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**U.S. Army Research Institute
for the Behavioral and Social Sciences**

Research Report 1619

C3I Test-Instrumentation System: MANPRINT Evaluation of the Data Collection Subsystem

**[With Additional Comments Pertaining to the
Data Reduction Subsystem]**

Richard L. Palmer
U.S. Army Research Institute

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U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES

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Technical Director

MICHAEL D. SHALER
COL, AR
Commanding

Technical review by

Jon J. Fallesen

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13. ABSTRACT (Maximum 200 words) The Data Collection Subsystem (DCS) of the Command, Control, Communications, and Intelligence (C3I) Test-Instrumentation System (C3I2) consists of mobile computerized hardware that provides automated data collection during operational tests of C3I systems. This research evaluated DCS-operator interfaces and DCS system documentation for manpower, personnel, training, human factors engineering, safety, and health hazards. Emphasis was on human factors engineering. The research was conducted in conjunction with two system tests conducted by the Army Test and Experimentation Command. The major findings were these: (a) Using contractor technicians as operators is wasteful because their maintenance skills are not exploited. Enlisted military personnel should be considered instead. (b) Because there was no formal training program, a formal training evaluation was not conducted. DCS operations were easy to learn, but there were gaps in operator and maintainer knowledge and performance. Manuals were inadequate. Sixteen training-related findings were documented. (c) Hard-wire setup required 1-1/2 hours; teardown required about 50 minutes. Rapid deployment to a new location would require at least 2 hours 20 minutes. (Continued)					
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minutes, not including transit time, site location and layout, weather delays, and so on. Much time is consumed by antenna erection and takedown. (d) Forty-nine software interface shortcomings were related to system self-test, complexity of menus and terminology, hard-disk backup capability, and software-induced operator errors. Crucial findings were inadequate data archiving process, inadequate system alerts, and easy accidental reinitialization of the system. Archiving has been improved; alert and reinitialization problems have been largely resolved. (e) Thirty-two hardware interface problems were noted in relation to power generators, procedures for stowing equipment, reflections in operators' eyes, location of equipment, and computer mounting procedure. (f) Three safety questions arose, most notably, possible instability of the DCS vehicle. (g) No health hazards were encountered. In sum, the research produced 105 findings and identified many potential improvements. Few of the problems were of major significance; of those that were, many have been at least partially resolved.

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Research Report 1619

**C3I Test-Instrumentation System: MANPRINT
Evaluation of the Data Collection Subsystem**

**[With Additional Comments Pertaining to the
Data Reduction Subsystem]**

Richard L. Palmer
U.S. Army Research Institute

**Field Unit at Fort Hood, Texas
Edwin R. Smootz, Chief**

**MANPRINT Division
Robin L. Keesee, Director**

U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

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FOREWORD

The MANPRINT Division of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) conducts manpower, personnel, training, and human performance research associated with the development, acquisition, and operation of Army systems. The MANPRINT research described in this report evaluates the data collection component of the Command, Control, Communications, and Intelligence Test-Instrumentation (C3I2) System, a system designed to provide Army operational testers with the capability for automated data collection and analysis during field tests of C3I systems.

The evaluation the C3I2 data collection subsystem (DCS) was conducted by ARI's Fort Hood Field Unit during the period November 1989 to June 1990. The findings are concerned primarily with human engineering factors, but the report also discusses manpower, personnel, training, and system safety issues; health hazards were not an issue of concern. The research has led to significant hardware and software modifications that have effectively increased the operability of the system and provided many lessons learned for use in the development of the mature C3I2.

This research was part of the Fort Hood Field Unit's research task: "Soldier-System Considerations in Force Development Testing." It was conducted in conjunction with the U.S. Army Test and Experimentation Command's (TEXCOM) validation testing of the prototype DCS and in accordance with the provisions of a Memorandum of Understanding between the ARI and Training and Doctrine Command (TRADOC) Combined Arms Test Activity (now TEXCOM) dated 7 May 1981.

Organizations that have received this report include the U.S. Army Test and Experimentation Command (system proponent, program director, project manager, and system tester), Applied Research Laboratories of the University of Texas at Austin (system developer), Planning Research Corporation (system support contractor), and the U.S. Army Communications and Electronics Command (currently, joint proponent with TEXCOM). Interim and final results of the research were briefed to the Commander, HQ, TEXCOM, and to representatives of the previously mentioned organizations in March and April 1990.



EDGAR M. JOHNSON
Technical Director

C3I INSTRUMENTATION SYSTEM: MANPRINT EVALUATION OF THE DATA COLLECTION SUBSYSTEM

EXECUTIVE SUMMARY

Requirement:

The Command, Control, Communications, and Intelligence Test-Instrumentation System (C3I2) is a computerized, soldier-operated hardware system being developed for Army operational testers. It provides automated data collection and near real-time data reduction during field tests of C3I systems. Because one of the two primary components of C3I2, the Data Collection System (DCS), was at the prototype stage of development during the period of this research, an opportunity existed to provide constructive user feedback to the developing contractor at a time more conducive to nondisruptive and cost-effective system modification. The other primary component, the Data Reduction System (DRS), was still in its conceptual stage and was not evaluated.

This research provides the Army and the developing contractor with the advantage of an early initial evaluation of the emerging DCS hardware and software interfaces and related system documentation. The evaluation was conducted in the context of the Manpower and Personnel Integration (MANPRINT) system acquisition concept, which comprises the domains of manpower, personnel, training, human factors engineering, system safety, and health hazards. Performed by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) MANPRINT Division, Fort Hood Field Unit, the evaluation emphasized human factors, but also dealt at some length with the other domains, except health hazards, which was dismissed as of minimal concern.

Procedure:

An evaluation office was maintained at the developing contractor's laboratories from November 1989 until May 1990. During this period, the evaluator underwent system familiarization and interacted daily with development teams.

Two operational field tests of the DCS were conducted by the Army Test and Experimentation Command (at Fort Sill, January 1990, and at Fort Hood, April 1990). ARI was part of the TEXCOM test team during both tests and was responsible for evaluating MANPRINT-related test issues.

Before the first field test, a detailed human factors evaluation of DCS hardware and software interfaces and operator-maintainer documentation was conducted. During this time, positions on manpower, personnel, and training

issues were being developed and discussed with the Army, the developing contractor, and the system support contractor. The latter was to provide field engineers, operators, and maintainers for the upcoming field tests.

During the field tests, the DCS was evaluated to determine the developer's progress in improving and correcting human factors engineering features. Previously unnoted findings, including safety problems, were documented, as were operator performance times and operator-maintainer errors and other problems related to human factors and training deficiencies. Evidence from the field tests was also used to finalize positions on manpower and personnel issues. Evaluator observations were documented as events occurred; operator-maintainer expenditure of time was documented on a minute-by-minute basis.

Findings:

1. *Manpower & personnel.* The major finding was that use of system support contractor technicians as DCS operators is wasteful because their maintenance skills are seldom exploited at the operator's position. The use of enlisted military personnel, trained as operators, would free the technician to use nonoperational skills more effectively.

2. *Training.* No formal training program had been developed (or planned); hence, no formal training evaluation was conducted. However, noticeable gaps in operator and maintainer knowledge and performance were noted during the field tests. Manuals for operators and maintainers were inadequate as training and reference documents and required considerable augmentation by other instruction. Altogether, 16 specific training findings were documented. Despite these observations, it is noted that the DCS seemed potentially easy to learn and operate; it will probably not require extensive training time.

3. *Human factors.* These findings fall into four categories:

(a) *DCS/DRS user interface uniformity:* It was argued that, from a MANPRINT perspective, emulation of the DCS interface by the DRS would be a mistake because it would mean incorporating significant human factors deficiencies into the DRS for the sake of an unnecessary commonality of "look and feel." It was resolved that DRS interface development would be independent, using lessons learned from the DCS effort only to the extent that they benefited the DRS interface.

(b) *Performance times for DCS setup and teardown tasks:* Hard-wire setup under ideal conditions required 1-1/2 hours. Teardown required about 50 minutes. Deployment of a new location would require, at a minimum, 2 hours 20 minutes, not including transit time, new site location and layout, weather delays, and so on. Much setup and teardown time is consumed by tasks associated with antenna erection and takedown. All significant tasks involved

in setup and teardown are listed in an appendix, along with a minute-by-minute task timeline.

(c) *DCS operator-software interface deficiencies:* Forty-nine software interface shortcomings were documented, including inadequacy of the self-test, complexity of menus and terminology, absence of hard-disk backup capability, and software-induced operator errors. Especially crucial findings were inadequate archiving process for data in volatile memory, inadequate system alerts, and easy accidental reinitialization with probable loss of data. The archiving process has been improved, and the alert and reinitialization problems have been largely resolved.

(d) *DCS operator-hardware interface deficiencies:* Thirty-two hardware interface problems were noted. They involved troubleshooting the power generator, cumbersome procedures for stowing equipment, ceiling lights reflecting into operators' eyes, location of the printer and other equipment, and computer mounting procedures.

4. *Safety.* Three safety problems were noted. Most notable was the reported instability of the DCS vehicle. The Army asked the developer to determine the vehicle's center of gravity and evaluates the danger.

5. *Health hazards.* No health hazards were encountered or expected to be associated with C3I2.

Utilization of Findings:

The evaluation of the C3I2 DCS prototype produced 105 MANPRINT findings and identified many potential improvements, not only for the prototype itself, but for its successors. Few of the noted problems were major; most of the major problems have been at least partially resolved.

Taken separately, some of the findings appear trivial. In aggregate, however, they describe a system with numerous "rough edges" that produce unnecessary operator and maintainer error and inefficiency. The rough edges were not expected, owing to the prototype status of the system. Documentation of the findings has already led to many improvements and a lessened likelihood that shortcomings will be carried over into the development of the DRS and to future versions of the DCS.

C3I TEST-INSTRUMENTATION SYSTEM: MANPRINT EVALUATION OF THE DATA COLLECTION
SUBSYSTEM

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**C3I TEST-INSTRUMENTATION SYSTEM:
MANPRINT EVALUATION OF THE DATA COLLECTION SUBSYSTEM**

System Description and Development

The Command, Control, Communications, and Intelligence (C3I) Test-Instrumentation System (C3I2) is a computer-based data collection and analysis tool consisting of two major components, the Data Collection System (DCS) and the Data Reduction System (DRS). The DCS and DRS are mobile computer systems currently housed in separate TEMPEST-certified S-710/M shelters mounted on modified four-wheel-drive M-880 "pickup" trucks with attached trailer-mounted 20 kW generators. Their primary purpose is to provide the capability for automated real-time data collection and data analysis during operational evaluations of Army Tactical Command and Control Systems. C3I2 is an automated instrumentation system capable of recording and analyzing command and control information flow at echelons from battalion to theatre Army.

The DCS is designed to record real-time digital and radio frequency information from a C3I system-under-test, such as AFATDS, ASAS, EPLRS, FAADS, MCS, MSE, SINCGARS, TACFIRE, and others. The DRS will accept the data collected by the DCS and provide the test officer in the field a near real-time "quick-look" analysis to evaluate the progress of the test. In the prototype C3I2 system, the DCS data is recorded on tape and manually transferred to the DRS (which may or may not be collocated) by carrier, where it is copied and analyzed. Extensive posttest data analyses must, however, be performed by the data analysis center of the testing organization rather than by the DRS.

The DCS is the primary focus of this report. The DRS, in a much earlier stage of development, was not available for detailed scrutiny at the time of this research.

The DCS is designed to collect both classified encrypted information and unclassified data transmitted in the clear. It collects data in either a hard-wire or radio frequency mode or in both modes simultaneously. In the hard-wire mode, the DCS is hard-wired to the system-under-test in such a way as not to interfere with the performance of that system during the test.

The DCS shelter includes, among other miscellaneous items and operator interfaces, the following primary equipment: an uninterruptible power source; a "ruggedized" computer with video terminal, keyboard, hard disk, TK50 tape recorder, and high-speed printer; an additional VHS tape recorder; an eight-channel modem with accompanying eight-oscilloscope bank and eight-speaker bank; a geostationary operational environmental satellite receiver; several VRC-12 or SINCGARS radios; a dual 28-volt power supply; KY-57 communications security devices; and a security safe.

C3I2 is being developed by Applied Research Laboratories of the University of Texas at Austin, in accordance with a required-instrumentation-capability document originally submitted in 1985 by the Combined Arms Test Activity (now Test and Experimentation Command [TEXCOM] of the U.S. Army Training and Doctrine Command [TRADOC]). The current version of the requirements document (22 September 1989) details the basic system requirements as (a) the capability of generating, tagging, tracking, auditing, and analyzing C3I

digital and analog messages, (b) the ability to stimulate as well as simulate the system-under-test, and (c) the ability to interoperate with current radios and other communication systems.

The TRADOC program director and manager for C3I2 is the Deputy Chief of Staff for Information, HQ TEXCOM. The operational tester for the system is the Director, Battlefield Automation Test Directorate, HQ TEXCOM. The U.S. Army Research Institute (ARI), Fort Hood Field Unit, conducts the manpower and personnel integration (MANPRINT) evaluations of the system during operational testing by TEXCOM.

Method

Data pertaining to the DCS were sought in the MANPRINT domains of manpower, personnel, training, human factors engineering, and system safety. (As noted earlier, findings were most prevalent in the human factors area, and there appeared to be little reason for concern in the area of health hazards.) Data were available from two primary sources: (a) in-depth on-site DCS training and detailed hands-on experience with the prototype DCS over three-and-a-half months (November 1989 - February 1990) during its final developmental stages at the University of Texas Applied Research Laboratories, and (b) participation as test team member in two operational field tests of the DCS conducted by TEXCOM, the first at the Fort Sill Field Artillery Board during the week of 28 January 1990, the second at a 1st Cavalry Division unit at Fort Hood the week of 16 April 1990. Throughout the period of research, contact with the individual members of the DCS development team was maintained, and extensive discussions of various aspects of the software and hardware development, as well as system documentation and training, were conducted. (Additional limited findings pertaining to the DRS were developed during the course of this research through communications with members of the developer's DRS team and the Army's project manager and system tester.)

The following sections describe the two primary data sources.

On-Site Laboratory Observation

Observations made at the developer's laboratory produced many specific findings--particularly within the human factors realm, but also within the areas of documentation and training--a number of which were fed back into the development of the system prior to the government acceptance testing by TEXCOM. Both software and hardware interface with operator and maintainer were scrutinized for shortcomings and characteristics that would tend to contribute negatively to system operation or operator training or that would bear upon personnel (operator and maintainer) selection factors. System documentation for operators and maintainers, which was also in development, was evaluated, with some suggested improvements incorporated by the developer prior to Army testing of the system. Significant problems were tracked throughout the three-month period prior to testing and noted as they appeared or reappeared during testing.

Field Observation

Initial Validation Test

The purpose of the DCS test at Fort Sill was to attempt to qualify the system for participation, as data collection instrumentation, in an upcoming operational test of the Single-Channel Ground/Airborne Radio System (SINGGARS). Data obtained by TEXCOM from performance of C3I2 during the SINGGARS test would be used to determine the feasibility of using the C3I2 system in future operational testing of C3I systems.

(The SINGGARS test, an initial operational test and evaluation of the integrated communications security model of the radio, was scheduled for the April - June 1990 time frame. Use of the DCS in that test would constitute the first field trial of the prototype DCS in a real operational situation. During that test, TACFIRE messages would be transmitted over the SINGGARS radio and recorded by the DCS using both hard-wire and radio receivers.)

During the Fort Sill validation test, two prototype DCS units were exercised by the TACFIRE system (to which they were hard-wired) located at the Artillery Board. Two contractor operators were assigned to each DCS, but actual operations were carried out by one operator at a time, the other acting as backup. A system engineer (system support contractor) was also on site to assist as needed, as were representatives of the system developer. ARI provided one MANPRINT evaluator who continually observed system operation and maintenance throughout the test and documented significant incidents, including operator and maintainer error and other phenomena as they occurred.

Revalidation Test

The DCS failed the Fort Sill test because of a crucial software bug and three crucial MANPRINT findings. The latter were: (a) it was too easy for the operator to reinitialize the system inadvertently; (b) the presentation of system alerts to the operator was inadequate; and (c) there was a possible safety hazard associated with vehicle instability. (These findings will be discussed in greater detail in the presentation of findings that follows.) Consequently, the system was returned to the developer for necessary modifications and then retested with TACFIRE at Fort Hood approximately two months later.

During the DCS validation retest at Fort Hood, tracking of human factors, notation of operational and maintenance errors, and documentation of other MANPRINT concerns was continued. In addition, it was possible to measure the overall duration of setup and teardown activities as well as the time required for most of the subtasks involved.

Most of the findings presented below, other than setup and operational task times, were observed prior to the Fort Hood revalidation test, although several new findings surfaced during that test. Problems known to have been corrected or ameliorated by the developer, the system support contractor, or the Army are noted.

Findings

As with other systems, the MANPRINT findings associated with C3I2 are sometimes difficult to pigeon-hole with respect to the six general MANPRINT domains because of their simultaneous impact on more than one area. Human factors engineering considerations, in particular, frequently have broad, and often-unforeseen, implications for the other areas. Nevertheless, each of the findings presented is listed under the MANPRINT domain to which it seemed most pertinent, except that manpower and personnel findings are combined into one section. Findings were obtained in the first five areas; no problems were detected in the sixth area, health hazards. Each finding is numbered for reference purposes.

Section 1: Manpower & Personnel

1.1 Operator Selection

FINDING: The DCS is currently operated by system support contractor technicians. These technicians receive training that goes substantially beyond that required to operate the system, including training in installation procedures, basic maintenance, and software management. Yet, problems of more than routine significance that occur in the field during normal operations are not addressed by the technicians, but by supervisory engineering personnel of the developing contractor and the system support contractor.

Impact: The technician's time is largely wasted at the operator's terminal. The use of contracted technicians as opposed to enlisted military personnel as system operators does not appear to be necessary strictly from the standpoint of skill requirements.

Comment: According to the TRADOC Required Instrumentation Capability document for C3I2, the DCS shall be capable of sustained operations of up to 22 hours out of each 24-hour period of the operational test of a C3I system, with the remaining two hours available for peripheral activities such as set up, calibration, and checkout. Additionally, the DCS must be able to record 90 percent of the data flow from the system-under-test. Hence, DCS problems encountered during field operations must be solved hastily. Meeting this requirement frequently requires rapid access to personnel with extensive knowledge of system hardware and software--knowledge that the technician may not be trained to provide even though technician training goes beyond that required of an operator. Consequently, the best division of labor may be to employ enlisted military personnel trained specifically for operating the system while using the contracted technician and engineering personnel in the maintenance support function. This solution would free up the technicians, whose potential maintenance skills seem to be largely wasted in their current role as system operators. A maintenance team composed of the technicians and headed by the hardware and software experts would then be available to move from site to site as required to provide a rapid response to maintenance needs.

1.2 Source of System Trainers

FINDING: The C3I2 required-instrumentation-capability document contains an apparent contradiction regarding organizational responsibility for furnishing C3I2 instructors; that is, whether they will be provided by the developer

or by an independent, system support contractor. The latter is the Army's intention.

Impact: Persons not knowledgeable about the Army's intent may be confused by the document.

Comment: The confusion stems from page 8 of the requirements document: Paragraphs 10b(1) & (2) imply that the developer will provide training only to subsequent trainers who will be supplied by an independent system support contractor; the next paragraph, accordingly, specifically states that subsequent training will be the responsibility of the system support contractor. Paragraph (4), on the other hand, seems to reverse matters, stating that the developer, not the system support contractor, will provide system instructors. The next revision of the document should make it clear that the system support contractor will provide instructors after the initial training of cadre by the developer.

Section 2: Training

2.1 Undeveloped Training Program

FINDING: No formal C3I2 training package has been developed. Consequently, it was not feasible to conduct a formal training evaluation. However, the system developer, as a matter of course, provided training and system documentation materials to the system support contractor and other key personnel in preparation for the DCS validation test. It was possible, therefore, to take note of several significant gaps in operator-maintainer knowledge and performance during the DCS test and in existing system documentation. Those observations are described below (Finding 2.4). Outside of the exceptions noted, the operator-maintainers appeared to possess an adequate understanding of system functioning; they were able to accomplish useful data collection in a manner consistent with the mission, except during hardware and software incidences, most of which were largely unrelated to MANPRINT concerns.

Impact: Operators and maintainers may not be able to take full advantage of the system's capabilities and documentation to perform with maximal effectiveness or solve operational and maintenance problems efficiently.

Comment: Once decisions regarding manpower and personnel requirements have been made, it would seem advisable to provide formalized C3I2 training, including complete reference and training manuals, programs of instruction, lessons plans, and training aids, all aimed at appropriate target audiences (system operators, maintainers, and software and hardware engineers). Training on the C3I2 system should be formal and systematic.

2.2 Operator and Maintainer Manuals

FINDING: There appeared to be minimal interest among principal proponents of C3I2 (the Army, the developer, and the system support contractor) in the production of high quality operator and maintenance documentation.

Impact: The user's manual provided by the developer--*Software User's Manual for the TEXCOM Prototype Instrumentation System (DCS)* (8431501/M0001, 14 Nov 89)--was not adequate to stand by itself as a complete training and reference

manual either for operators or maintainers. Its shortcomings will have to be compensated for by instruction and user experience.

Comment: The lack of interest in user documentation development is attributed to several factors:

(a) The Army is requiring the developer to provide lesson plans, agendas, training aids, and instructors, but only for training initial training cadre, (supplied by an independent system support contractor) who will be responsible for training future operators and maintainers. Consequently, the developer does not view documentation development as a priority in C3I2 development.

(b) The system support contractor envisions occupying the role of "system operator" as well as "system technician/maintainer" well into the future. Consequently, in their view, there will be a continuity of personnel of high caliber who will have minimal need for supportive documentation, especially for purposes of operator training. Most training would be "on-the-job."

(c) Traditionally, system documentation takes a back seat among the various priorities in the system acquisition process. Normally, hardware concerns predominate during most of system development; but then acquisition milestones become urgent, and operator's and maintainer's manuals, which, of necessity, must be among the last system components to be finalized (though not, of necessity, the last to be initiated), tend to be rushed and inadequately realized.

(d) The developer did not have personnel whose primary mission (or interest) was documentation development as opposed to software and hardware development--a situation apparently not uncommon among system developers. Responsibility for C3I2 documentation was primarily assigned to programmers whose main interest lay, naturally, in writing code, not documents.

The current system employment documents for the DCS make little distinction between the operator user and the maintainer user. Probably this fact results from the anticipation that the operator and maintainer will be one and the same person. Finding 1.1, however, suggests that it may be beneficial to divide these responsibilities--in which case it would be advisable to create separate documentation for operators and system technicians and maintainers. If, indeed, the system support contractor will continue to be the operator as well as supervisor and maintainer, then the requirement for system employment documentation in general is minimized, though not obviated. If TEXCOM or others will supply system operators, then the need for a high quality operator's manual becomes greater because the system support contractor will have greater technical knowledge and longer association with the system than military supplied operators. (There is an additional developer's document, *C3I Instrumentation Data Collection System Hardware Deployment Training Manual* [GE-EM-89-5, 8431501/M001, 14 Nov 89] that has not been evaluated. It probably needs to be combined with the software user's document cited above.)

Considerations similar to those presented in the discussion of this finding also need to be applied to the prototype DRS and to all subsequent C3I2 systems. Documentation requirements and documentation standards for subsequent versions should be considered now while the system is still in its relatively early stage of development. Because the future versions will be

significantly more complex than the prototype, questions relating to operator personnel selection and documentation become more significant factors.

2.3 Training Time

FINDING: From informal observations of the training provided to the system support contractor by the developing contractor, the prototype DCS appears to be relatively easy to learn and operate.

Impact: It is estimated that an effective training package would require less than a week to train a system operator educated at the high school level to perform DCS physical setup and operational tasks.

Comment: Trained tasks would include those peripheral tasks necessary to operate the DCS and support an operational test of a C3I system: site selection; vehicle preventive maintenance, checks, and service; hard-wire deployment, and so on; but not DCS system software management (software installation & modification, disk formatting, etc.) or other than routine system adjustment, repair, and maintenance. For these additional tasks, additional technical personnel would be required. Also, given less than one week of training, it would not be possible to include other than rudimentary training on the installation and operation of the SINGARS radio and associated equipment that may be present, such as the KY-57; however, minimal training on these subsystems may be quite sufficient for the purposes of C3I2.

2.4 Specific Training Deficiencies: Gaps in Operator and Maintainer Knowledge and Performance

Several performance and knowledge deficiencies were documented during the validation and revalidation tests. Because of such deficiencies, the DCS operator may not be able to take full advantage of the system's capabilities and documentation to solve operational problems efficiently. The solution lies in better training (see comment at Finding 2.1). Specific deficiencies are described in the following paragraphs.

2.4(1) Training of operational details.

FINDING: The training left to the students the task of learning by trial and error many of the fine points of the operational procedures.

Impact: Operators may not learn efficient operational procedures or how to respond to certain unusual or unanticipated conditions. For example, during the revalidation test, it was discovered that the operators disagreed about whether or not the TACFIRE DEVICE ID needed to be entered as a capital letter during a required channel configuration procedure. One operator had been using capitals unnecessarily--a small matter, undoubtedly, but one of many factors related to the streamlining of operations. In another, more significant instance (see Finding 2.4[7]), when the operators lost power to the shelter and tried to check breaker switches, they did not know which switches controlled which circuits, which caused a significant time delay before operations could be resumed. The switches had not been labeled (a human factors deficiency), and the training had made no mention of them.

Comment: A well-developed and administered training package would help to solve the problem.

2.4(2) Procedural changes.

FINDING: Certain system changes introduced by the developer during the period between the initial validation test and the subsequent revalidation test were not adequately communicated to the operators.

Impact: Operators experienced confusion; they were likely to experience setup or operational delays when the system did not perform as expected because of software or hardware changes. For example, on the first day of the revalidation test, the operators were puzzled about the procedure for configuring new channels, since a "NEW" option, previously available, had been removed from the list of primary options (see Finding 3.4[3]). Another example was the addition of a new tape recorder with no operational instructions.

Comment: Such problems are difficult to counteract with systems in a state of evolution, such as C3I2. Nevertheless, greater official emphasis on operator and maintainer training would help to alleviate the difficulties.

2.4(3) Electrical grounding of DCS shelter.

FINDING: While the system documentation describes normal grounding procedures ("pound the ground stake into the earth about 2 feet"), no discussion of alternative methods is provided. Also, as is true with many other systems, no method is provided for the operator to determine that a proper ground has been achieved.

Impact: In locations where it is not feasible to drive a grounding rod two feet into the ground, the likelihood of achieving a proper ground may be diminished.

Comment: System documentation should provide adequate discussion of grounding procedures for all operational situations that may be encountered (e.g., parking lot locations). To the extent that grounding of the system is important, it should be stressed in training. And, ideally, there should be a method for determining the adequacy of the ground once it is installed.

2.4(4) Geostationary Operational Environmental Satellite (GOES) antenna operation.

FINDING: During the revalidation test, one operator concluded that something was wrong with the GOES antenna equipment because he had waited "over 5 minutes" for satellite lock-up without success. Consequently, he readjusted the angle of the antenna, replaced the antenna cable, checked the antenna connection, and manipulated the GOES receiver panel controls. Ten minutes later the GOES receiver began to display the proper time. The system developer said that the problem may have been simply the "impatience" of the operator and that it normally takes the GOES receiver about five minutes to lock-up with the satellite.

Impact: If not waiting long enough for the receiver to accomplish satellite lock-up was the essence of the problem, then approximately 10 minutes was wasted making unnecessary corrections to the system because of the lack of sufficient procedural training.

Comment: The amount of time an operator should wait for lock-up should be established as an operational prescription, and training should include the information. The problem was not operator "impatience," but rather the lack of specific instructions on how long one should wait.

2.4(5) "Boot-up" procedures.

FINDING: An operator asked whether during boot-up an incorrect time entry could be corrected without starting the initialization over from the beginning. He believed it was impossible, which was true. He was unaware, however, that the correctness of the time entry is unimportant at this point. According to the developer, any time can be entered with no effect on the data collection system, since the latter uses GOES time.

Impact: The operator reported that he had been rebooting the system to correct erroneous time entries--a significant waste of time.

Comment: If the correct time is neither necessary nor useful to the system, it should not be required of the operator in the first place (a human factors problem). Because the system does, however, require the entry, operators should be informed in their training and in associated documentation that entry of the correct time is unnecessary.

2.4(6) TK50 data archiving.

FINDING: During the validation test, one or more of the operators could not provide self-satisfactory answers to the following questions: (a) How would the system respond should an imminent condition of "tape full" arise? That is, would the system provide an alert? (b) What happens when the tape is removed and replaced with another? That is, does hard disk archiving continue where it left off with the previous tape or go all the way back to the beginning to archive all the data again? (c) What is the correct procedure for switching tapes during data collection? (d) What happens when the operator tries to shut down the system with normal shutdown procedures before all data have been archived? One operator was of the opinion that normal shutdown procedures could be concluded before all data were archived and that, as a consequence, unarchived data on the hard disk would be lost. The operator could not find information pertaining to this question in the documentation available to him after searching for approximately three minutes.

Impact: Incomplete or erroneous knowledge of the data archiving process could lead to mistakes in data collection, data handling, troubleshooting, and problem solving procedures; and although the system guards against loss of data, the operator may be led to perform operations conducive to data loss and inefficient or ineffective operations.

Comment: Complete knowledge of the data archiving process is essential to efficient, sustained operations without loss of data or operational efficiency. Additional training needs to be provided in this area, and documentation should be complete and easily referenced.

2.4(7) Circuit breaker panel switches.

FINDING: An operator who was questioned about this panel was not familiar with the function of any of the switches. It is presumed that none of the operators had been trained in this subject (see also Finding 2.4[1]).

Impact: Operator inability to use the panel effectively.

Comment: Ensure that all equipment that must be understood and used by operators is included in operator training and system documentation.

2.4(8) Modem LEDs and labels. (See also Finding 3.5[23].)

FINDING: None of the system operators (/maintainers) knew the meaning of each row of indicator lights (light emitting diodes) on the modem panel. The eight rows have the following unexplained labels: TD, RD, DCD, CTS, RTS, DTR, DSR, and RI.

Impact: The labels are so cryptic as to be useless to the person who has not committed their meanings to memory. The operators knew the meaning of the first four rows of lights (although not the translation of all of their labels), but had only sketchy knowledge of the others. They constitute an operational and troubleshooting handicap.

Comment: All signals and labels should provide useful information to the operator; they should be fully explained and understood. Otherwise, they should be disabled and removed if feasible.

2.4(9) Computer panel display-control toggle switches. (See also Finding 3.5[30].)

FINDING: At least one of the operators was unfamiliar with the functions of the three toggle switches on the upper right-hand corner of the computer's front panel. Not all of these switches were functional in the DCS.

Impact: Operators may be unaware of the ability to switch the contents of the panel display.

Comment: These controls, as well as all others with which the operator should be familiar, should be illustrated, described, and discussed in system documentation; and their operation should be covered in training.

2.4(10) Computer access door. (See also Finding 3.5[28].)

FINDING: The operators were not given guidance regarding the tightening of the computer door screws, nor when, exactly, the door must be closed for security reasons. During the validation test, the door was frequently left open during operations.

Impact: Possible breach of security.

Comment: Appropriate guidance should be provided in training, and the doctrine should be clearly detailed in system documentation. The operator needs to know the answers to questions such as, Is the shelter secure-- regardless of whether the computer access door is closed--if the shelter door

is closed? If appropriate, the inside of the computer access door (exposed when the door is open) should have a caution or warning label.

2.4(11) Power generator.

FINDING: The engine fuel mixtures began to run rich several days into the validation test (see Finding 3.5[1]). The operators were unaware of the cause of and solution to the problem.

Impact: Possible loss of reliable power.

Comment: Operators and maintainers should be trained to avoid the problem by taking appropriate maintenance actions. The problem and its solution should be noted in system documentation.

2.4(12) "ORIGIN" & "SENDER" (RUNTIME SYSTEM screen).

FINDING: One operator reported that the distinction between these two concepts had not been made during training. He did not know the difference.

Impact: Degradation of operational effectiveness.

Comment: The meaning of all software interface items should be made clear, both in training and in documentation.

2.4(13) Operator checklist.

FINDING: There is no current listing of important tasks that should be performed during normal operations.

Impact: Some operators may forget to perform certain tasks that, while perhaps not critical to operations under many circumstances, could lead to serious consequences in unusual circumstances.

Comment: Place a short list of important reminders on the inside of the shelter door. The list should be located as high as possible on the door so that it will be noticed by operators entering the shelter. The list should include topics such as grounding requirements (ground rod depth, etc.), the requirement to have circuit breaker 13 in the off position prior to starting the generator, the advisability of operating with the computer panel lock in the locked position, and so on.

Section 3: Human Factors

3.1 User Interface Uniformity Between the Data Collection System & the Data Reduction System

FINDING: The developer originally intended to pattern the DRS user interface closely after that of the DCS. However, in light of the MANPRINT findings associated with the DCS (herein described), they began to question whether that approach should be followed. The arguments summarized in the comment section below were presented to the Army and the developer, and, consequently, a decision was made against emulation.

Impact: In emulating the prior developed DCS, the DRS would have a consistent and familiar "look and feel." However, such conformity would be achieved at the cost of having to incorporate known MANPRINT deficiencies of the DCS into the DRS.

Comment: Ideally, the DCS and DRS (as components of a single system) would have the same "look and feel." However, when one component (here, the DCS) is developed in advance of the other, the question arises, *Should the subsequent component incorporate "lessons learned" during the initial development if doing so tends to make the user interfaces dissimilar?*

Other considerations aside, the superficial aspects of the different components of a system should be designed to accommodate user's needs as students, operators, and maintainers of the system. Variables involved in design-for-user considerations include three that are particularly relevant to the present concern: (a) transfer of training (including negative transfer) from system component to system component; (b) retention of skill and knowledge levels over periods during which the system is not used; and (c) ease of learning, operating, and maintaining the system. They are discussed in turn:

(a) Transfer of training. Upon rare occasion, the unusual requirements of an upcoming Army operational test, may create a need for the operator of one C3I2 system component to cross train on the other. Normally, however, the DCS operator will not be a DRS operator, and the DRS operator will not be a DCS operator. Once the operational test is underway, the operator of one subsystem will not have to cross over to the other, because robbing one system component to fill a void in another would normally be an unsatisfactory solution; backup operators (including maintenance personnel, if necessary) will be available for both the DCS and DRS. (In an emergency, DCS operations would have to take priority.)

Positive transfer would be desired if an operator needed to switch between different, complex system components; but that is not the case with C3I2. Hence, the need for positive transfer of training is, here, at a minimum.

Furthermore, owing to the absence of complex operational requirements and the ample allotment of time in which to accomplish operational tasks in the C3I2 system, negative transfer of training between components should not be of great concern regardless of interface characteristics. Negative transfer would, nevertheless, tend to be minimized to the extent that the DCS and DRS interfaces were different.

So, under most foreseeable circumstances, the DCS and DRS operators will be different persons; and if, upon occasion, they were the same, neither positive nor negative transfer would be of great concern.

(b) Skill and knowledge retention. It is expected that both DCS and DRS operators (and, to some extent, maintainers) will experience significantly long periods of C3I2 inactivity during hiatuses between operational tests and that, consequently, there will be prolonged periods of little or no practice operating (or maintaining) the system. The system support contractor has noted, however, that their standard procedure is to exercise skills on a regular basis. Thus, if the Army supplies system operators while the system support contractor supplies maintainers (as recommended), the retention of

performance and knowledge levels may be more problematical for operators than for maintainers.

Retention will be directly correlated with the operational simplicity of the system. It is important, therefore, that both the DCS and DRS be designed for simplicity--especially the follow-on versions, which hold the promise of being considerably more complex than the prototypes. The prototype DCS interface is to a great extent complete at this time. But basic operations are sufficiently easy despite a considerable number of human engineering rough edges. The prototype DRS, incompletely developed at the time of this report, may be somewhat more difficult to operate. Thus, while DRS is still in an early stage of development, it is an opportune time to ensure that its user interface is effective and conducive to the easy retention of operating knowledge and skill.

(c) Maintainers and the operator interface. The maintainer may have to be familiar with both systems and may, therefore, require a passing knowledge of both DCS and DRS operators' jobs, but will not be required to be skilled in operations. Consequently, operator interface considerations are not of major importance to the maintainer either for the DCS or the DRS or for the relation between them.

All things considered, there appears to be little reason to take into account the interface design of the DCS in the design of the DRS, except insofar as shortcomings of the former can be avoided. Lessons learned from the DCS development effort should be referenced by the DRS developers without regard for a need to emulate the DCS. If anything, operation of the DRS should be made distinct from that of the DCS, which would be of benefit to the few users who may be required to operate or maintain both systems. The DRS interface designer should concentrate on making the interface easy to learn, easy to operate, and easy to remember. An attempt to make the interface characteristics of the two system components alike can only be to the detriment of the DRS, its users, and the C3I2 system as a whole. Finally, future versions of the DCS could benefit from lessons learned from the independent development of the DRS.

3.2 System Setup Time

DCS setup performance times were recorded on three days during the revalidation test, which employed the same operators as the original validation test. Hence, the operators were experienced, which lends credence to the time data as representative of moderately seasoned operators.

Setup started at approximately 0800 hrs with the "buttoned-up" DCS vehicle and attached trailer already in place at a predetermined trailer location. Weather and other physical site conditions were ideal. Two operators were present. Setup included the following major activities:

1. Detaching generator trailer from shelter vehicle, and associated tasks.
2. Positioning shelter vehicle, opening shelter, unpacking equipment, and associated tasks.

3. Deploying four antennas (receive/transmit, receiver-only, GOES, & test-coordination antennas), and associated tasks.
4. Booting-up computer, configuring DCS software, printing hard copy of configuration information, and associated tasks.
5. Hard-wire layout to five TACFIRE vehicles located within approximately 100 feet, and associated tasks.

FINDING: On Day 1, only start and stop times were recorded. Complete setup, including hard-wire layout, required 1 hr 35 min. On Day 2, the times to accomplish major steps in the setup procedures were recorded. Table 1 shows the setup timeline for the second test day. Note that cumulative time through achievement of data collection capability was 1 hr 18 min. The remaining time required to complete hard-wiring into the host system (here, TACFIRE) would be expected to be variable from system to system and situation to situation. Complete setup including the hard-wiring required 1 hr 45 min.

Table 1

Timeline for major setup tasks: Revalidation test, day 2

<u>Elapsed time (min)</u>	<u>Operator activity</u>
000	Start setup.
060	DCS software program started.
078	Computer prepared to collect data ("runtime system" up).
105	Last of 5 hard-wire connections to TACFIRE completed.

Table 2, slightly more detailed, shows the setup timeline for Day 3. Complete setup, including wire layout required 1 hr 33 min. Time to data collection capability was 52 min.

Table 2

Timeline for major setup tasks: Revalidation test, day 3

<u>Elapsed time (min)</u>	<u>Operator activity</u>
000	Start setup.
009	Computer turned on.
031	Computer self test completed; DCS software started.
052	DCS channel configuration started and completed; computer ready to collect data.
093	Last of 5 hard-wire connections to TACFIRE completed.

(A greatly expanded version of Table 2 is provided in the appendix. The value of the expanded table lies both in its detailed description of the nature of the DCS setup tasks and its potential for use in analyzing time requirements for significant setup subtasks and the development of critical task information.)

Impact: The requirement of an hour and a half for hard-wire setup under the most ideal of conditions (good weather; flat, unencumbered terrain; short distances, stationary system-under-test) complicates considerably the task of making hard-wire connections to a mobile system-under-test. Additional DCSs may have to be deployed to anticipated locations in advance of the system-under-test to allow sufficient time for data collection preparations. (See also Finding 3.3.) Once site location and preparation are completed, the DCS can, under ideal conditions, be prepared to collect radio traffic in approximately one hour.

Comment: Examination of the expanded table in the appendix shows that one of the largest consumers of setup time is antenna deployment. One operator worked alone for approximately 30 minutes on nothing but antenna deployment tasks. Both operators worked together for another 26 minutes only on antenna deployment tasks. Thus, the total clock time required for deployment of antennas was 56 minutes; while the total number of man minutes was 82. Since the number of man minutes required for all tasks necessary for data collection capability (by radio) was approximately 180, antenna deployment tasks consumed about 45% of the time required for data collection preparation. It stands to reason that a more easily deployed antenna system (e.g., hydraulic, pneumatic, or both) could substantially reduce the amount of time required for setup. (See also Finding 3.3, Comment.)

3.3 System Teardown Time

The time required to teardown the two primary antennas (receive/transmit & receive-only antennas), including the time to stow all related equipment (masts, guy lines, stakes, etc.) was recorded on the second day of the revalidation test. On the third day, a detailed record of all teardown procedures was kept. The procedures were, of course, essentially the reverse of the setup procedures and included the following major tasks:

1. Exit data collection software; conduct computer shutdown procedures; complete end-of-shift bookkeeping.
2. Stow and secure all loose equipment inside the shelter, including monitor, keyboard, and operator chairs.
3. Take down and stow antennas, guy lines, and related equipment.
4. Disconnect, spool, and stow field wire from system-under-test.
5. Disconnect and spool power and generator control cables.
6. Connect generator trailer to vehicle. Conduct final cleanup and stow any remaining items in preparation for transit.

FINDING: Teardown of the receive/transmit and receive-only antennas on Day 2 required 23 minutes. Table 3 shows the major tasks involved in teardown

and the associated cumulative timeline established on Day 3. Note that teardown was less time consuming than setup, as would be expected. (A much expanded version of Table 3 is found in the appendix. Like the expanded version of Table 2 for setup procedures, the expanded teardown table is useful for examining procedural details.)

Table 3

Timeline for major teardown tasks: Revalidation test, day 3

<u>Elapsed time (min)</u>	<u>Operator Activity</u>
000	Start teardown; begin computer shutdown.
002	Computer off.
007	Shelter equipment stowed and secured for transit.
024	Antennas down and stowed.
039	All field wire in and wound.
043	Power cables stowed.
046	Trailer connected to vehicle.
049	All equipment stowed; teardown complete.

Impact: Despite the shorter duration of teardown activities, the amount of time required is significant, especially when the purpose of the teardown is to allow movement to a new location in response to movement of the system-under-test. The amount of time required to teardown at one location and setup at another location (not including transit time and site location and layout) would, according to the present data, be approximately 2 hrs 20 min under ideal conditions. Transit time and other variables (e.g., weather) could add substantial amounts of time.

Comment: During teardown, the taking in of field wire and antennas were the major time consumers (see expanded teardown table in the appendix). Automatic antenna systems (as mentioned in Finding 3.2) would save much time. Additionally, consideration might be given to the notion of abandoning the field wire temporarily (to be recovered later, perhaps by another crew).

3.4 DCS Operator-Software Interface Deficiencies

Although the prototype DCS software interface as a whole is not complex, it is somewhat inelegant in most of its features, and some procedures are more complicated than necessary. The CRT screens often include unnecessary items and verbiage, but they normally lead the operator through steps in a manner that minimizes error even though certain important errors can and do occur. (Specific examples of interface findings are presented below.) As a consequence of the "roughness" of the software interface, inexperienced students of the system and new operators or maintainers may experience some confusion in learning and some time delays in operating the system. Experienced operators may overcome most of the learning hurdles, given sufficient time, though not all of the time delays, some of which are "hard-wired" into the system. In general, learning and performance decrements should not be of great import for the prototype DCS or DRS, but they promise to be of greater concern for follow-on versions now in development, especially the DRS.

3.4(1) *System start-up procedure.*

FINDING: The procedure required unnecessary participation by the operator. The console first conducted an automatic self test and then presented the operator the message "VT 320 OK." Here, the operator had to remember to press <Return>, followed by b (for "boot"), and <Return> again. The monitor then prompted for entry of the date and time, after which a series of messages that were not meaningful to the operator scrolled by, ending with "System logged out," a message that could easily be misunderstood. Then the operator had to press <Return> again to receive the messages "Welcome to Micro VMS 2.4.6" and "Username:" Here, the operator typed in the enigmatic term "exedir" (see Finding 3.4[30.7]) followed by <Return>. At this point a TK50 tape had to be in the tape drive to allow subsequent data collection. ("Exedir" has since been replaced with a more meaningful term.)

Impact: The new operator or student may be confused by the requirement to memorize unnecessary responses, view enigmatic messages, and wait during blank screens without feedback indicating whether or not machine processing is progressing in a normal manner.

Comment: The start-up procedures should be revised in a manner similar to the following: The first message "VT 320 OK" should be expanded to something like "Console OK. Press return key twice to boot system." (The two presses of the return key would allow the system supervisor or technician with knowledge of the appropriate command to intervene between returns for maintenance or troubleshooting operations. Other method for accomplishing the same effect could be devised.) The screen should then display a time filler (to indicate that boot-up is taking place) until the date-time prompt appears. When the date and time have been entered (without having to type in punctuation delimiters), the screen should return a message like "Please ensure that the TK50 tape is inserted in the tape drive if you wish data to be archived during data collection. Press <Return> to continue or <F14> ('EXIT') to quit." Upon pressing <Return>, the main menu should appear.

3.4(2) *Validation of system functioning.*

FINDING: There is no efficient, non-intrusive way for the operator to verify that the system is responding normally to an inactive external data environment.

Impact: If no "traffic" has been observed for a time, the operator may wonder if the system is working properly and be unable to make a conclusive test without interfering with ongoing data collection. (The impact of this problem would be expected to be minimal during a DCS test because of the communication channels established for test control. The DCS operator is made aware of when and when not to expect data transmission. During a normal deployment of C312, however, such communication channels can be expected to be considerably less dependable or, possibly, absent.)

Comment: Certain system features can provide relevant information to the operator: (a) The channel oscilloscopes might help the well-trained operator who can associate particular waveforms with particular emitters; (b) alert queues provided at the display reveal certain local DCS problems; (c) an internal, hard-wired self-test loop indicates whether the DCS hardware is functioning appropriately, but would interfere with ongoing data collection

activities. Some sort of non-intrusive, periodic means of system self-examination (for real-time as well as posttest analysis) would be useful and should be considered in future development efforts.

3.4(3) *Removal of "NEW" from the data collection start-up options.*

FINDING: During the DCS validation test, the initial menu allowed the operator to choose between resuming (RESUME) a previous data collection operation or starting anew (NEW). The NEW option was removed prior to the revalidation.

Impact: The advantage of this change is that the operator is prevented from accidentally choosing the NEW option, which reinitializes the system, erasing information from the previous session, including configuration information, alerts, information messages, and data collection summary data. At a minimum, this would cause an inconvenient time delay while the operator reconfigured the system. However, several disadvantages also accrue:

(a) The operator cannot begin data collection with a clean slate, so to speak. The configuration parameters can be revised, but certain information, such as screen clocks and message rates remain intact whether or not they are desired. They cannot be revised through normal operational procedures. The operators complained about the loss of the NEW option and the consequences: "I don't like that [expletive deleted] 'resume.'"

(b) The RUNTIME SYSTEM screen has a column (CHN) for channel numbers on the right-hand side that is supposed to indicate which of the channels are active during a given data collection session. After removal of the NEW option, this indicator appeared to act in a cumulative fashion: For example, if the previous session had had eight channels active and the current session had five of those eight active, the indicator would continue to show eight channels active. The usefulness of the CHN column is much reduced. (See also Finding 3.4[23].)

(c) In order to keep track of message counts and hours of operation, the operator must remember to make a note of the initial readings immediately after initiating the runtime system. If the message environment is active when the data collection is started, and the operator fails to take immediate note of the information, it cannot be subsequently obtained.

(d) The average messages per hour readout is meaningless at first and becomes accurate only after the first hour of operation. This anomaly occurs because the first hour's information is based on data collection activity in a previous session rather than on the current session.

Comment: From an operational standpoint, a better way to solve the accidental reinitialization problem would be to allow the NEW option, but to include with it a strong warning to the operator that information from the previous session will be lost. The operator should then be forced to perform a key sequence that would make accidental selection of the NEW option highly unlikely.

3.4(4) *Accidental exit from "Runtime System" (the F5 key).* (See also Finding 3.4[31.1].)

FINDING: During a human factors evaluation of the operator's keyboard interface, conducted during the revalidation test, it was discovered that pressing the F5 function key during the data collection process caused an immediate halt of the data collection software and the presentation of the underlying system prompt ">>>."

Impact: Data collection was in grave danger of accidental termination at all times. Fortunately, no data were lost during the test because of this deficiency.

Comment: Loss of data collection capability during an operational test is a serious problem. The haphazard or accidental pressing of the terminal keys (as might occur if the operator leaned on the keyboard or rested a clipboard on it) should not be able to terminate data collection operations.

3.4(5) *Channel configuration.*

FINDING: The operator cannot configure an additional channel, once data collection has begun. The data collection software program must be exited and rerun.

Impact: In an active data environment, reinitializing the runtime system would cause all incoming data to be lost during reconfiguration.

Comment: Ideally, the system should allow such revision of the configuration during data collection without interruption of the data collection process.

3.4(6) *Channel configuration feedback.*

FINDING: In the version of the software examined prior to the validation test, when the last parameter was entered for a channel during "channel parameterization," the system "beeped," apparently to indicate that there were no more parameters to enter for that channel.

Impact: The beep would be confusing to many new users, since it would often be interpreted as signaling an error (the typical meaning of such a signal on a personal computer).

Comment: As proposed, a different indicator was provided. The operator now receives a message on the screen rather than the beep. The beep sounds only if the operator attempts to continue beyond the end of the process; that is, it now appropriately indicates error.

3.4(7) *"CHANNEL SELECTION" screen.*

FINDING: Channel 10 appeared as "Channel 0."

Impact: Operator confusion.

Comment: The problem was reported to the developer and subsequently corrected.

3.4(8) *Tape dismounting.*

FINDING: During the validation test it was discovered that the F12 ARCHIVE DATA option did not actually cause data to be archived. Instead, it "prepared" the TK50 tape for dismount. Hence "archive data" was a misnomer. The label has now been changed to "dismount tape," which more closely reflects the actual function of the option.

Impact: Until the labeling was changed, the operators were confused about the purpose of the option.

Comment: While operator confusion has been eliminated, the system shortcoming that underlay the confusion still exists to a degree (see Finding 3.4[9]).

3.4(9) *Data archiving.*

FINDING: During the validation test, a software bug prevented periodic archiving of data either automatically or manually under the particular circumstances of the test (relatively low density traffic). The fault had been disguised and confounded by the mislabeling of the "dismount tape" option, which the operators initially thought provided them a means of manually archiving data at will (see Finding 3.4[8]). The problem was partially remedied prior to the revalidation test.

Impact: A hard disk failure prior to data archiving could mean the loss of test data. This was a serious shortcoming that required fixing.

Comment: The system will now archive data at intervals dependent upon the amount of data collection activity: The greater the density of data, the more frequently archiving occurs. For low density data environments, the archiving intervals could still be unacceptably long. Furthermore, the operator is still not permitted to archive data at will. A hard disk failure prior to data archiving could still mean the loss of test data. The system needs to archive data automatically at regular intervals specifiable by the operator or system supervisor and to allow discretionary archiving by the operator.

3.4(10) *TK50 tape backup.*

FINDING: No means for backing up the original TK50 storage tapes is provided at the DCS.

Impact: With current deployment planning there is a possibility (probability unknown) that collected test data will be lost.

Comment: During normal operations, data that have been collected onto the hard disk should be automatically copied (spooled) to the tape on a regular basis (as processor activity allows). The original data should also remain on the hard disk until it becomes full. As currently designed, when the disk is full, it begins to overwrite its oldest data, as necessary, to make room for new incoming data. If hard disk data should become unretrievable (for whatever reason), the TK50 archive tape is the only copy remaining until it is transferred to the DRS and copied into that system. Should the tape be damaged prior to analysis at the DRS, required test information may be unattainable. The Army tester has decided that because of redundancies in collected data at different DCS sites, the probability of a significant data

loss owing to hard disk failure would not warrant including additional tape backup hardware in the DCS. A formal assessment of this probability would require knowledge of message traffic densities, how the tapes would be handled during a given operational test of a C3I system (the amount of time it will take to deliver tapes to the DRS, etc.), and so on. It would be advisable to remember that such a loss is possible, despite its perhaps low probability in the "normal" test scenario.

3.4(11) *Cursor speed.*

FINDING: The cursor does not respond quickly enough to keep up with a key repeat, producing cursor skid in certain situations--as when the operator is erasing a line with a repeated backspace key.

Impact: If a key is repeated by holding it down, the cursor continues to move after the key is released; making it difficult to gauge how long to keep the key depressed. The problem may be only a minor irritation to most operators who notice it.

Comment: According to the developer, the trailing cursor results from slow processor speed, inherent in the current system. The problem may disappear if faster processors are used in future systems.

3.4(12) *Speed of screen rewrites.*

FINDING: Screen changes are slow and incremental. Parts of some screens are written horizontally (apparently resulting from the particular screen management utility used).

Impact: The process of going from one "mode" to another; conducting necessary start-up, shutdown, and operating procedures; accessing help and utility screens; and so on, is relatively tedious compared with the speed to which today's computer users are accustomed. In a menu-driven program like this one, the operator accomplishes many functions by moving in and out of menus, which makes the slow response time especially noticeable.

Comment: The system developer notes that the speed of screen updates is determined by both the hardware and the screen management utility and is currently unavoidable for all practical purposes. As in the previous finding, the solution may lie in faster processors.

3.4(13) *"ABORT PRINT."*

FINDING: Prior to the validation test, the option ABORT PRINT tended to be confusing, appearing at times to be available when it was not.

Impact: Operator confusion.

Comment: The developer corrected this "bug" prior to test.

3.4(14) *"Virtual" function keys.*

FINDING: The DCS employs an ineffective operator interface technique using so-called "virtual function keys," which are representations of keyboard

function keys displayed in boxes across the bottom of the operator's monitor.

Impact: This feature, which is in reality an ill-designed on-screen menu index, tends to slow down function selection unnecessarily, wastes screen space that could be better devoted to other information or blank space, and may increase the probability that the operator will inadvertently press an incorrect function key. This menu index was probably directly responsible for at least two instances of inadvertent reinitialization of the DCS front-end processors during the validation test. The operators were occasionally observed requiring excessive amounts of time (on the order of 2 to 4 seconds) just to determine which function key to press to select a desired menu item.

Comment: Any of a number of other selection devices for menus are available that would be a significant improvement over the "virtual" keys. Keyboard keys should be indicated on the screen, adjacent to the menu option, whether listed vertically or horizontally. An example of a six-item horizontal menu would be:

1 Archive; 2 Clear Alert; 3 Freeze; 4 Refresh; 5 Setup; 6 Utilities.

This example would easily fit across one line at the bottom of an 80-column screen. The cursor would default to one of the innocuous options in the menu (Freeze or Refresh). The "virtual" function key feature should be avoided in future developments. The system developer has discontinued use of the term "virtual function keys" (a term that may be confusing to new operators), but, in the prototype DCS, not the feature itself.

3.4(15) Overemphasis of "EXIT" & "HELP" options.

FINDING: Most of the screen menus include EXIT and HELP as basic menu items that are given equal status (emphasis) with other menu selections that are much more likely to represent the sought-after functions.

Impact: The unnecessary and repetitive presentation of EXIT and HELP as basic menu items tends to make it more difficult for the viewer to glean the appropriate information from the menu. It also reduces the amount of available screen space, which, in turn, may necessitate the creation of unnecessary and conceptually complicating sub-menus.

Comment: These two menu items need to be treated separately from the others. A menu should contain only those selections that are major operational options at the time the menu is displayed. The screen predominance of the EXIT and HELP items should be minimized by relegating them to the upper or lower screen corners, or by other means.

3.4(16) Non-utilization of "HELP" facility.

FINDING: The operators made essentially no use of the help screens during either the validation or revalidation test.

Impact: The help facility is wasted.

Comment: The initial version of the help feature was inadequate because many help screens were missing and those that existed provided little real help. Prior to the revalidation, the developer enlarged upon the help facility, but

it was still not used. The later version was not evaluated, but its disuse was probably related to its lack of salience and the operator's anticipation that it would not be helpful.

3.4(17) Mode selection "HELP" screen.

FINDING: The screen simply repeats information already provided by (or easily deduced from) the MODE SELECTION screen itself. Part of the wording is awkward: The explanation for the menu item "CONFIG CHANS" is "Prepare channel parameters for use," which indicates that the parameters are being prepared for use, rather than the channels.

Impact: The content of this help information is of little or no use. It wastes time.

Comment: In general, help screens should not be provided if the information presented does not give the operator significant additional information. A simple rehashing of information already at hand is not useful. Such information wastes time and may be a source of frustration to operators.

3.4(18) Self test.

FINDING: This utility, still in the design stage, is limited. A "bug" was noted in the current prototype version.

Impact: At one point after the F11 SELF TEST option is selected, the operator cannot abort the procedure even though a menu providing that option is presented.

Comment: While, according to the system developer, this problem may continue to exist in the prototype system, there are plans to devote considerable attention to further development of the self-test utility.

3.4(19) "SELF TEST UTILITY" screen.

FINDING: In preparation for conducting the self test, the operator is forced to proceed through this screen, which is essentially an unneeded help screen.

Impact: Entering the self test is more cumbersome and time consuming than it need be and gives the impression of being more complicated than it really is.

Comment: Such screens should be included in the optional help facility rather than as a part of the required operational sequence.

3.4(20) Mis-referencing of "RUNTIME SYSTEM" screen.

FINDING: This screen is referred to in the operator's manual as a menu screen. Its basic function, however, is to provide information rather than to provide options.

Impact: The student may be confused by the fact that this "menu" is not a menu.

Comment: The screen should be referred to as a display rather than a menu.

3.4(21) *Runtime system clock.* (See also Finding 3.4[30.2].)

FINDING: During data collection, the monitor keeps track of the amount of time elapsed since the last system initialization. This clock is labeled "TEST TIME," the meaning of which may not be immediately apparent to the student or operator, and which is a misnomer if the system has been reinitialized since the beginning of the test (a likely event during the validation test).

Impact: The usefulness of the clock is diminished.

Comment: It may be useful for several reasons to allow the operator to modify the clock from the keyboard: (a) The times at various DCS sites could be easily coordinated through time hacks; (b) the clock could be used by the operator to time various test events; (c) the clock could be reset to reflect cumulative times even if the system has been reinitialized during the test. Furthermore, it might be useful if two such clocks were available (perhaps occupying the same screen space via a toggle): One could be used as a timer, as mentioned, while the other is cumulating run time. Also, the name of the clock should be changed (see Finding 3.4[30.2]).

3.4(22) *Runtime system message rates.*

FINDING: "MSG RATE" and "TOTAL MSG RATE" on the RUNTIME SYSTEM screen are given with two decimal places.

Impact: Unnecessary precision. Screen clutter (see also Finding 3.4[27].)

Comment: Show as whole numbers. One operator raised the question, Of what operational importance is the total message rate? He could not think of any possible use for the information. If the information is indeed of value, then operator training and system documentation should inform operators of its purpose and importance; if not, it should be removed. Would message rate during operator-specifiable intervals be of greater or additional value?

3.4(23) *Runtime system active-channel indicator.* (See also Finding 3.4[3], Impact [c].)

FINDING: The far right column on the screen presents a column of channel numbers. The active channels are highlighted. The label "CHN" above this column does not indicate the purpose of the column.

Impact: The student must overcome the inadequacy of the column heading.

Comment: Short of revising the whole screen, the column heading could be changed to "ACT CHN," meaning "active channels" (with the first abbreviation placed over the second in the column heading).

3.4(24) *Presentation of alerts.*

FINDING: During the validation test, the "alert" line at the bottom of the operator's screen continued to flash messages (some informational, others bona fide alerts) until the operator manually canceled the message. New messages overwrote previous ones. The operators were frequently observed operating for long periods of time (e.g., all day) with an uncanceled message

flashing. Alerts were not accompanied by audible signals. The method of presenting system alerts to the DCS operator was greatly improved during the interval between the initial and subsequent validation tests.

Impact: Because the operator was not forced to act upon alert messages (such as "TAPE NOT MOUNTED, NOT MOUNTED CORRECTLY, OR RED BUTTON NOT PRESSED. S: 7471700"), a message could continue to flash indefinitely. Incoming messages, which overwrote the flashing message, could therefore have gone unnoticed and could themselves be overwritten by yet newer alerts.

Comment: The method of visual alerts presentation is now considered good. They are presented very noticeably in the middle of the monitor screen, and appropriate action is required. They are still not accompanied by audible signals.

3.4(25) Alert follow-up.

FINDING: Currently, alerts are presented with no prescribed action indicated for the operator. Many different alert messages are possible.

Impact: The operator may not know what action to take, if any, in the presence of some system alerts. The meaning of the alert may not be understood.

Comment: Each alert should force the operator to respond in some way with appropriate available options.

3.4(26) Alert message content.

FINDING: Many different messages are possible, and some of them, owing to their technical content, may not be understood by the operators. The alerts are not documented.

Impact: Without complete documentation of alerts, including their meaning and prescribed action, the operator may not be able to take appropriate action.

Comment: Each alert message should be accompanied by an identifying number that can be referenced in the operator's manual. The documentation should prescribe appropriate operator action for each message. Highly technical alerts could be presented on the operator's display as a reference number only. No information should be presented on the display that is not understood by the operator (such as "S: 7471700" in the message "TAPE NOT MOUNTED, NOT MOUNTED CORRECTLY, OR RED BUTTON NOT PRESSED. S: 7471700").

3.4(27) Screen clutter and message reports.

FINDING: Some of the screens are cluttered with unnecessary verbiage. One example is the "MESSAGE REPORTS" screen. The operator's manual depicts the following:

MESSAGE REPORTS

MESSAGE REPORT PARAMETERS

ENTER STARTING TIME FOR REPORT DD-MMM-YYYY HH:MM:SS

ENTER ENDING TIME FOR REPORT DD-MMM-YYYY HH:MM:SS

ENTER CHANNELS FOR REPORT ALL

ENTER CLASSIFICATION CODE (1-4) ... UNCLASSIFIED

[1-UNCLASSIFIED, 2-CLASSIFIED, 3-SECRET, 4-TOP SECRET]

The word "message" appears twice. The word "report(s)" appears five times (not including an additional occurrence on the "virtual" function key line not shown here). The word "enter" appears four times.

Impact: Screen clutter requires longer reading time and causes the screen to lose distinctiveness: The intent of the screen may be less clear; any options on the screen may be less distinguishable from one another; and the screen may be less distinguishable from other screens. The net result is increased operational and training difficulties.

Comment: All screens should be reviewed for unnecessary clutter and revised accordingly. The example shown above could be revised as follows:

MESSAGE REPORT DEFINITION

CURRENT TIME IS: HH:MM:SS

START TIME: DD MMM YY HH MM SS

STOP TIME: DD MMM YY HH MM SS

CHANNELS: ALL 1 2 3 4 5 6 7 8

CLASSIFICATION CODE: UNCLASSIFIED
CONFIDENTIAL
SECRET
TOP SECRET

The cursor should jump to the appropriate positions for date and time. Start time should default to the date and time of the first message logged since start-up. Stop time should default to the current date and time. Channels

should default to ALL (other choices selected by highlighting with arrow key and space bar or return key). Classification should default to "unclassified" (others chosen by highlighting or by toggling [not shown]). Variations on this general approach are, of course, possible. Note the inclusion of current time for operator's reference.

3.4(28) *"EDIT WHICH CHANNELS?" procedure.*

FINDING: The operator is unnecessarily required to have learned and remembered the proper response format.

Impact: This shortcoming constitutes an easily avoidable cognitive requirement placed upon the student and operator.

Comment: It is unnecessary (and inconsistent with other procedures) to require the operator to generate a response and a format at this point. The possible response options could easily be presented in a small menu from which the operator could choose the appropriate items.

3.4(29) *Conceptual complexity (menus).*

3.4(29.1) *Unnecessary categorization of options.*

FINDING: The operator interface, while simple enough in many ways, is to some extent unnecessarily complicated by subdividing primary options into two separate menus. Thus, the UTILITIES option on the current MODE SELECTION screen calls for a sub-menu, the UTILITIES SYSTEM screen, containing additional selections that could be presented on the parent screen. Adequate room is available on the parent screen, especially if the "virtual function keys" were removed (as they should be; see Finding 3.4[14]).

Impact: The operator's conceptual picture of the overall system and the way it operates is made unnecessarily complex. System operations may be harder to learn, slower to perform, and more prone to operator error than necessary.

Comment: The following is suggested as one possible alternative to the currently separate MODE SELECTION and UTILITY SYSTEM screens:

PRIMARY OPTIONS

F6	Alerts	
F8	Configure Channels	
F10	Begin Data Collection	
F11	Channel Statistics	-----
F12	Configuration Parameters	-- -- Status Reports
F13	Message Summary	-----
F14	EXIT	
		F15 HELP

The screen would appear with the first alternative, **Alerts**, highlighted; at which point the operator could select **Alerts** in any of three ways: by pressing the F6 key, by pressing the bolded "a" key, or by pressing the return key. Similarly, other menu items could be chosen by pressing the associated function key, the bolded letter, or by using the arrow keys to highlight the selection and then pressing the return key. (Particular items in menus could be grayed whenever they are temporarily unavailable as choices.)

The advisability of categorizing operation options and then presenting each category in a separate selection menu is dependent on a number of factors, among which the following three are especially relevant here: (a) the conceptual relation among the categories; (b) the amount of available screen space; and (c) the speed with which the screen management software presents the screens. If categories exhibit dependencies, and screen space is at a premium, and speed is fast, then separate presentations tend to be more justifiable. On the other hand, the extent to which categories and the items within them are parallel, and the greater the amount of available screen space, and the slower the processor, the less the advantage in separate menus.

In the DCS, the primary operating options can be considered parallel (existing dependencies can be shown on the same screen, as for Status Reports shown in the illustration above), screen rewrites are quite slow, and ample screen space is available.

Combining the current MODE SELECTION and UTILITY SYSTEM screens would, of course, have ramifications for the design of other related screens.

3.4(29.2) Listing of menu items.

FINDING: (a) In one top-level menu the option items were not listed in logical sequence. (b) Another instance in which a menu item was not a viable option was observed.

Impact: (a) Operators may be led to attempt procedures in the wrong sequence.
(b) Operators may experience confusion when trying to exploit unavailable options.

Comment: Generally, menu items should be listed in a logical sequence related to efficient and orderly system operation. For example, selections that are often chosen before others may best be placed at the beginning of the menu. It goes without saying that all menu options should be selectable, unless temporarily suspended with appropriate indication. Both noted instances were corrected by the developer.

3.4(30) *Conceptual complexity (terminology).*

FINDING: The terminology used to name and describe the operations, processes, menus, and other system components is sometimes enigmatic, inconsistent, overused, easily confused, or easily forgotten--especially for the newcomer. For example, the terms "MODE" (as in "MODE SELECTION") and "SYSTEM" (as in "UTILITY SYSTEM") tend to complicate rather than simplify matters conceptually for the operator. Detailed examples and discussions are provided in subparagraphs 3.4(30-1) through 3.4(30-16).

Impact: Teaching system operations to new students is made more difficult. Student retention of learned information is less stable. The subtle confusions that may result from the inadvertently careless use of terminology contribute to operator error and system failure.

Comment: Persons who have had a long-time relationship with a system tend to be insufficiently appreciative of the extent to which "everything is new" to the naive observer, student, or operator. The terminology used to describe a system is an important factor contributing to the ease of learning and remembering system operations. The meaning of all labels, titles, and the like, that are presented to a student or operator should be immediately apparent; they should not themselves constitute additional learning tasks. (There are, of course, situations in which physical space or other constraints require the coding of information into short or otherwise cryptic forms that must be learned by operators before they become useful guides.) The need to learn and remember special terminology in order to effectively operate a system should be minimized. Simple alternatives for such terms can often be substituted. (For example, "MODE SELECTION" and "UTILITY SYSTEM" could be replaced by alternatives such as "OPTIONS," "SELECT ONE," or the like.) A conscious effort by hardware, software, and documentation developers must be exerted to overcome the inertia of their experience in order to create a user interface that will minimize learning problems, maximize learning and operational speed, and maximize the retention of knowledge and skills.

3.4(30.1) *Term: "System."*

FINDING: The term "system" is overused because the developer tends to present the system (i.e., the C3I2 system) to the operator and student as a collection of related systems rather than as a single system with several related functions. The term "system" appears in the following:

- "C3I2 System"--the system
- "Data Collection System" ("DCS")
- "Data Reduction System" ("DRS")--the DCS and DRS are two physically and functionally separate system components requiring different operators
- "RUN SYSTEM"--the command to start data collection within the DCS
- "RUNTIME SYSTEM" and "Runtime Subsystem"--both used to refer to the DCS data collection function
- "UTILITY SYSTEM" and "Utility Subsystem"--both used to refer to a small collection of functions providing operational status information
- "SYSTEM QUEUE"--one of several sets of notices, or "alerts," that reveal operational problems
- "Operating system"--which, according to the operator's manual, refers to both "overall system operations" and the computer's software "operating system" (VMS)
- "System logged out"--the boot-up message referring, not to the C3I2 Data Collection system, but to lower level software

Impact: The inexperienced student operator may find it difficult to conceptualize the C3I2 system (the manner in which its components are related), and the resultant operating skill level may be lower than necessary. The greater the complexity of any system, or the inadequacy of the system-user interface, the greater the tendency for some operators to learn little more than that necessary to make the system work at a minimal level.

Comment: The terms "Data Collection System" and "Data Reduction System" can be tolerated because they describe very discrete aspects of the overall system; however, they would be better described as "components," "facilities," "elements," "modules," or the like, rather than "systems." Other simple changes would also help to clarify the conceptual portrayal of the system. Examples: (a) The command "RUN SYSTEM" (an option on the MODE SELECTION menu) should be something like "COLLECT DATA" or "BEGIN DATA COLLECTION," both of which more accurately reflect actual functionality; (b) an alternative for "RUNTIME SYSTEM" (the name of the data collection display screen) could be "DATA COLLECTION," or the like; (c) "RUNTIME SETUP" could be "DATA COLLECTION SETUP"; (d) "UTILITY SYSTEM" could be simply "UTILITIES"; (e) "SYSTEM QUEUE" could be changed to "COMPUTER," "GENERAL," or some other term that accurately reflects the meaning of this alert category.

3.4(30.2) Term: "TEST TIME."

FINDING: This heading, which appears on the RUNTIME SYSTEM screen, is not necessarily indicative of the time shown. If the operator reinitializes the system, either accidentally or purposefully, the time will not be cumulative from the beginning of the test. (See also Finding 3.4[21].)

Impact: Interpretation of the time shown is ambiguous.

Comment: A term like "CUM[ulative] RUN TIME" would be less confusing because it would imply duration of the current run.

3.4(30.3) Term: "Queue."

FINDING: This term, as in "ALERT QUEUES," "SYSTEM QUEUE," "HARDWARE QUEUE," "SOFTWARE QUEUE," "CHANNEL QUEUE," and "MISC QUEUE" may be new to some student operators.

Impact: It constitutes a small, nonfunctional obstacle that the student may have to work around. It may detract from understanding and does not elucidate operations. It clutters the ALERT QUEUES menu screen.

Comment: The term does not significantly improve understanding and should be dropped. The so-called "alert queues" could be simply referred to as "alerts."

3.4(30.4) Term: "Runtime."

FINDING: This term, which appears in "RUNTIME SETUP" and "RUNTIME SYSTEM," is not inherently meaningful.

Impact: The student operator must learn and remember that its meaning is simply "data collection," an unnecessary requirement.

Comment: The term should be abandoned and replaced by "DATA COLLECTION."

3.4(30.5) Term: "Self Test Utility."

FINDING: The self test is not a part of the "utility system," as one might expect on the basis of the terminology.

Impact: Additional confusion for the student or operator.

Comment: Drop the use of "utility" in connection with the self test. Refer to the self test simply as the "self test."

3.4(30.6) Term: "Mode."

FINDING: The term is used in "MODE SELECTION," which refers to primary operational options available to the operator in preparing for data collection.

Impact: The word "mode" complicates the student's picture of the system by suggesting one must enter different "modes" of operation to accomplish different objectives.

Comment: A simpler approach is to treat the alternative menu items simply as alternative choices--as shown in the sample screen (PRIMARY OPTIONS) depicted in Finding 3.4(30.1). While it is possible that the "mode" concept was useful during system development, it is not useful to the operator.

3.4(30.7) Term: "EXEDIR."

FINDING: During training and the validation test, operators had to type the esoteric term "exedir" during start-up procedures (see Finding 3.4[1]).

Impact: Initially, the term was not meaningful to the operators; it may have remained so for some. Furthermore, at this point in the procedures, it should have been unnecessary to enter any command at all.

Comment: The term "exedir" derives from "directory of executable files" and was handy for programmers involved in developing the system software. It should not be required of the operator.

3.4(30.8) Term: *"Top-level."*

FINDING: This term, which appears in the operator's manual to refer to initial menu options, is not a term well known to the layman.

Impact: A learning obstacle.

Comment: Either define it when first used or replace it with "main," "primary," "initial," or the like.

3.4(30.9) Term: *"DATA COLLECTION SYSTEM" menu.*

FINDING: This main menu, which appears after the system is booted, is not well named. The menu does not list all primary components of the so-called data collection "system." What is more, the operator has, just before receiving this menu, been informed by the "system" that the "system" has "logged out" (see Finding 3.4[1]).

Impact: The operator may misconstrue the meaning of the term "system" (see Finding 3.4[30.1]).

Comment: Retitle the menu "MAIN MENU."

3.4(30.10) Term: *"Front end processors."*

FINDING: This term, which appears in screen menu items and in the operator's manual is not defined and is not meaningful to computer illiterate persons.

Impact: Lack of understanding or confusion about the purpose and functioning of certain operational options.

Comment: Replace with an innocuous but meaningful term such as "data collection processor" or other appropriate lay designation.

3.4(30.11) Term: *"PARMS," "PARAMS," "parameters," & "parameterization."*

FINDING: The first two both appear as abbreviations for "parameters." The terms are not defined.

Impact: Some operators will have to learn the terms or follow instructions without a clear understanding of their meaning.

Comment: While "parameter" is familiar enough to persons with technical or professional backgrounds, it may be new to the DCS operator. Neither of the two abbreviations is desirable if avoidable; if used, "PARAMS" is preferred to

"PARMS." "Parameterization" should be avoided, as in "CHANNEL PARAMETERIZATION MENU"--this menu appears in response to selecting the "CONFIG CHANS" option on the MODE SELECTION menu, and could, therefore, be re-entitled "CHANNEL CONFIGURATION MENU."

3.4(30.12) Term: "SEE PARMS" & "SHOW PARAMETERS."

FINDING: The INPUT/EDIT PARAMETERS menu presents the option "SEE PARMS," which produces a screen entitled "SHOW PARAMETERS." The terminology is inconsistent, and the word "show" is inappropriate.

Impact: Operator confusion.

Comment: "SEE PARMS" should be "REVIEW PARAMS" (if the "virtual" function keys are retained on the screen), and "SHOW PARAMETERS" should be simply "PARAMETERS" or "CURRENT PARAMETERS," or the like.

3.4(30.13) Term: "RESULTS FROM TEST ALL CHANNELS."

FINDING: This is the title of a screen that may appear after the self test is conducted. The wording is awkward.

Impact: The intended meaning may not be immediately apparent to the student or operator.

Comment: Better wordings would be: "RESULTS FROM ALL-CHANNEL TEST," "RESULTS: ALL-CHANNEL TEST," "ALL-CHANNEL TEST RESULTS," or the like.

3.4(30.14) Term: "PREV SCREEN."

FINDING: This command is unnecessarily cryptic.

Impact: Possible misunderstanding as "preview screen" rather than "previous screen."

Comment: Change to "PRIOR SCREEN."

3.4(30.15) Term: Menu headings & screen generating commands.

FINDING: Some of the screen menus have unnecessary dual headings. Examples are: "REVIEW CONFIGURATION" (subheading: "CURRENT ACTIVE CHANNEL CONFIGURATION"); "REVIEW STATISTICS" (subheading: "CURRENT CHANNEL STATISTICS"); "MESSAGE REPORTS" (subheading: "MESSAGE REPORT PARAMETERS"). The subheadings tend to be redundant and somewhat inconsistent with the primary headings. The commands (options) selected by the operator to produce these screens are often semantically inconsistent with the screen titles they produce. Examples: The command (option) REVIEW CONFIG produces a screen called "REVIEW CONFIGURATION," which should be "CONFIGURATION REVIEW"; the command (option) "CHANNEL STATS" produces the screen "REVIEW STATISTICS," which should be "CHANNEL STATISTICS"; the command (option) "MESSAGE REPORTS" produces "MESSAGE REPORTS," which shows, not message reports, but message report parameters and, therefore, should be entitled "MESSAGE REPORT PARAMETER SELECTION" (an extension of the screen's subtitle, which is "MESSAGE REPORT PARAMETERS") or, perhaps better, "MESSAGE REPORT DEFINITION"; the command

(option) "MAKE REPORT" produces "REVIEW REPORT," which should be "MESSAGE REPORT."

Impact: Student and operator confusion.

Comment: The information provided by the dual headings would be more effectively presented in single, logical headings that correspond semantically to the commands, or menu options, that generate them.

3.4(30.16) Term: "START OVER" (F10).

FINDING: The meaning of this option, which is presented on the MESSAGE REPORTS screen, may not be clear to the operator because what is to be restarted is not clearly indicated.

Impact: The operator may wonder how far back into the procedures the function will loop and, consequently, may hesitate to use the feature when it would be appropriate.

Comment: The option should be given a more informative name that indicates "reset message report parameters to default values." Of course, the "virtual" functions keys do not allow room for more than two groups of seven characters each to describe any given function--another reason for abandoning this cumbersome screen index.

3.4(31) *Operator Errors Resulting from Software Interface.*

Two types of errors occurred that could be attributed directly to deficiencies in operator-software interface:

3.4(31.1) *Accidental reinitialization.* (See also Finding 3.4[4].)

FINDING: During the validation test, accidental rebooting of the system occurred easily. If EXIT (F14) was selected from the RUNTIME SYSTEM screen (either accidentally or purposefully), the operator could not return to the screen without the front-end processors being reinitialized. No warning was given to the operator. Prior to the revalidation test, revisions to the software effectively solved the problem of accidental reinitialization via the EXIT function key (although see Finding 3.4[4]). Three examples of documented accidental reinitialization via the EXIT function are described:

(a) In one recorded instance, the operator reported that the system did not provide sufficient warning when he "pressed the wrong key."

(b) In another instance a system engineer reported that he had accidentally shut down the system when coming out of the quick-look procedure before he realized what was happening; he did not know what exact sequence of steps produced the result.

(c) A third instance appeared related to the second: The operator reported that the following sequence produced accidental reinitialization: 1--In RUNTIME SYSTEM; 2--Pressed F13 UTILITIES; 3--Chose ALERT QUEUES from UTILITY SYSTEM menu; 4--Received AITG ALERT; 5--Pressed F14 EXIT; 6--In UTILITY SYSTEM menu; 7--Pressed F14 EXIT; 8--In MODE SELECTION menu; 9--Should have pressed

F14 to return to RUNTIME SYSTEM, but pressed a different key by mistake [which key, unknown], which reactivated the front-end processors without warning.

Impact: Accidental reinitialization via the EXIT function would not reliably reactivate all of the previously active channels and, obviously, involved the possible loss of important test data.

Comment: Reinitialization or shutdown of the system should be possible only after the operator has been strongly warned of the consequences and has been required to perform an operational step that is sufficiently dissimilar to all other procedures to minimize the possibility of pressing inappropriate keys out of habit. Software revisions incorporated after the validation test effectively achieved this goal.

3.4(31.2) Zero vs. the letter O.

FINDING: The operator, attempting to follow instructions in the documentation for a diagnostic test, typed the letter instead of the number. The documentation showed the number zero without a hash mark; the operator read it as the letter O.

Impact: The operator was unable to perform the desired test.

Comment: The distinction between Ø and O should be clearly indicated in the operator's documentation by including the hash mark across the number.

3.5 DCS Operator Hardware Interface

The following hardware shortcomings were observed:

3.5(1) Power generator.

FINDING: According to the system developer, the generator engine is known to have the tendency to run rich after several days (50 hours) of operation. The spark plugs in the two center cylinders, which are closest to the center of the intake manifold, tend to get fouled. When this occurred during the validation test, replacement plugs were not immediately available. (See also Finding 2.4[11].)

Impact: Power source becomes unreliable. The two spark plugs must be changed.

Comment: Extra plugs should be carried with the system at all times.

3.5(2) Power cable connector.

FINDING: The power cable connector on the vehicle exterior has a collar that tightens counterclockwise from the installer's position.

Impact: The requirement to tighten the connector by turning the collar counterclockwise is counter intuitive and tends to fool new personnel until they learn that the correct procedure is "backwards."

Comment: It was suggested that some sort of directional arrow and a legend be placed on or near the cap. The developer added appropriate labeling prior to the validation test.

3.5(3) *Fire extinguisher.*

FINDING: The locking pin on the handle of the fire extinguisher included with the equipment was not retained with a seal. It was easily removable.

Impact: The absence of a seal causes a potential user to question whether the canister is charged appropriately. The canister could have been accidentally emptied.

Comment: The problem was corrected by the developer prior to the validation test.

3.5(4) *GOES antenna.*

FINDING: The turn screw for locking the satellite antenna mount in position is not captive.

Impact: The screw could be lost, especially during vehicle movement, when it could vibrate loose if not tightened down.

Comment: All operated screws, pins, locks, tie downs, and the like should be captive to prevent accidental loss. (The GOES antenna itself is normally stowed safely during movement.)

3.5(5) *GOES antenna lead wire.*

FINDING: The wire is strung loosely over the top of the shelter from the antenna to the connector on the side of the shelter.

Impact: The ample slack in the wire would allow a brisk wind (less than 35 mph) to blow the wire off the shelter top and down across the back of the shelter and the shelter door. Although perhaps unlikely, the wire could be damaged by the opening and closing of the heavy door, especially if it were to fall between the hinge edge of the door and the outside shelter wall when the door is open.

Comment: Although the presence of the curbside receive/transmit antenna mast, when it is mounted, would help to keep the GOES antenna wire on the roof of the shelter. An additional helpful measure would be to attach a guy device atop the shelter near the rear curbside corner where the wire could be secured. An interim substitute for the latter procedure would be to tie off the slack at the handhold located topside.

3.5(6) *Junction box (shelter exterior).*

FINDING: During the validation test, some of the Velcro strips that hold the canvas flaps in place when the cover is raised were beginning to come loose.

Impact: The flaps are seldom used, but there may be times during which they should be used, as during certain severe weather conditions. Without effective fasteners the flaps will not be used.

Comment: Prior to the revalidation test, the loose strips were replaced.

3.5(7) *Padlocks.*

FINDING: Padlocks were provided for locking the antenna storage tubes and the exterior storage compartments, but there was no method provided for temporarily closing these spaces if the padlocks became unavailable.

Impact: The storage compartments could not be used during transit without a means of securing their openings.

Comment: Prior to the validation test, the developer secured the padlocks at their appropriate locations with chains.

3.5(8) *Padlock retaining chains.*

FINDING: There are two padlock chains on each of the two exterior storage compartments doors. Each of the four chains forms a stiff, three- to four-inch loop that protrudes approximately two inches outward from the widest part of the vehicle.

Impact: The chains are vulnerable to catching on brush or other objects that might be encountered in tight maneuvering.

Comment: The retaining screw for each chain needs to be relocated so that while the padlocks are in place the chains are situated horizontally in a straight line, allowing sufficient slack only for installation and removal of the padlocks.

3.5(9) *Shelter door (ladder hanger).*

FINDING: During the validation test, there was a ladder hanger on the inside of the shelter door that was not used or needed.

Impact: Probably minimal; but the hanger could catch on clothing or otherwise get in the way.

Comment: A new staircase ladder with improved foot traction, which replaces an earlier version that used the hanger, is now stowed in the generator trailer. Prior to the revalidation test, the hanger was removed.

3.5(10) *Tie-downs.*

FINDING: Rubber bungee straps are provided as tie downs for equipment during vehicle movement. Within the shelter they are used to secure such items as the CRT monitor and keyboard, the operator chairs, a tool case, and a first aid kit. In the generator trailer, they are used to restrain extra fuel cans and other equipment. One operator reported an occasion in which one of the straps broke during application.

Impact: The straps provide an interim solution for securing equipment, but they are awkward to install and possibly unreliable. Because they are not customized for specific applications, they require the operator to decide where and how to attach them--there is no prescribed way. They may be lost or misplaced and constitute a supply requirement. The item most at risk is the CRT monitor.

Comment: The CRT shelf should provide secure attachments (e.g., hasps, or other easily operated connectors) for the CRT. Each item of equipment requiring stowing and unstowing and which is subject to damage or which may damage other equipment during movement should be provided customized stowage with built-in, easily-operated mechanisms for securing and unsecuring.

3.5(11) Utility drawer latches.

FINDING: Gravity holds the latches in the locked position. The operator must turn the latch upward to allow the drawer to be opened. It can be turned only one way because of protruding bolt heads on the drawer frame. When the drawer is pulled out, the latch is released and it falls back into the locked position so that it must be lifted again before the drawer can be closed and secured.

Impact: It requires two hands to open or close the drawer, one to hold the latch, one to move the drawer. It was not uncommon for the operators to forget that the latch had to be lifted in order to close the drawer; in these instances, the drawer was slammed against the latch, which, of course, then reminded the operator to lift the latch.

Comment: Consider redesigning the drawer latches.

3.5(12) Lights switch.

FINDING: The interior shelter lights switch was not labeled.

Impact: The purpose of the switch was not immediately apparent.

Comment: Labeling was added prior to the revalidation test.

3.5(13) Ceiling lights.

FINDING: The fluorescent ceiling lights inside the shelter are reflected from the oscilloscope windows directly into the operator's eyes.

Impact: It is difficult for the operators to read the oscilloscopes; they hold up a hand to shade their eyes from the glare.

Comment: Moving the location of the scopes, as suggested in Finding 3.5(22), would solve this problem.

3.5(14) Cabling.

FINDING: Installation cables were identified by labeling and referenced in diagrams. One technician noted that a useful addition to the system would be the visual coding of installation cables, which would allow visual tracing at a glance.

Impact: Maintenance time is increased and made more difficult if cable tracing is problematical. Wire bundles may have to be unwrapped or a continuity test performed to locate related cable connectors.

Comment: If it is not possible to trace visually the entire length of an individual cable, it would be helpful if the cable ends were similarly marked and distinguishable from the markings of other cables in the vicinity. This would provide a means for easily relating the two ends of a given cable, especially when the cable is bundled or intertwined with others or located in a cramped or dimly lit location. Identically coded collars with patterns and bright colors could be placed adjacent to the connector at both ends of a cable. (The system developer notes that some of the cables are interchangeable, which might preclude using specific plug-to-jack coding.)

3.5(15) Air conditioner.

FINDING: The operators acknowledged that the air conditioner was noisy, but that it did not bother them; they said they had adapted to the point that they were normally unaware of it.

Impact: Minimal negative impact.

Comment: There are three fan speeds. The system developer reports that the lowest speed is about 3dBA lower in radiated sound level than the highest and that part of the noise emanates from air flow over EMI filters in the louvre areas. The developer also noted that a quieter unit could be substituted were it desired. At this time, there does not appear to be a significant need to replace the current unit, but a quieter unit is recommended for future versions of the system.

3.5(16) Air conditioner switch labeling.

FINDING: The meaning of the term "condition" on the VENT/OFF/CONDITION switch is unclear. When one operator was asked to explain the label, he could not. He only knew that he was supposed to put it in the "condition" position.

Impact: Use of the air conditioner may be confusing to new operators.

Comment: Does "condition" mean "recirculate"? Does it apply to both HEAT and COOL? Clarify by relabeling.

3.5(17) Emergency light labeling.

FINDING: The meaning of the labeling is not clear. On the side of the "Enable/Disable" switch box is an LED with a test switch. The LED, which is normally on, is labeled "CHARGE MONITOR," which to the uninitiated could mean either "charge the monitor" or "monitor the charge." The test switch, labeled "PRESS TO TEST," is a toggle that must be pushed down rather than in, as the label would seem to imply. When the test switch was tried, nothing happened.

Impact: Student and operator confusion. Some operators may have to be told what the "CHARGE MONITOR" label means. The LED, normally on, is apparently meant to signal a problem when it is not on, but then it would probably not be noticed.

Comment: (a) The meaning of labeling should be self-evident and, unless necessary, not constitute another learning hurdle. (b) Either the operation of the LED should be reversed, which might cause electronic complications, or additional labeling should be added to indicate its purpose clearly. (c) Operation of the emergency light should be covered in system documentation. The operator should not encounter a situation in which the test switch is tried with no response from the system unless the switch is accompanied by instructions indicating when such an occurrence is normal.

3.5(18) Printer location.

FINDING: The current location of the printer (directly across the shelter aisle from the operator's console) may not be ideal. It occupies the space most logically suited for operator writing, referencing of manuals, and so on. Furthermore, the current orientation of the printer (front of printer toward aisle) leaves less than a page length of space behind it for continuous paper to feed and accumulate.

Impact: (a) Having swiveled around (up to 90 degrees) to use the desk surface on the roadside of the aisle, the operator must lean forward toward (or roll the operator's chair toward) the shelter access door to use the available desk surface. The problem would be exacerbated for the left-handed operator. (b) Accumulating paper does not stack appropriately behind the printer.

Comment: A better location and orientation for the printer may be the following: Place the printer so that it faces the front wall of the shelter, with its right side as close to the curbside of the shelter as possible while allowing sufficient hand space between the printer and the curbside wall. Set the back edge of the printer as close to the rear wall as possible while allowing sufficient space for the accumulation of continuous paper. While this places the printer farther from the operator, the disadvantage is minimal because the operator does not need frequent access to the printer. With the printer in this location, all of the desk surface closest to the operator becomes available for the operator's use. The desk surface would be accessible to the right-handed operator who swivels clockwise 90-180 degrees and to the left-handed operator who swivels clockwise 135-180 degrees.

3.5(19) Circuit breaker panel.

FINDING: This panel was examined in one of the DCS vans during the validation test. The cover on the panel (curbside wall, lower left of operator) had no labeling (the contents were not identified). The panel behind the cover contained four switch locations and three switches (one switch location was empty). One of the three switches (upper left corner of panel) had no label, but was white in color as if to distinguish its function from the others, which were black. The other two switches were labeled CB14 and CB15. The switch handle on CB15 was broken off. The empty switch hole was labeled CB16. The operator was able to find CB14 and CB15 on the AC wire diagram, but not CB16 or the white switch.

Impact: Whether or not the broken switch on CB15 could be manipulated with a tool such as a screwdriver was undetermined. There was some confusion about the purpose of the CB16 label--was there a switch missing? Even if operators were trained in the use of this panel (apparently they were not), the absence

of informative labeling would make it unnecessarily difficult to remember the switch functions because of their infrequent use.

Comment: Include informative labeling on both the cover and the switches. If the white color of the unlabeled switch is significant, so indicate; if not, ensure that like switches have the same color. Fix the broken switch.

3.5(20) A.C. power/generator monitor/control panel dials.

FINDING: The dials on the left side of this panel, which monitor "INPUT POWER" and "U.P.S. POWER" have what are, seemingly, strips of green-colored paper pasted above the scales to indicate normal (or acceptable) ranges. The colored strips are crudely made (apparently, by hand) and are beginning to buckle and peel off three of the five dials (checked only in one of the two DCS shelters). On the top two dials ("A.C. VOLTS" for "INPUT POWER" & "U.P.S. POWER"), the strips have red colored bands at either end of the strips to indicate danger (or unacceptable) ranges. The green and red colors are not highly saturated.

Impact: Besides being of questionable durability, the strips are not colored adequately. The red-green color-deficient person may be unable to distinguish either the red or the green and, more important, be unable to distinguish the red from the green. Both of these effects were, in fact, observed in one such person.

Comment: The strips should be redone so that they are durable and are colored to maximize the distinction between the green and the red.

3.5(21) Uninterruptible power source dials.

FINDING: The two dials ("AC VOLTS" & "DC VOLTS") on the U.P.S. unit (bottom unit in power rack) have poor viewing angles. While the operator can see the position of the needles, the scales above them are not in view from the normal operating position.

Impact: Minimal, in this system.

Comment: This is a common manufacturing "defect" that prevents easy reading of the dials unless the viewer is positioned rather directly in front of the dial windows. The actual dials are inset behind the windows so that the window frame cuts off the viewing angle. The only recourse for the user is to position the equipment where operators can see the dials easily.

3.5(22) Panel equipment positioning.

FINDING: The relative positions of the GOES antenna readout ("N.B.S. time"), modem, speaker bank, and oscilloscope bank are not optimal. The present configuration puts the often-viewed oscilloscopes at the top of the rack, high above the operator's eye level.

Impact: Although the operators did not complain about the current configuration, they were observed to strain their necks constantly upward. For operators with bifocal or trifocal lenses (one operator wore trifocals), this could be troublesome during normal operations, which are often sustained.

Comment: The speaker rack should be at the top because it does not need to be viewed. Under it should be the satellite time readout receiver, which does not have to be viewed with great frequency. The oscilloscopes should be third down in the rack because the operator frequently refers to them. The most frequent reference point above the CRT monitor is the modem panel; therefore, it should be as low as possible without obstructing the view of the CRT. According to the system developer, there is no system constraint that would make reordering these items unadvisable; therefore, they should be reordered.

3.5(23) *Modem panel.* (See also Finding 2.4[8].)

FINDING: The most frequently referred-to rows of LEDs are at the top of the panel. The least frequently viewed rows are at the bottom.

Impact: The operator must look higher for the more frequently needed references.

Comment: Though not of drastic importance, the ideal ordering of the LED rows would put the least often viewed at the top and the most often viewed at the bottom.

3.5(24) *Keyboard & shelf.*

FINDING: The keyboard is too wide for its sliding shelf; it overlaps at both ends. The keyboard contains many keys that are not used by the DCS software (e.g., the "Help" key and the entire right-hand bank of 18 keys).

Impact: Because of its width (required by the unused keys), the keyboard cannot be stowed either on its pullout shelf or on the monitor shelf during system transport. Operators may wonder, for example, why the "Help" key (in the F15 position) is not used for the HELP option.

Comment: A narrower keyboard would be much better, from the standpoint of both physical size and operator usage. A smaller keyboard would also allow the incorporation of an additional feature: Another sliding shelf could be installed just above the current keyboard shelf. The shelf on which the monitor now rests could be moved up enough to accommodate the new shelf without making the monitor too high (the current height of both the keyboard and monitor is appropriate). The new shelf would accept the keyboard, which would be clamped to it. It would be able, with the keyboard installed on it, to slide in beneath the monitor shelf. Because the keyboard is not used constantly, it could remain in the stowed position much of the time, during which the current keyboard shelf would be available as an excellent writing surface or surface for reading manuals, or performing other duties. (The pullout keyboard shelf provides for knee room, since there is no knee well. The pullout feature is a modification of the original stationary shelf that provided no knee room.)

3.5(25) *Keyboard dust cover.*

FINDING: The keyboard used during the training classes was protected by a type-through plastic dust cover.

Impact: The cover was annoying to some personnel. It tended to make the operator's or technician's fingers stumble and reduced the readability of the keys, especially the frequently used function keys.

Comment: It was suggested that removing the covers would not entail undue risk, since contamination by dust, liquids, and so on should be minimal under most operational circumstances. Prior to the validation test the covers were removed. Terminal users should be trained to exercise normal precautions.

3.5(26) Computer mount.

FINDING: The MicroVAX II computer is mounted in an equipment rack and bolted in place. The bolt holes in the mounting rack did not line up well with the frame of the computer.

Impact: On one occasion during the validation test, two operators were observed having extreme difficulty mounting the computer. It was necessary to lift the heavy computer while attempting to insert the bolts at the same time --a two-person task.

Comment: The support contractor reported that the rack alignment was good prior to system transport and that a shift had occurred during transit. Apparently the racks are not constructed to completely resist the jolting and twisting motions accompanying normal system transport. The solution, according to the support contractor is to enlarge the holes in the mounting rack, which, reportedly, they could easily accomplish.

3.5(27) Computer cover panel.

FINDING: The top panel of the MicroVAX computer is secured by 36 screws. Using a high-speed hand-held drill, a technician required approximately 4.5 minutes to remove all screws and approximately 3.5 minutes to reinsert and tighten them. The front panel holds 10 screws, requiring about 1 minute to remove and 2 minutes to install.

Impact: The total labor time involved in removing and replacing both panels is about 11 minutes.

Comment: The process is quite time consuming. Can doctrine allow the use of fewer screws during non-secure operations? Are all the screws necessary, even for secure operations? (During the revalidation test, the operator-technicians conducted operations with only a few of the screws in place so that the cover could be quickly removed if necessary.)

3.5(28) Computer access door. (See also Finding 2.4[10].)

FINDING: The computer access door, which should be closed during normal operations, displays no notice of that requirement to the operator. The operators were fairly conscientious about keeping the door closed.

Impact: Some operators might establish an undesirable, relaxed attitude toward the need (especially during secure operations) for keeping the door closed.

Comment: Both the inside and outside of the door should display an appropriate notice. Keeping the door closed not only allows secure operations, but helps to regulate computer temperature and to prevent the entry of foreign objects into the compartment that houses the disk drive and tape recorder.

3.5(29) Computer panel lock & key.

3.5(29.1) Operating with panel buttons enabled or key in lock.

FINDING: At times, operators were observed operating with the computer panel lock in the unlocked position, sometimes with the key still in the lock.

Impact: (a) When the panel is not locked, the panel buttons could be inadvertently activated, which would halt operations and perhaps cause a loss of mission data. (b) In one incident, a shelter occupant brushed against the front panel of the computer with his leg, causing the panel lock (in which the key was still inserted in the unlocked position) to break out of the panel. The lock mechanism had to be replaced. (Incidentally, had the lock been in the locked position, as it should have been, the operator would not have been able to shut down the system normally.)

Comment: Despite the fact that, in this particular situation, having left the lock unlocked allowed the operator to perform a normal shutdown, the DCS should not be operated with the key still in the lock or the lock in the unlocked position. Operators should be reminded of the importance of disabling the panel buttons and removing the key while operating. A warning to that effect should be posted in a prominent location, such as on a list of important operational considerations placed high on the inside surface of the shelter door.

3.5(29.2) Computer lock unlabeled.

FINDING: The lock has no accompanying labeling or instructions to indicate its purpose or how it functions.

Impact: The operator cannot tell by looking at the panel buttons whether they have been disabled or not. The only clue is the position of the keyhole, the significance of which the operator is forced to remember without the aid of labeling. If the operator is unsure of the proper direction in which to turn the key to disable the buttons, the key may be turned in the wrong direction, causing the computer to reboot with the possible loss of important data.

Comment: The lock and its functions should be clearly labeled. There is room for a label decal on the top surface of the computer panel just above the lock. The lock mechanism should have a detent that would proscribe moving the key into the "reboot" position accidentally.

3.5(30) Computer panel display-control toggle switches. (See also Finding 2.4[9].)

FINDING: The three toggle switches were labeled S3, S2, and S1 from left to right, respectively.

Impact: The labels impart no meaning to operator regarding the functions of the switches. The numerical order of the switches is opposite to intuitive expectations.

Comment: There is little space for these labels. Nevertheless, it may still be possible to use labels that have more mnemonic value.

3.5(31) *Generator alarm.*

FINDING: An audible alarm sounds if the generator shuts down abnormally, as, for example, when the fuel tanks become empty. The alarm does not sound prior to impending shutdown.

Impact: Abnormal loss of generator power is normally quite apparent even without the alarm, because the shelter lights go out. The uninterruptible power source keeps the computer functioning for a time without the generator.

Comment: Much more helpful would be an alarm that warns of *impending* shutdown due to empty fuel tanks. While a fuel gauge is provided inside the shelter for the operator, its location is behind the operator's back, and the operator is not inclined to check it periodically.

Section 4: Safety

4.1 *M-880 Truck with Shelter*

FINDING: The operators reported that the center of gravity is shifted to the rear because of the weight of the S-710/M shelter and its equipment, and that at 55-60 mph the vehicle is unstable on uneven roads. Furthermore, they stated that the weight of the shelter appears to be unevenly distributed, with more on the curbside, which might contribute to the shelter's tendency to "rock" during movement and during operations when the wind is high. They also noted that the effect seems to be greater *without* the M101A2 generator trailer attached.

Impact: The operators felt that the instability of the vehicle could create a lack of mobility or even a safety hazard in the field. One operator reported that during training prior to the validation test he had experienced queasiness while operating on a windy day.

Comment: A determination needs to be made regarding the adequacy of the current configuration from the standpoint of both safety and mobility. The operators suggested that the shelter needs to have some sort of stabilization device to prevent it from rocking in the wind during operations. The Army has asked the developer to look into the matter.

4.2 *Shelter Entrance Way*

FINDING: The low profile of the top of the doorway presents a constant threat to persons entering or leaving the shelter.

Impact: During the validation test, one person received a bleeding cut to the top of his head. Others reported hitting their heads.

Comment: This is a common complaint for shelters of this type. Nevertheless, serious injury, though improbable, could occur. Minor injuries will occur from time to time in the life of the system. Consider retrofitting the entranceway with some sort of padded protection.

4.3 Halogen Desk Lamp

FINDING: The 100 watt halogen desk lamp (ELECTRIX, Model 2V945) generates much heat, which, besides providing an additional burden for the air conditioner, constitutes a physical safety hazard for personnel and a possible fire hazard.

Impact: A person who sits on the shelf beneath the light (a natural place for an observer) may receive a burn or clothing may be damaged. One such instance occurred prior to the validation test: A person seated on the shelf with his shoulder beneath the lamp was unaware that his jacket had started to smoke. He was warned by others, and no injury or serious destruction occurred.

Comment: The lamp should be removed or replaced by a light source that presents no hazard.

Conclusions

Many evaluative comments pertaining to the C3I2 DCS have been made. However, as with any detailed examination of a system, the sheer number of findings may tend to reflect more the level of detail of the evaluation than the overall quality of the system. Considering the prototype nature of the DCS, the absence of "high drivers" (such as time pressure on system operators and complex operational tasks), and the significant improvements effected since this evaluation began, the system can be considered satisfactory with regard to most general MANPRINT concerns.

Manpower and personnel considerations were minimal, centering largely on whether or not contractor technicians should be used as system operators. It was suggested that an effective use of manpower would place military enlisted personnel in the operator's position and use contractor personnel as system controllers and maintainers.

As for *training*, it was noted that the prototype DCS should be fairly easy to operate. Therefore, the amount of time required to train system operators should not be extensive. However, no formal training evaluation was conducted (owing to the absence of a training program); therefore, this conclusion is tentative and needs empirical validation.

From a *human factors engineering* perspective, many small improvements could be made; indeed, many have been implemented as a result of this evaluation. In general, the system appears to have been given reasonable, if not thorough, human factors attention, and future decisions regarding changes in non-crucial areas of the prototype DCS design should be based upon considerations of cost and ease of accomplishment.

Many of the lesser human factors findings could be overlooked without great injury in the prototype DCS, but some would take on greater importance in subsequent versions of the system. Several findings were of major import,

even for the prototype system, and they required attention. The system developer has already implemented suggested changes in several areas and has begun implementation of others. All of the findings should be considered for whatever implications they might have for the development of the DRS and the next version of the DCS.

Few *system safety* findings emerged--the most important involving vehicle instability. No *health hazard* was associated with the system.

The following summarizes primary MANPRINT concerns for the prototype DCS system in terms of whether or not they have been resolved.

Largely Unresolved Issues

- Military enlisted personnel as DCS operators may be more appropriate than contractor technicians, whose technical skills are not utilized effectively at the operator's position. (Finding 1.1)
- Formal, separate training courses and system documentation need to be developed for operators and maintainers of the system, without which gaps in skills and knowledge will occur. (Findings 2.1 & 2.4)
- Training time for DCS operators should not be extensive (probably less than a week). Empirical validation of this assertion is needed. (Finding 2.3)
- Total system setup and teardown times appear to be excessive, owing substantially to the amount of time required for antenna erection and takedown. (Findings 3.2 & 3.3)
- The system needs an effective self test for determining that it is functioning properly both before and during data collection sessions. (Finding 3.4[2])
- Conceptual complexity of the software interface could be reduced significantly for the student in areas such as general screen clutter, menu design, and system terminology. Significant improvements have been made in some instances, but much remains to be done. (Findings 3.4[27], [29], & [30])
- Panel equipment should be repositioned, especially the oscilloscopes, which catch glare from the ceiling lights and cause operators to strain their necks upward. (Findings 3.5[13] & [22])
- The current location of the printer should be reconsidered. (Finding 3.5[18])
- Mounting the computer in its rack and removing and installing its top cover are excessively time consuming procedures. (Findings 3.5[26] & [27])
- The instability of the M-880 truck, which houses the operations shelter, may constitute a safety hazard. (Finding 4.1)

Resolved or Partially Resolved Issues

- The DRS user interface should not be patterned after that of the DCS for the sake of conformity. It was decided that effective design should take priority. (Finding 3.1)

- The probability of accidental reinitialization of the data collection software was too high. These problems were mostly resolved prior to the revalidation test, although an oversight (concerning the F5 key) was discovered during that test. (Findings 3.4[4] & [31.1])

- The system should archive data on a regular basis, regardless of traffic density. This problem, discovered during the validation test was partially resolved prior to the revalidation test. No manual archive option is provided; it should be. (Finding 3.4[9])

- If data on the hard disk should become inaccessible, the TK50 tape would have no backup prior to input into the DRS. The Army is relying on the redundancy effected by the presence of more than one DCS in the field, some or all of which may collect partially overlapping sets of data. (Finding 3.4[10])

- The presentation of alert messages to the operator was unsatisfactory, creating a significant chance that they would go unnoticed. This shortcoming was vastly improved prior to the revalidation test. (Findings 3.4[24] & [25])

Appendix

Setup and Teardown: Detailed Descriptions

Table 4

Detailed Setup Timeline for Revalidation Test, Day 3 (Table 2, Expanded)

<u>Time/Elapsed Time (Minutes):</u> <u>Operator Activity</u>	<u>Time/Elapsed Time (Minutes):</u> <u>Operator Activity</u>
0812/000: Start setup. Buttoned-up vehicle with attached trailer is already in place at predetermined trailer location. Two operators, A & B, are present.	B finishes connecting generator control-panel cable between trailer & shelter.
A & B disconnect trailer chains & trailer lights cable from vehicle; lower front trailer support; remove trailer from hitch (a two-person task).	0818/006: A unstows GOES antenna from inside shelter; installs on roof of shelter.
A moves vehicle straight forward about 80 feet to its predetermined operating location.	B enters shelter; unstows operator chairs & miscellaneous items.
0813/001: A lowers shelter steps; unlocks & opens shelter door. B begins to deploy power cable between trailer & shelter.	0819/007: A finishes installing GOES antenna. B does paperwork on system note sheet.
0814/002: A opens curbside storage compartment on side of shelter. Begins to drive 1st electrical grounding rod near shelter. A continues laying out power cable.	0820/008: A opens roadside storage cabinet & antenna mast storage tubes. B completes paperwork.
0815/003: A finishes setting 1st grounding rod. B finishes deploying power cable.	0821/009: A mounts roadside antenna mast assembly at rear of shelter. B turns on computer; unstows monitor & keyboard.
0816/004: A drives 2nd grounding rod near generator trailer. B begins deploying generator control-panel cable between trailer & shelter.	0822/010: A mounts curbside antenna mast assembly at rear of shelter. B installs keyboard.
0817/005: A unstows antenna cables from shelter storage bin.	0823/011: A unstows various antenna-related items from roadside storage compartment. B performs miscellaneous small tasks.
	0824/012: A stakes antenna base plate to earth beneath roadside antenna mast.

Table 4. continued

B removes TK50 tapes from safe;
waits for computer to warm up.

0825/013:

A lays out radius line for positioning 1st roadside guy line stake.
B exits shelter to help A with antenna setup.

0826/014:

A drives 1st guy line stake for roadside antenna; lays out radius line for locating 2nd stake.
B obtains stepladder from chase vehicle (parked beyond generator trailer) for use in deploying curbside antenna whip.

0827/015:

A drives 2nd roadside antenna stake; lays out radius line for locating 3rd stake.
B climbs atop shelter & installs transmit/receive antenna on curbside antenna mast.

0828/016:

A drives 3rd (last) roadside stake.
B installs receive-only antenna on roadside antenna mast & dismounts shelter.

0829/017:

A stakes antenna base plate to earth beneath curbside antenna; lays out radius line for 1st curbside antenna guy line stake.
B emplaces & connects test-coordination radio antenna atop shelter for local base communications.

0830/018:

A drives 1st curbside antenna guy line stake.
B unwinds antenna cable for test-coordination communications antenna.

0831/019:

A lays out radius line for 2nd curbside guy line stake.
B Enters shelter.

0832/020:

A drives 2nd curbside stake.
B prepares for computer initialization (miscellaneous tasks).

0833/021:

A lays radius line for 3rd curbside stake; drives 3rd (last) stake.
B starts computer initialization & waits for computer to run self-tests.

0834/022:

A connects GOES antenna cable.
B waits.

0835/023:

A begins unstowing (unwinding) 6 antenna guy lines.
B waits.

0836/024:

A continues to unwind antenna guy lines.
B waits for completion of computer self tests.

0837/025:

A continues to unwind guy lines.
B sets wire jumpers in preparation for hard-wire loop test of modem channels.

838/026:

A connects antenna cable to roadside antenna; raises antenna slightly & starts to place 1st antenna cable tie wrap.
B continues waiting for completion of computer self tests.

0839/027:

A completes installation of 1st roadside antenna cable tie wrap.
B initiates AITG test.

0840/028:

A connects antenna cable connector to curbside antenna.
B waits for completion of AITG test.

Table 4. continued

0841/029:

A connects antenna cables to shelter junction box & continues with deployment of antenna guy lines.
B continues to wait for AITG test.

0842/030:

A connects guy lines to curbside antenna; continues guy line layout.
B continues to wait for AITG test.

0843/031:

A works on guy lines.
B loads & activates data collection system.

[At this time, generator power to interior of shelter is lost, although generator continues to run. Air conditioning & lights turn off. Computer equipment continues to operate on emergency battery power (UPS).]

A checks outside circuit breaker box & reseats generator power cable connector. [Negative results.]

0844/032:

[Operations halted for approximately 1 minute for consultation not related to power loss: Because TACFIRE system is not completely functional, a change in hard-wire layout to TACFIRE is planned.]

0845/033:

A & B readdress power loss problem.
A attempts to open high voltage panel cover inside shelter, but reports that latch key will not work. [Apparently, key unlocks latch, but latch sticks; key cannot be used as a handle to pull out latch--the normal procedure.]

0846/034:

A wrestles with the lock.
B waits.

0847/035:

A looks for a screwdriver.

B waits.

0848/036:

A pries open latch with screwdriver; examines switches [None tripped.]

B waits.

0849/037:

A closes & locks high voltage panel cover.
B checks interior breaker box at lower front curbside. [CB-14 is tripped. See Finding 2.4(1)&(7).]

0850/038:

[Operators report that this particular problem had never happened before.]

A waits.

B resets CB-14. [Power is restored.] Continues modem channel testing procedures.

0851/039:

A & B prepare for continuation of operations: pickup tools, etc.

0852/040:

A retrieves & stows antenna base plates [used in current application solely as retainers for guy lines during guy line layout]; drives tie-off stake for field wire (WD-1) under curbside rear junction box.

B continues channel testing procedures.

0853/041:

A rewinds & stows radius line.
B continues channel tests.

0854/042:

A begins laying out guy lines for curbside antenna.
B continues channel tests.

0855/043:

A & B discuss layout of field wire to TACFIRE vehicles.

Table 4. continued

0856/044:

A suspends work on guy lines; begins laying field wire.

B continues with channel tests.

0857/045:

A strips insulation from wire for connecting to 1st TACFIRE vehicle.

B continues channel testing.

0858/046:

A begins making connection at 1st vehicle.

B continues channel testing.

0859/047:

A continues connecting at 1st vehicle.

B continues channel testing.

0900/048:

A completes connection at 1st vehicle.

B continues channel testing.

0901/049:

A strips insulation from other end of 1st vehicle wire for connecting at C3I2 shelter.

B continues channel testing.

0902/050:

A connects wire from 1st vehicle to shelter junction box & tie-off stake.

B waits for last channel test (channel 8) to end.

0903/051:

A writes ID label for 1st vehicle wire; attaches it at C3I2 shelter end.

B waits for last channel test (channel 8) to end.

0904/052:

A starts wire layout to 2nd TACFIRE vehicle. Strips wire at vehicle end.

B performs "configure channels" procedure & starts "runtime system" (data collection process).

0905/053:

A begins connecting wire to 2nd vehicle.

B prepares to print out current configuration information.

0906/054:

A continues connecting to 2nd vehicle.

B begins print of configuration information.

0907/055:

A continues connecting to 2nd vehicle.

B completes print of configuration information.

0908/056:

A continues connecting to 2nd vehicle.

B begins to check for software alert messages.

0909/057:

A completes connection at 2nd vehicle.

B finishes checking alert information [no negative alerts present].

0910/058:

A strips 2nd vehicle wire at C3I2 shelter end; connects to shelter junction box & tie-off stake.

B waits, observes monitor. Messages begin to come in.

0911/059:

A labels wire from 2nd vehicle at shelter end.

B observes monitor.

0912/060:

A starts deploying wire to 3rd TACFIRE vehicle.

B comes outside of shelter to assist.

Table 4. continued

0913/061:

A & B finish laying wire to 3rd vehicle.

0914/062:

A making wire connection to 3rd vehicle.

B looks for wire cutters [which A has].

0915/063:

A completes wire connection to 3rd vehicle; makes ID label for C3I2 shelter end.

B uses jackknife to strip 3rd wire for connection to shelter.

0916/064:

A begins to lay out wire to 4th vehicle.

B continues attempting to strip 3rd wire with jackknife blade.

0917/065:

A continues laying wire for 4th vehicle.

B still working to strip 3rd wire.

0918/066:

A begins making connection to 4th vehicle.

B completes stripping of 3rd wire.

0919/067:

A continues connecting to 4th vehicle.

B connects 3rd wire to shelter & attaches ID label.

0920/068:

A completes connection at 4th vehicle.

B secures 3rd wire to tie-off stake; begins to strip shelter end of 4th wire with knife.

0921/069:

A gives wire cutters to B.

B strips wire for 5th vehicle, thinking it to be shelter end for 4th vehicle.

0922/070:

A labels 4th vehicle wire at shelter end.

B continues to strip wire for 5th vehicle.

0923/071:

A starts to connect 4th wire to shelter; discovers that ends are not stripped; informs B. Begins to lay out wire for 5th (& last) vehicle; discovers patched break in wire; cuts off at break & starts over with new wire.

B begins to strip shelter end of 4th wire.

0924/072:

A continues laying out wire for 5th vehicle.

B completes stripping wires for 4th vehicle; gives cutters to A.

0925/073:

A strips 5th vehicle wire at vehicle end; gives cutters to B; continues laying wire to 5th vehicle.

B begins connecting 4th vehicle wire to shelter.

0926/074:

A starts connection at 5th vehicle.

B finishes connecting 4th wire to shelter & tie-off stake.

0927/075:

A continues working on connection at 5th vehicle.

B begins to strip 5th vehicle wire at C3I2 end.

0928/076:

A finishes connecting wire at 5th vehicle.

B continues to strip 5th vehicle wire at shelter.

0929/077:

A makes label for 5th vehicle wire.

B completes stripping.

Table 4, continued

0930/078:

A stores leftover wire.
B connects 5th vehicle wire to shelter.

0931/079:

A continues work on antenna mast guy lines; begins to connect remaining lines to stakes.
B ties off 5th vehicle wire at retaining stake.

0932/080:

A raises curbside antenna; tie-wraps antenna cable to mast as mast is being raised.
B plays out guy line as curbside antenna is raised by A & connects to stake.

0933/081:

A attaches 2 of 3 guy lines to curbside antenna midsection collar.
B lays out guy lines & connects to stakes.

0934/082:

A continues to raise curbside antenna & tie-wrap antenna cable (8 tie-wraps altogether). Attaches remaining guy lines to antenna mast (3 at midsection collar & 3 at top plate).
B assists by playing out guy lines as antenna is raised.

0935/083:

A & B continue raising curbside antenna.

0936/084:

A & B continue raising curbside antenna.

0937/085:

A & B complete raising curbside antenna; adjust guy line tension to straighten antenna. Begin erection of roadside antenna.

A tie-wraps curbside antenna cable to antenna mast; attaches guy line to incorrect collar.
B plays out guy lines.

0938/086:

A discovers attachment of guy line to incorrect mast collar; lowers mast section; reattaches guy line to correct collar.
B waits.

0939/087:

A & B continue erecting roadside antenna mast.
A attaches 3 guy lines to midsection mast collar.

0940/088:

A & B continue erecting roadside antenna mast.

0941/089:

A & B continue erecting roadside antenna mast.

0942/090:

A & B continue erecting roadside antenna mast.

0943/091:

A & B complete erecting mast & begin adjusting guy lines to straighten antenna.

0944/092:

A & B finish deployment of roadside antenna.
A returns stepladder to chase vehicle & stows it inside; closes exterior shelter storage compartments & enters shelter.
B enters shelter.

0945/093:

A stows wire cutters & extra tie wraps in tool chest.
B enters time in mission log.

Table 5

Detailed Teardown Timeline for Revalidation Test, Day 3 (Table 3, Expanded)

<u>Time/Elapsed Time (Minutes):</u> <u>Operator Activity</u>	<u>Time/Elapsed Time (Minutes):</u> <u>Operator Activity</u>
1608/000: Start shutdown. DCS software already exited.	B detaches & stows shelter ground rod cable.
A retrieves tape labeling materials from storage.	1616/008:
B removes analogue and TK50 tapes from recorders.	A begins to lower roadside antenna.
	B begins to wind up roadside antenna guy lines.
1609/001:	1617/009:
A takes tapes from B; begins to prepare tape labels.	A continues to lower roadside antenna; removes guy-line clips from upper antenna mast collar; cuts antenna cable tie-wraps.
B retrieves computer panel key.	B continues to wind guy lines.
1610/002:	1618/010:
A continues to prepare labels.	A continues taking down roadside antenna; removes guy-line clips from lower antenna mast collar.
B uses computer panel key to enable panel buttons; turns off computer.	B continues to wind guy lines.
1611/003:	1619/011:
A affixes label to analogue tape.	A completes roadside antenna take-down.
B makes entries in mission log.	B continues winding guy lines.
1612/004:	1620/012:
A affixes label to TK50 tape; exits shelter.	A & B continue winding guy lines for roadside antenna.
B continues to write in mission log.	1621/013:
1613/005:	A winds up roadside antenna cable.
A disconnects field wire (WD-1) from shelter junction box; removes GOES antenna from shelter roof; stows GOES antenna in shelter.	B continues winding guy lines.
B turns off air conditioner; secures tapes in shelter safe; places keyboard in storage drawer & secures monitor with bungee cord.	1622/014:
	A stows antenna cable.
1614/006:	B winds guy lines.
A disconnects generator control-panel cable from shelter; disconnects shelter ground rod cable.	1623/015:
B secures chairs with bungee cords; exits shelter; disconnects power cable from shelter.	A takes down & stows test-coordination radio antenna & cable; removes roadside antenna mast from rear of shelter; places it in storage tube.
1615/007:	B completes winding up of guy lines for roadside antenna; gets step-ladder from chase vehicle.
A closes shelter junction box hatches on curbside.	

Table 5. continued

1624/016:

A stows roadside antenna whip in storage tube.
B begins takedown of curbside antenna; disconnects upper guy lines; cuts antenna cable tie-wraps.

1625/017:

A stows guy lines from roadside antenna in utility bag; pulls roadside antenna stakes & stows in utility bag.
B continues to take down curbside antenna.

1626/018:

A begins to wind up guy lines for curbside antenna.
B removes lower set of guy lines from curbside antenna mast.

1627/019:

A continues to wind guy lines.
B removes whip antenna from curbside antenna mast; removes mast.

1628/020:

A winds guy lines.
B stows curbside antenna mast in storage tube.

1629/021:

A winds guy lines.
B stows curbside antenna whip sections in storage tube.

1630/022:

A stows storage bag in roadside compartment; begins to pull curbside antenna guy line stakes.
B winds guy lines.

1631/022:

A finishes pulling guy line stakes; stows them away.
B winds guy lines.

1632/023:

A starts to take in field wire from TACFIRE vehicles.
B finishes winding up curbside antenna guy lines.

1633/024:

A continues taking in field wire.
B winds up curbside antenna cable; stows in curbside compartment.

1634/025:

A & B take in field wire.

1635/026:

A & B take in field wire.

1636/027:

A & B take in field wire.

1637/028:

A & B take in field wire.

1638/029:

A & B take in field wire.

1639/030:

A & B take in field wire.

1640/031:

A & B take in field wire.

1641/032:

A & B take in field wire.

1642/033:

A & B take in field wire.

1643/034:

A & B take in field wire.

1644/035:

A & B take in field wire.

1645/036:

A & B take in field wire.

1646/037:

A & B take in field wire.

1647/038:

A stows second storage bag; locks roadside compartment padlocks.
B winds field wire.

1648/039:

A pulls shelter ground rod & stows in curbside compartment; pulls generator trailer ground rod.

Table 5. continued

B winds field wire.

1649/040:

A stows trailer ground rod & ground rod puller in shelter curbside compartment; locks compartment padlocks.

B carries stepladder to chase vehicle.

1650/041:

A removes steps from rear of shelter; closes, but does not lock, shelter door.

B winds up generator control-panel cable.

1651/042:

A assists B in winding-up power cable.

1651/043:

A carries WD-1 spool & shelter steps as far as generator trailer; helps B wind & stow power cable at generator trailer.

B finishes stowing power cable with A's assistance.

1652/044:

A stows shelter steps in generator trailer.

B stows WD-1 spool & stepladder in chase vehicle.

1653/045:

A backs up shelter vehicle to trailer.

B stands by.

1654/046:

A & B connect trailer to vehicle.

1655/047:

A locks antenna storage tube padlocks.

B retrieves trash from shelter.

1656/048:

A stows used WD-1 wire in shelter.

B stands by.

1657/049: Teardown completed.

A secures shelter door.

B stands by.

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