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Satellite Command and Control Training for the 21st Century

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Satellite technology has become commonplace in almost every part of the military. From Global Positioning System receivers in cockpits to Milstar terminals in foxholes, the military relies on the services provided by space-based technology. Therefore, satellite operators must receive high quality training. Providing high-fidelity, interactive training programs to limit risk to personnel and resources operating satellite missions around the world requires a well-defined, standardized training plan that clearly documents the "cradle to grave" process for developing a qualified satellite operator for the 21st Century. Well-publicized mishaps involving satellites and ground operating systems are becoming commonplace; and in almost all cases, an improved training plan and program would have reduced these mishaps and their ultimate impact on operations. The impact of these mishaps is not fully appreciated because average military users of space-based support systems do not yet understand their ever-growing dependence on commercial, civil, intelligence, and military satellite systems. Ultimately, satellite command and control training needs to be improved to reduce the risk of a major mishap that could lead to loss of the mission, personnel, or resources.

After describing the research that shows training as the key to preventing satellite mishaps in military organizations; this paper recommends training standards for satellite command and control organizations. Following this, it describes a training plan to meet those standards. Lastly, this paper defines the process and outlines a program under which such a training plan would operate. Developing this training plan will result in highly qualified satellite operators who provide seamless, safe, and efficient satellite operations to military personnel around the globe.

Introduction

At 1530 Eastern Standard Time on 20 May 1998, the $250 million Hughes/PanAmSat Galaxy IV satellite spun out of control and became inoperable. The outage interrupted television stations, approximately 40 million pager users, bank automated teller machines, fast-pay pumps at gas stations, and internet services including Reuters News, DirecPC, and National Public Radio. The outage inconvenienced numerous federal and local government agencies, businesses, and organizations. This apparently simple inconvenience proved that the United States relies on space-based technology to conduct business. Engineers overcame the problem by moving a new satellite into orbit to cover the area lost by the outage of the Galaxy IV. Engineers also switched users to the Galaxy VII satellite to restore complete services to all users. The entire process took nearly 15 hours to complete. In the future, space-based technology may not fare so well. This mishap proved technology that uses satellites is already seamlessly integrated into American society. Many people affected by the outage did not even realize that their pager, telephone, or other convenience relied on a satellite to relay their communications (Galaxy IV Outage, 1998). While this incident was not a training-related problem, similar malfunctions have resulted from a lack of training; and due to the current reliance on satellite systems, efforts must be taken to minimize such training shortfalls. Colonel Frank Morgan, former Commander of the Air Force Information Warfare Center, said, "We must recognize…that the same qualities making information functions so indispensable, make them alarmingly vulnerable" (Grier, 1997, p. 20). In other words, any system on which organizations, governments, or the general public rely is a weakness because a cascade of problems can happen if the system fails. Effective and efficient satellite command and control training will not eliminate future mishaps but can reduce the probability of the occurrence of those mishaps. Ultimately, attention to training could prevent the loss of lives or the mission. Due to this reason alone, satellite command and control training in the Air Force requires serious attention from all organizations involved in satellite operations.

Aerospace agencies and the aerospace industry spend vast amounts of money on space-related technologies. For example, one Global Positioning System satellite costs up to $35 million, and one Milstar communications satellite costs up to $1.5 billion. Organizations also spend large amounts of money on the up-front costs to build a satellite system. These up-front costs include satellite construction costs, launch costs, and initial operating costs. However, money spent on training is often an afterthought. Each year, the money earmarked for training continues to lag in many budgets. The result of this lack of money often manifests itself in the performance of the crews and maintainers who operate and service today's satellite systems. Furthermore, several mishaps have occurred in satellite operations that resulted in degraded or lost missions such as the Galaxy IV mishap. In many cases, improved training could have reduced the risk of a mishap. Organizations in the satellite operations realm need adequate training to prevent a catastrophic mishap from occurring. Simply put, given the cost of these systems, the Air Force cannot afford needless training related mishaps. Adequate training requires sufficient funding, resources, and personnel to reduce the risk of a catastrophe involving a satellite mission.

Researching a Better Program

The research data compiled for this paper came from a survey, a study of mishaps at the United States Air Force' 50th Space Wing (50 SW), and a literature review. To accomplish the survey, various aerospace organizations received a seven-question message via e-mail that asked the recipients to assess their training programs. A review of mishaps from the Operational Review Panel (ORP) Minutes from the 50 SW at Schriever Air Force Base (AFB), CO provided information on the number of satellite and ground mishaps that required corrective training or were attributable to a training deficiency. Lastly, a literature review revealed a significant lack of research in the area of satellite training. These three areas of research provided the foundation for the results discussed in this paper.

To accomplish the survey, commercial, civil, intelligence, and military organizations received an e-mail that asked questions on how they conducted training and how they ensured satellite operators were qualified to perform satellite command and control duties. Respondents included organizations such Boeing, European Space Agency (ESA), National Aeronautics and Space Administration (NASA), and each United States military service. The data gathered exposed several deficiencies and shortfalls in many satellite training programs.

In addition to the survey, the 50 SW ORP Minutes illustrate the premise that training is not receiving adequate attention in many organizations that conduct satellite operations. The mission of the 50 SW is to command and control satellites in the United States Air Force inventory. These satellites include Global Positioning System (GPS) satellites, Milstar satellites, Defense Satellite Communications System (DSCS) satellites and Defense Support Program (DSP) satellites. The overall purpose of the ORP is "to ensure all requirements to accomplish assigned missions are reflected in unit procedures and training programs" (4 SOPSI 10-212, 1998). Furthermore, the ORP minutes briefly list and explain actions concerning any ground or satellite mishap within a particular satellite system. Research in this area reveals that many satellite training programs must still be improved.

The literature review shows that little research has been accomplished in the area of satellite training. However, training programs in other fields provide a wealth of information that can be applied to satellite training. The aviation industry provides the most closely related and applicable information. The Federal Aviation Agency Web site and Federal Aviation Regulations Parts 61 and 91 provide a great deal of information on the training process for a pilot. Air Traffic Controllers also have a great deal of information on the internet and in training books such as *Air Traffic Controller* that outline their training process. Of particular note, the aviation industry requires many types of tests to become any type of pilot, air traffic controller, or aircraft maintainer. Well-established programs, such as those used in the aviation industry, can serve as benchmarks for the relatively new field of satellite operations and aid in providing adequate satellite training.

Results From The Research

Fifteen out of 21 organizations responded to the training survey. Among the fifteen responses, three organizations did not provide usable data. The first organization did not provide usable data because it did not have a training program in place. The second organization stated that they would not provide information to the survey due to the "sensitivity" of their operations. The third organization stated that the operation of their satellites was subcontracted to another organization that had already responded to the survey. The organizations contacted fall into one of four areas as defined by the United States General Accounting Office August 1994 report titled *National Space Issues*. The areas are: commercial, civil, intelligence, and military organizations (National Space Issues, 1994). The responses from organizations within each area were generally the same, but the responses between the areas varied.

In general, commercial aerospace companies tend to have the least organized and structured training programs for satellite operations. These companies have no external regulations governing their operations except those placed on them by contracts from the organization for which they operate a satellite system. Any other regulations, if they exist, come internally from the company. These companies tend to have few or no requirements concerning the number of shifts an operator must accomplish to stay proficient in their satellite operations job. They also rarely require formal positional evaluations to prove that they are ready to conduct satellite operations, and they rarely use recurring evaluations to ensure they stay proficient. Commercial companies often use a combination of classroom training and/or reading requirements to instruct new applicants for a given position on an operations crew. Lastly, they routinely conducted on-the-job training using the actual satellite operations equipment instead of a simulator. The commercial companies tend to have less organization and structure in their training programs when compared with federal agencies and military organizations. A probable reason for this is to reduce overhead cost and manning.

Civil agencies tend to have no regulations governing them, but they often have regulations that govern any contracted companies that work for them. Initial training tends to take longer than the training provided by a commercial company. On average, initial training takes up to one year for a civil agency whereas it takes two or three months for a commercial company. The civil agencies often use simulators for training, but they rarely require initial or recurring evaluations. Overall, training in civil agencies has slightly more organization and structure than the commercial companies.

No organization responded that would be qualified as an intelligence agency. Intelligence agencies provide command and control for satellites that provide intelligence related information such as imagery, analysis, and monitoring.

In general, the military organizations have well-established and structured satellite training programs. The United States Army satellite training programs resemble the programs found in the civil agencies. The Army satellite career field requires four and a half months of classroom and simulator training. After initial training, selected individuals receive 180 days of training using real-world equipment before being allowed to command and control satellites. There is an informal certification process accomplished by the local unit, but no formal recurring training is required for normal operations. However, the Army training programs require weekly reading for infrequently accomplished tasks.

The United States Navy satellite training programs consist of courses adapted from those formerly taught by Air Education and Training Command (AETC) and Air Force Space Command (AFSPC) instructors. These courses include Ultra-High Frequency (UHF) Follow-on courses and Fleet Satellite (FleetSat) courses. Although the Navy derived the programs from existing AETC courses, these training programs were redeveloped to meet the needs of the Naval Service. The Navy program requires approximately six weeks of contractor taught classroom training followed by on-the-job training with a certified crewmember that lasts up to six months. The Navy program also consists of monthly recurring training, but proficiency requirements and certification policies are not as stringent as AFSPC's requirements. The small number of operators (18 total) required to command and control these satellites reflects the great deal of automation placed in the Navy satellite programs.

The United States Air Force has an established and structured satellite operations training program. All personnel that command and control satellites in the Air Force are assigned to AFSPC. The 50 SW is the component of AFSPC that provides command and control for all Air Force satellites. AFSPC trainees currently undergo an initial two-phase training program run by AETC. All AETC instructors are on temporary assignment from AFSPC to be instructors for these courses. In the first training phase, trainees attend either the 23-day Enlisted Space Prerequisite Training course or the 37-day Officer Space Prerequisite Training course that includes subjects such as orbital mechanics, satellite modeling, and design and background information on the various satellites in the Department of Defense (DoD) inventory. The second phase of training is the initial qualification training (IQT) course. At this course, the trainee receives specific information on how to operate a particular DoD satellite. These courses last from 25 to 98 training days depending on the type of satellite. After completing the two-phase AETC training program, a trainee reports to one of the space operations squadrons at the 50 SW and should require approximately 20 days of local training before becoming mission ready. The exception is the 2d Space Operations Squadron training since AETC is just beginning to teach classes with simulation capability to train students to the appropriate level of learning. In the future, AETC plans to use a three-phase program in place of the current two-phase program. The first-phase of training will be a shortened version of the current first phase. The second phase will include training that is common for every type of satellite. For example, emergency action procedures (e.g. fire procedures, evacuation procedures, threat condition changes, etc.) will be taught during the second-phase. The third phase of training will consist of the training required for a specific satellite system. Once arriving to a space operations squadron, the trainee receives on-the-job training with a satellite operations crewmember certified in his or her applicable position. Finally, the trainee will undergo an evaluation by a team of evaluators from outside the squadron to insure that the trainee is qualified to operate the satellite. Every six months during the first year and annually thereafter, the fully qualified operator receives a recurring evaluation to insure that he or she is still qualified. On the surface, the AFSPC’s structured training programs appear to need no improvement, but ORP minutes revealed that improved training could lead to fewer mishaps and more efficient operations.

In addition to the survey, the authors researched the 50 SW ORP minutes. These minutes identified a need for improved training even though AFSPC has the most structured training program among those surveyed. The ORP minutes document any problem on a satellite system that led to an "outage" or non-operational time on a satellite. The incidents noted were the result of "lack of attention to detail, incorrect procedures, lack of checklist discipline when using procedures," and in one case, an untrained person accomplishing a task on a satellite (see Table 1). Out of nine incidents reviewed in 1997, seven incidents had recommendations that training be developed or re-accomplished as necessary. Out of 14 incidents reviewed in 1998, nine incidents required additional training or re-accomplishment of training. In 1999, there were 11 incidents and five required retraining. In 2000, there were 15 incidents and nine required retraining. Finally, in 2001, there were 11 incidents and eight required retraining. This trend supports the premise that all satellite operations organizations need to continue to improve their training programs.

The most adequate satellite operations training will consist of a training program that is standardized throughout all organizations that operate satellites. A program similar to that used by the Federal Aviation Administration to certify pilots is necessary to insure the safety and well being of today’s satellite missions. Specific requirements should vary depending on the organization. For example, a commercial aerospace company would not need an extensive initial qualification training program in most cases since they hire personnel based on previous experience. On the other hand, military organizations need extensive initial qualification training since personnel are not hired based on previous experience but rather on aptitude to accomplish a job. The military operators also work on a particular system for three to four years before they are moved to another program in AFSPC that may or may not deal with satellites. At the least, a training program should consist of some kind of initial qualification training that includes classroom lectures, practice time on a simulator and/or practice on the actual satellite operations equipment. The program should also include an initial evaluation to insure the trainee is ready to operate a satellite. Lastly, the program should include a requirement to complete monthly proficiency shifts and an annual recurring evaluation to insure that the qualified operator remains fully qualified. When these measures are in place, training will improve satellite operations fidelity and reduce the risk of a mishap.

If the United States truly wants to integrate space technology into society, the United States should be willing to operationalize and regulate the industry to ensure further growth. Dependence on space technology in numerous applications in support of industry is obvious. A simple outage causes many problems that have far reaching impacts to society as a whole. If a pilot cannot use GPS due to a system outage, he loses confidence in the system and its usefulness. A regulated satellite industry is necessary to prevent a "wild, wild west" mentality that seems to currently grip the industry.

Total 50 SW Satellite/Ground Mishaps	1997	1998	1999	2000	2001	Total
Total Satellite/Ground Mishaps	9	14	11	15	11	60
Caused by Personal Error Requiring Retraining (Percentage out of Total Satellite Mishaps)	7 (78%)	9 (64%)	5 (45%)	9 (60%)	8 (63%)	38 (63%)

Table 1. Total 50 SW Satellite/Ground Mishaps Versus Incidents Caused by Personal Error Requiring Retraining

There are international organizations that control radio frequencies, airline operations, and shipping operations, but no organization governs satellite command and control. Since millions of people depend on the products provided by today’s satellites, command and control of these systems should be carefully regulated to reduce or prevent future mishaps.

Building a Better Training Program

Standards for Training

Research revealed a distinct lack of coordination and cooperation between all organizations involved in the command and control of satellite systems. The root cause of this problem is the lack of standardization between these organizations. A two-fold process will help eliminate this problem. First, the Federal Government should establish a parent organization similar in function to the Federal Aviation Administration to act as the governing body and authority to enforce standards for all satellite command and control organizations. Second, standards should be developed so all organizations accomplish minimal requirements to ensure the safe operation of their equipment. Implementing these two suggestions should significantly reduce the risk of a major mishap that could lead to loss of the mission, personnel, or resources.

The creation of a parent organization governing satellite command and control operations will allow cohesive decision making and development of acceptable standards for all such organizations. This organization would be responsible for periodic inspection of all types of satellite command and control organizations to ensure compliance with federal regulations and laws applicable to satellite operations. The organization would also be responsible for the development and implementation of standards that all satellite command and control organizations would follow. This would require that all satellite command and control organizations register with this government organization and comply with required regulations prior to executing any satellite command and control operations. Implementation of such procedures will ensure the safe function and preservation of mission for all satellite programs.

Standards of training are one particular and simple function that will result in the quickest and most efficient means of reducing the risk of a satellite mishap in any organization. AFSPC has significant standards that all agencies under their jurisdiction must comply with prior to any person being "certified" to command and control a satellite. Training standards include the requirement that all personnel attend formal training prior to operating satellite command and control equipment. This training is "Initial Qualification Training" (IQT) which refers to formal training courses such as those conducted by AETC and "Unit Qualification Training" (UQT) which refers to formal training conducted by the satellite command and control organization. The IQT courses should include classroom instruction covering topics such as basic satellite operations, components, subsystems, and simulation training on a satellite command and control simulator. This training length will depend on the complexity of the software and satellite system. The UQT courses should include classroom instruction covering topics to familiarize the student with the organization's operations and simulation instruction with a qualified satellite command and control operator. Finally, at the end of UQT, the trainee should receive hands-on practice using real-world equipment to familiarize the trainee with daily operations. For safety, this training must be conducted only under the supervision of a qualified operator. UQT should also include tests and evaluations to ensure that the student understands how to safely and efficiently operate the particular system. Upon completion of UQT, the student should receive a standardized performance evaluation from an evaluator who did not have contact with the student during IQT or UQT phases of training. The lack of contact is important to ensure impartiality during the evaluation.

Training Plan to Meet Standards of Training

Instructors and training developers should develop satellite command and control training using the traditional instructional systems design (ISD) model as the basis (see Table 2). The training plan should outline what the course will cover, how it will cover it, and to what level the trainee should be proficient. Currently, AETC requires the use of ISD as the basis for developing and revising all technical training including satellite command and control courses (AETCI 36-2203, para 1.8.1). New equipment and new personnel drive the need to develop and implement a new training course. Furthermore, instructor and student feedback and updates to the current system drive modifications to an existing course. Developers should also consider recurring training requirements when developing the training plan. Recurring training should be conducted on a periodic basis using simulation equipment. While developing the training program, developers should consider various methods of training to include: interactive courseware, video teletraining, classroom instruction, and performance instruction using simulation equipment. However, cost-effectiveness and efficiency of training will be the ultimate determinant of the method.

Step 1: <u>Analysis</u> (accomplished by training organization, qualified operators, and evaluators, as applicable)

- Identify training requirements for GPS, MILSATCOM, SBIRS, MILSTAR, etc. (equipment and personnel)

- Identify tasks to be trained from technical data for the crew commander, crew chief, and ground systems operators

- Identify the number of personnel requiring training per year and per class by operational position and satellite system

- Identify the number of instructors required to provide training by crew position and satellite system

    -- One instructor per classroom

    -- Identify number of instructors for simulator instruction (e.g. One instructor per two simulator consoles)

Step 2: <u>Design</u> (accomplished by training developers from the training organization)

- Write objectives for training each task required to support the satellite system from launch to decommissioning (e.g. If training a satellite state of health task, there could be three objectives. One objective on configuring ground equipment, one objective on reviewing telemetry data, and one objective on deconfiguring equipment.)

- Write test measurements (written and performance tests)

    -- Minimum of two questions per objective

    -- Performance tests cover objectives and evaluate student's ability to apply acquired knowledge on the simulator

Step 3: Development (accomplished by training developers from the training organization)

- Write lesson plans with specific teaching steps that train the objectives based on technical data

- Identify methods of training (interactive courseware, video teletraining, classroom instruction, performance instruction using simulation equipment)

- Write student guides, handouts, and any other learning aids for the students

- Establish guidelines for passing the course (e.g. 80% or better on all test measurements)

Step 4: Implementation (accomplished by training instructors)

- Each instructor should personalize lesson plans with teaching notes

- Teach the course using the lesson plans to ensure standardized training is provided to every student

- Administer written test measurements

- Administer performance test measurements

Step 5: Evaluation (accomplished by the evaluation organization, training instructors, and training developers)

- Evaluation should be accomplished after each ISD step

- After step 4, evaluate and validate the entire training program

    -- Gather student feedback through critiques and interviews with instructors, students, and supervisors

    -- Review all feedback for improvements to the course

    -- Provide lessons learned to instructors and developers

- Implement applicable changes to the training system and the operational system

Table 2. Satellite Command and Control Training Instructional System Design Sample Model for Developing Training

Use of the ISD model should ensure efficient and effective training programs. Training developers first need to identify the tasks to be trained based on anticipated training requirements. After the training developers identify the tasks, they can then determine the specific objectives required to meet each task. The training developers then need to identify how to measure each objective. The accurate way to measure objectives is through written and performance testing. Written testing could consist of multiple choice, true/false, matching, fill-in-the blank, and essay type questions. A mix of these types of questions will provide the most accurate assessment of the student's knowledge level. The performance test should be a realistic scenario that demands decision-making within realistic time frames. Once the training developers create objective measurements to meet the desired skill level, they can develop a curriculum and select instructional methods that will best enable the student to learn and retain training. A complete curriculum should contain standardized lesson plans that include the objectives, teaching steps, and teaching personalization for the instructor. The curriculum should also include the test measurement devices (i.e. written and performance tests), study guides, and aids for the students. After training is conducted, the training developers need to determine the effectiveness of the course and change or update the course as required (Air Force Doctrine Document, 1998, p. 27).

For satellite performance training, an off-line simulator that simulates all required tasks is the key to a successful training program. An off-line simulator is an independent system that is not connected to the operational satellite command and control equipment or testing hardware/software. This simulator needs to be off-line since an on-line simulator could impact the satellite mission if a trainee makes intentional or unintentional mistakes. An off-line simulator also enables instructors to provide instruction on tasks that cannot be accomplished without mission impact such as safemode or launch and early orbit operations. This requires that the simulator have enough fidelity to simulate all actions that an operator could perform on the actual system. Instructors should use the simulator to train students on new procedures and tasks, allow student practice on procedures and tasks, and test students in performance evaluations. Additionally, the simulator should be used to train certified operations crews on new procedures, tasks, and proficiency and recurring training. The use of simulators as described serves to increase the educational effect and ensures students meet the required performance level to pass their training.

The number of instructors and developers needed for a training program depends on the class size and type of training required. Since an operations crew may consist of several individuals certified in different crew positions, several courses may be necessary to fully train an operations crew. As a general rule, there should be at least one instructor per position and one training developer per course. The instructors and developers will comprise the training organization for a particular satellite system.

Training Operations Plan

The training operations plan is used to develop training and evaluation programs for satellite command and control duties. It defines roles, responsibilities, and minimum training standards to become a qualified satellite command and control operator. First and foremost, the training operations plan provides mission-ready (MR) personnel who have the required skills and knowledge to perform satellite command and control duties. The skills and knowledge are obtained through a structured and standardized training program, and the program is validated through periodic evaluations. The organizational training office should develop training material, administer initial training, administer recurring training, review publications for impacts to training before implementation by satellite controllers, evaluate need for supplemental training, and train instructors. The organizational training office should also maintain MR personnel historical documentation to include certification, decertification, and recertification dates, supplemental training dates, placement in and removal from restricted status, tracking of MR workhours, and evaluation/observation results. This will ensure accurate and consistent training throughout the life of the course.

Instructor/Evaluator Training and Certification Program

The purpose of this program is to ensure standardized training and qualified, unbiased evaluations. Instructors or evaluators must be trained, evaluated, and maintain currency in the tasks they train and evaluate. A MR individual may be both an instructor and an evaluator as long as the individual does not evaluate trainees that he or she instructed. Furthermore, the instructors and evaluators should be trained on how to provide classroom instruction, performance instruction, and evaluations before being allowed to be certified as an instructor or evaluator. Training organizations should consider sending instructors to formal training courses to teach them how to provide training. Implementing these measures will ensure accurate and consistent training.

Evaluation Program

Before a student becomes a MR satellite command and control operators, an evaluator who has not trained the student should certify that the student can perform MR operations. It is important that the evaluator not be involved with the training of the student to avoid any bias in the evaluation. After becoming MR, the individual should be evaluated annually. The evaluation will verify the evaluatee's capability to perform routine operations as well as emergency operations. The evaluator should also assess a qualified or unqualified rating at the end of the evaluation. If a MR individual receives an unqualified rating, he or she should be decertified and retrained by instructor personnel and be reevaluated before being allowed to return to MR status.

Qualification Training Program

Qualification training provides system specific and positional specific instruction for a new employee. Before the employee uses operational equipment, the training organization should provide classroom training and simulation exercises to ensure all knowledge and performance tasks are covered.

Recurring Training Program

Recurring training will ensure continued proficiency on all tasks, especially those not routinely accomplished during normal operations. The training organization should maintain an annual plan of instruction that identifies all tasks covered and when the task will be covered throughout the year. Each task should be identified for its criticality, and the most critical tasks should be taught more than once per year. For example, a satellite recovery from loss of earth scenario may be critical so the scenario would be trained on a quarterly basis. Monthly recurring training should include self-study guides accomplished before classroom training and written testing. At least quarterly, the training organization should provide MR performance training that practices all tasks trained over the past three months on an off-line simulator.

Conclusion

No completely standardized way of accomplishing satellite training exists today. When compared to the aviation industry, satellite operations is in its infancy. Federal regulatory bodies govern aviation safety and operations. However, no one particular entity governs satellite operations which leaves these operations ripe for accidents. Some accounts of satellite mishaps are well publicized, while others remain classified due to the sensitive nature of their operations. However, as the military continues to rely on space-based information, a governing body will be necessary to ensure the safety of equipment and missions. Satellite command and control training is a necessity, and the regulation of satellite training is of utmost importance for a mission to be successful. Ultimately, these actions will reduce the risk of loss of life or mission during military operations.

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