective crew coordination requires crew members to take into account the personalities of other crew members.

34. The Flight Commanders responsibilities include the coordination of module activities (i.e. Repairs to Mod XX).

35. A truly professional crew member can leave personal problems behind when on duty.

36. My decision making ability is as good in emergencies as in routine operations.

37. The pre-pass briefing is important for vehicle safety and for effective crew management.

38. I use an operations procedure (checklist) for every operation, no matter how routine.

Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1	2	3	4	5

The following questions concern your crew as a whole team.

39. My crew establishes guidelines for coordination between all crew positions. The entire crew participates in briefings as a team, when appropriate.

40. Crew members establish and maintain a team concept and an environment open for communications (i.e., crew members listen with patience, do not interrupt or "talk over," do not rush through the briefings, and make eye contact when appropriate).

41. The crew ensures the operational situation matches the group climate (i.e., presence or lack of social conversation).

42. The crew ensures non-operational factors do not interfere with necessary tasks.

43. Crew briefings are operationally thorough, interesting and address crew coordination while planning for potential problems. The crew sets expectations on how to handle deviations form normal operations.

44. Crew members accept performance feedback objectively and non-defensively.

45. Crew members openly ask questions regarding crew actions and decisions.

46. Crew members "speak up" and state their information with appropriate persistence until there is some clear resolution and decision.

47. When conflicts between crew members arise, the crew's focus remains on the problem or situation at hand.

48. Crew members listen actively to ideas and opinions and admit mistakes when wrong.

49. The Flight Commander coordinates operations floor activities to establish a proper balance between command authority and crew member participation, while acting decisively when the situation requires.

50. Crew members clearly state operational decisions to other crew members and receive acknowledgement.

51. The "crew" includes all crew members and others as appropriate to conduct operations.

Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1	2	3	4	5

52. The crew prepares for expected and/or contingency situations (i.e., adverse weather at remote sites or preparing for orbital maneuvers).

53. Crew members clearly communicate workload and task distribution and receive acknowledgement from other crew members.

54. The crew allots adequate time to complete tasks.

55. The crew prioritizes secondary operational tasks (i.e., dealing with tour needs, command post communications,...) to retain sufficient resources to deal effectively with primary flight duties.

56. During long duty periods, crew members are proactive in remaining alert, and plan and use fatigue countermeasures.

57. The crew's actions do not create self-imposed stress and additional workload (i.e., a late satellite contact due to lack of situational awareness/ planning).

58. Crew members recognize and report when their duties or the duties they observe others performing cause an overload.

59. The crew remains calm under stress.

60. Crew members check-in with each other during times of high and low workload to maintain situational awareness and to remain alert.

61. The crew establishes guidelines for the use of automated systems (i.e., when they will disable systems and when they must verbalize and acknowledge programming actions).

62. When programming demands could reduce situational awareness and create work overloads, the crew reduces the level of automation or disengages automated systems (i.e., manual control of space vehicle or disabling automatic ground scheduling software).

63. The crew outlines the duties and responsibilities of crew members with regard to automated systems (i.e., attitude control computer entries/uploads and cross checking those entries/ uploads).

Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1	2	3	4	5

64. Crew members periodically review and verify the status of space vehicle automated systems (this does not include post contact analysis by staff).

65. Crew members verbalize and acknowledge entries and changes to automated system parameters.

66. The crew plans for sufficient time for programming of spacecraft attitude control/ payload computers prior to maneuvers/ user operations.

67. The crew consistently assess the complexity of the operating environment (remote site weather, communications, maintenance outages, solar flares, eclipses, etc.)

68. The crew assess the severity of abnormal ground or space systems operation and other system events during operations.

69. Overall, the crew displays technical proficiency.

70. Overall, the crew effectively performs the mission.

71. I enjoy spending off-duty time with my crew.

72. I often spend off-duty time with my crew.

For the following questions, please fill in the appropriate bubbles on the computer answer sheet.

73. Results of first attempt to qualify for current position?
    1. Unsatisfactory
    2. Qualified
    3. Highly Qualified

74. Results of most recent recertification?
    1. Unsatisfactory
    2. Qualified
    3. Highly Qualified
    4. Too new for recertification

75. Have you ever received a real-world critical error?
    1. Yes
    2. No

APPENDIX B:

Space Operations Rater's Crew Resource Management Questionnaire

SPACE OPERATIONS
RATER'S
CREW RESOURCE MANAGEMENT
QUESTIONNAIRE

Department of the Air Force
Air University (AETC)
Air Force Institute of Technology

Information
About this Research Study

Thank you for agreeing to participate in this research study. Your work experience can make an important contribution to the goals of this study.

Description of the study: The goal of this study is to establish a baseline for Crew Resource Management (CRM) attitudes and behaviors in Space Operations. To accomplish this, we have adapted three CRM Attitude and Behavior surveys used by Air Mobility Command and NASA to measure the performance of flight crews.

How your responses will be used: The information you provide will be correlated against crewmember measures provided to us by your subordinates in strict confidentiality.

Confidentiality of your responses: This information is being collected for research purposes only. NO ONE in your unit, base, or MAJCOM will EVER see your individual responses.

PRIVACY ACT STATEMENT

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Authority: 10 U.S.C. 8012, Secretary of the Air Force; powers and duties; delegation by; implemented by AFR 30-23, Air Force Personnel Survey Program.

Purpose: To improve the quality of training given to Space Operations crews.

Routine Use: Future 50th SPW instructors can draw upon training techniques proven to improve effective cockpit crew operations to better train space operations crews. Data will be grouped prior to analysis. No analysis of individual responses will be conducted and ONLY members of the research team will be permitted to access the raw data. Reports summarizing trends in crews may be published. *No crew or squadron will be identified to anyone outside of the research team.*

Participation: Participation is VOLUNTARY. No adverse action will be taken against any member who does not participate in this survey or who does not complete any part of this survey.

Contact Information

If you have any questions, please feel free to contact me:

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comm: (937) 879 1018

Please circle the appropriate answer for each question. You DO NOT need to fill out a computer answer sheet for this survey.

1. Current Squadron
   1. 1 SOPS 2. 2 SOPS 3. 3 SOPS 4. 4 SOPS 5. 5 SOPS

2. Current Position
   1. DO 2. FCMDR

3. Current Crew (Do not answer if you are the squadron DO or DOO).
   1. Alpha 2. Bravo 3. Charlie 4. Delta 5. Echo

4. Time in Space Operations
   1. 0-6 months 2. 6-12 months 3. 12-18 months 4. 18-24 months 5. 24+ months

5. Time in Current Position
   1. 0-6 months 2. 6-12 months 3. 12-18 months 4. 18-24 months 5. 24+ months

6. Rank
   1.O1 2. O2 3. O3 4. O4 5. O5

7. Did you attend (please respond to most recent of the following)
   1. USMT 2. UMT 3. UST 4. 277x0 Tech School 5. Other

TEAM BUILDING

Crewman actively participates in crew briefings when appropriate.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 1

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

Crewman listens with patience, does not interrupt or "talk over", does not rush through briefings, and make eye contact when appropriate.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 2

↓

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

OPERATIONAL SITUATION

Crewman ensures social conversation does not interfere with operational tasks.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 3

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

CREW BRIEFINGS

Crewman's briefings are operationally thorough, interesting, and address crew coordination while planning for problems.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 4

↓

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

PERFORMANCE FEEDBACK

Crewman provides positive and negative feedback to fellow crewmen at appropriate times.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 5

↓

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

FEEDBACK ACCEPTANCE

Crewman accepts performance feedback objectively and non-defensively.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 6

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

EFFECTIVE INQUIRY

Crewman openly asks questions regarding crew actions and decisions.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 7

↓

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

ASSERTIVENESS

Crewman speaks-up and states his information with appropriate persistence until there is some clear resolution and decision.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 8

↓

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

CONFLICT RESOLUTION

When conflicts arise, the crewman's focus remains on the problem or situation at hand, listens actively to ideas and opinions, and admits mistakes when wrong.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 9

↓

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

LEADERSHIP

Please answer the following question only if the ratee is a flight commander. Otherwise, skip to the next question.

The flight commander coordinates operations to establish a proper balance between command authority and crew member participation; while acting decisively when the situation requires.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 10

↓

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

CREW PARTICIPATION

The Crewman clearly states operational decisions to other crew members and **receives acknowledgement.**

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 11

↓

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

CREW PREPARATION

The crewman properly prepares for expected and/or contingency situations.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 12

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

WORKLOAD MANAGEMENT

The crewman clearly communicates his current workload level to other crewmembers. He allots adequate time to complete his tasks.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 13

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

TASK PRIORITIZATION

The crewman prioritizes secondary operational tasks to retain sufficient resources to deal effectively with primary operational duties.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 14

↓

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

FATIGUE

During long duty periods, the crewman is proactive in remaining alert.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 15

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

SELF-IMPOSED STRESS

The crewman's actions (lack of action or errors) do not create additional, unnecessary workload for himself or others.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 16

↓

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

OVERLOAD RECOGNITION

The crewman recognizes and reports when his duties, or the duties he observes others performing, cause an overload.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 17

↓

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

STRESS LEVEL

Crewman remains calm under stress.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 18

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

SITUATIONAL AWARENESS

The crewman checks-in with others during times of high and low workload to maintain situational awareness of operations resources (i.e. antenna activity, who's doing what with which satellite) and to remain alert.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 19

↓

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

AUTOMATED SYSTEMS

The crewman establishes guidelines (or utilizes established guidelines) for the operation of automated systems (i.e., when he should disable satellite or ground systems and when they must verbalize and acknowledge programming actions).

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 20

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

OVERALL OBSERVATIONS

Crewman consistently assesses the complexity of the operating environment (weather at the remote sites, solar flares, PMI activity, etc.).

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 21

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

OVERALL OBSERVATIONS

The crewman assesses the severity of abnormal systems operation and other system events during operations.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 22

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

OVERALL OBSERVATIONS

Overall, the crewman displays technical proficiency.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 23

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

OVERALL OBSERVATIONS

Overall, the crewman effectively performs the mission.

1. **Strongly Disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**

For each person you directly supervise, write the number in Column 24

RANK	NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

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Vita

Capt John E. Varljen was born on [redacted] and is the son of a retired U. S. Air Force Master Sergeant. An avid flyer, Capt Varljen soloed at age 16 and gained his pilot's license on his 17th birthday. He graduated from the University of Arizona in 1988 with a degree in Aerospace Engineering emphasizing Astronautics.

Realizing a childhood dream, Capt Varljen was commissioned into the U. S. Air Force via ROTC and assigned to the 2d Space Operations Squadron (2 SOPS), Falcon AFB, Colorado from 1989 to 1994. There he served on the Satellite Operations crew responsible for the Global Positioning System (GPS) constellation as a Satellite Engineering Officer. He went on to serve as a crew instructor, staff instructor and a senior satellite systems analyst.

From 1994 until 1997, Capt Varljen served as a project officer in the GPS Joint Program Office (GPS JPO) located at Los Angeles AFB, CA. There he managed contracts for engineering, training and hardware support of his previous squadron.

In 1997, Capt Varljen was assigned to the Air Force Institute of Technology to obtain a Masters Degree in Systems Management. Upon graduation in September 1998, he will be assigned to the National Air Intelligence Center at Wright-Patterson AFB, OH.

Permanent Address: [redacted]

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13. ABSTRACT (*Maximum 200 Words*)

This study is a first step in formalizing CRM training as part of Undergraduate Space and Missile Training (USMT) and individual Unit Training thereby capitalizing on techniques already developed and in place for pilots. We evaluated the usefulness of two modified versions of existing CRM measures. Because an attitude measure is easier to implement, this study analyzes the use of an established flight crew attitude measure, the Cockpit Management Attitudes Questionnaire (CMAQ), and a modified version of the Air Force Mobility Command AMC Form 128, March 1995. We conducted the study in two phases. Phase 1 dealt only with Space Operations crews. Phase 2 dealt with the participants of the Guardian Challenge Competition.

The data collected seem to indicate that beyond using Assertiveness, attitude measures are a poor indicator of whether or not an individual crewman will successfully utilize CRM in the Space/Missile Operations environment. The Form 128 may still serve as a guide for designing a CRM evaluation sheet for Space/Missile crews, but the sheet does not seem well suited as a self-assessment sheet to be used by individuals.

Lastly, the Air Force needs to train young enlisted Space Operators to be more assertive with senior enlisted and officers.

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