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March 1980 DCIEM Report No. 80-R-57

TACCDAS TESTBED HUMAN FACTORS EVALUATION METHODOLOGY

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DEPARTMENT OF NATIONAL DEFENCE - CANADA

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SUMMARY

This report reviews the approach to be taken for a human factors evaluation of the TACCDAS testbed that will be fielded by the Canadian Forces in order to assess the value of automated aiding to a brigade command post operating in the field. The major milestones involved in the evaluation process leading up to the evaluation of the complete testbed in the field are identified. Test methods and test procedures are discussed and objective and inferred measures of user performance are outlined.

TACCDAS TESTBED HUMAN FACTORS EVALUATION METHODOLOGY

INTRODUCTION

This report considers the human factors procedures for the evaluation of the design, functional performance and environmental considerations for the major test functions (operability, maintainability, portability/usability, and habitability) related to the TACCDAS testbed evaluation. In the development of the procedures and criteria that can be applied in the testbed evaluation, the recommendations contained in the reports by Perkins et al (1977) and by Malone (1978) on human factors test and evaluation of military systems have been used as a basis and made relevant to an information system evaluation.

The primary aim in such testing is the assessment of the effectiveness and degree of safety with which test items can be operated, maintained, occupied, transported or otherwise used by qualified personnel in the designated environment.

Military testing of new systems must include an assessment of performance of personnel using the system. It is often assumed that personnel performance testing is not necessary, since the user can adapt to the demands of his equipment, and so overcome the features that cause difficulty. His ability to be flexible and adaptive in combat is reduced, however, by the presence of stresses, and the areas of potential performance unreliability should be identified by performance testing while applying those stresses.

A human factors evaluation of a system includes the complex of elements that affect personnel performance,

1. the physical design characteristics of the equipment
2. procedures for operating and maintaining the equipment
3. training for effective operation and maintenance of the equipment
4. the design and the utility of manuals and documentation
5. the environment in which the system is operated

There are three major sources of information for the evaluation:

1. the system documentation

2. observation of the system

3. the users of the system, in this case, the test participants who are the users of the command and control information sub-system (the testbed) and who are the users of sub-systems commanded and controlled by it.

The system description documentation is available, so the formal and intended structure and functioning of the testbed is known. Observation of the system in use provides data on the system as it really is, which inevitably will be different in several ways from the intended system as foreseen by the system designers. The system users provide insights into these differences, why they exist, and the most profitable approaches to improving the system functioning and acceptability.

TACCDAS TESTBED EVALUATION SCHEDULE

This schedule for the sequence of events for evaluation through the development of the minitestbed and the testbed is based on the decisions made by the TACCDAS project team up to the time of publication of this report.

1. MEASURES DEFINITION AND CONSTRUCTION

The evaluation team will identify, define and construct the tools required to obtain the necessary measures of effectiveness during field operations. These may include questionnaires, interview proformas and methods for direct observation. The behaviours that are to be measured or assessed will be defined at a preliminary level, to be validated in the assessment of the manual execise.

Reference will be made to

1. the findings of and techniques employed by the 'Study of the combat data handling procedures within the Canadian Land Forces in the field', P. S. Ross and Partners, 1969-70, as contracted to DND under contract GR 733006, 26 March 1968.

2. the experience and findings of the Exercise Talfos series, especially as summarized in 'User concept evaluation trials of the DREV Phase I TADPS facility. Exercise Talfos summary report,

D. Heckman et al, DREV Report 4126/79. May 1979.

2. MANUAL EXERCISE EVALUATION

The techniques to be used for evaluation of the workstation and testbed will be tested during a manual command post exercise. This will provided an opportunity for collection of baseline data for comparative purposes and for the definition of field concept evaluation measures.

Test participants will be identified and classified according to the factors outlined in the Test Method section of this paper. Operator tasks will be assessed during a walk-through of the user task procedures. This can form a basis for determining relative task criticality, from which the tests that are to included for evaluation are selected. Refinement of the classification of task criticality can be made after the manual exercise data has been reviewed.

The questions relating to performance requirements will be answered for all the relevant tasks during the manual exercise, to be used as a guide for data capture and observer tasks during the subsequent evaluations.

Performance measures used in the manual exercise can only be based on observation , interview and questionnaire techniques, since no data logging of operator behaviour at the workstation will be possible. Most of the information processed in the command post is transient, insofar as it is recorded temporarily on some medium until it is erased when superceded by new information. A review of these records after the exercise would provide only end solutions and status conditions, therefore. Data on operator actions must be obtained by observation. These observation records will provide a basis for further definition of the tasks elements that are most suitable for data logging in the minitestbed evaluations, however.

In conducting observation procedures, the information in the Performance Tests section of this paper should be applied. Observers should use a reporting form on which to record the events that are observed. It should be based on an operating procedure as a guide to task performance so that steps can be checked off or annotated as the task is performed, for those parts of the task that are proceduralized. For more continuous and variable aspects of the tasks, a checklist of significant elements of the task should be prepared as a guide as to what should be observed. A sample of the format for the reporting form is attached as Annex F.

For the conduct of interviews the information in the

Performance Tests section of this paper should be applied. The sample list of items provided in that section can be used as a basis for constructing a structured interview format. This can be refined after the experience of the manual exercise to form an interview format most suitable for the minitestbed evaluation.

For preparing and administering questionnaires the information provided in the Performance Tests section of this paper should be applied.

3. CRITICAL DESIGN REVIEW - TECHNICAL

This stage involves initial engineering trials of the workstation to ensure proper interaction between the display and data manipulation devices and the software programs.

These trials will involve the technical design staff only with no military subjects. No scenario or gaming will be attempted, since the aim will be to establish the functional integrity of the hardware and software modules of the workstation as designed and built, and their efficient interaction.

4. CRITICAL DESIGN REVIEW - OPERATIONAL

The aim of this evaluation will be the assessment of the individual workstation in terms of physical design characteristics and the facilities provided for the carrying out of procedures typically employed at brigade or at unit level. This review will constitute acceptance of the physical design and the functioning of the workstation for use in the subsequent evaluation trials. No military subjects will be used in this design review. No scenarios will be employed in the sense of a predetermined game with continuity and integrated meaning extending over an extended period.

For the conduct of the critical design review, the factors outlined in the applicable part of the Test Procedures section of this paper should be applied. A checklist approach should be used to ensure that all relevant issues are considered, and this should be applied by several project and scientific evaluators independently. The checklists should then be combined to obtain concensus opinion on the factors assessed.

5. MINITESTBED ENGINEERING EVALUATION

Engineering trials will be conducted on two or more workstations working together, communicating information and interacting simultaneously with the software system.

These trials would be conducted by the technical design staff with no military subjects required. The aim would be the proving of the communication links between the various workstations (already proven individually) and the computer software system, and the proving of the software system working with more than one user terminal. The application of predetermined sequences to exercise the system will ensure completeness in this phase of the testing of the system, but advantage can be gained by also permitting the use of non-standard sequences that have not been anticipated by the system designers. This can identify previously undetected interactions within the software or hardware system and so avoid their appearing for the first time when used by the test subjects.

6. MINITESTBED CONCEPT EVALUATION

A user evaluation will be conducted on the use of the facilities, work procedures and the software response for two or more workstations working together simultaneously. Communication between the staff cells would be assessed, and the ability to monitor changes to data elements effected by another station would be noted. System response to the demands made by the players would be measured. Subjective measures would be made of the players' responses and attitudes to the testbed system.

The evaluation would concentrate on one area at any one time, due to the facilities provided in the mini-testbed. With other portions of the operation simulated, the evaluation will be of

1. the Operations cell manned by 2 duty officers

2. the Intelligence cell, manned by one or two as appropriate

3. the Operations and Intelligence cells working together

4. a unit CP, with either one or two duty officers, and operating both in the manual and the TACCDAS mode.

Military subjects would be used under a limited scenario designed to cover a broad range of workstation activities rather than to present the users with a realistic sequence of military events. A training period would be required to familiarize users with the workstation and the procedures for communicating with the computer system. This would be a 'laboratory' style of test insofar as there would be minimal attempt made to achieve military exercise conditions.

The measures used will be both objective data logging of test participant performance, and subjective data collection by observation, interview and questionnaire. The information provided in the Performance Tests section of this paper should be applied, as developed and refined by the experience of the manual exercise evaluation.

7. COMMAND POST TECHNICAL EVALUATION

This stage comprises a technical evaluation of the hardware and software system for a Brigade command post as to be fielded for the field concept evaluation.

Military subjects will be used to provide the manpower to operate the system for the technical design staff, in order to provide the data on system operation necessary for assessing its functional status. These should not be the subjects to be used in the field concept evaluation, to avoid influencing attitudes of trial subjects by exposure to a system in the proving stage. It would be unnecessary to attempt realism in this trial for the reasons outlined in para 6 above. A predetermined set of procedure modules would provide more technical information while avoiding the complication of maintaining a scenario continuity.

8. COMMAND POST CONCEPT EVALUATION

CPX-style evaluation of testbed use with the full command post operating with a prescribed scenario and as much realism as can can be generated with no troops on the ground.

Military subjects would be trained in testbed use, in terms of procedures for use of the testbed systems, and would be briefed on the aims and limitations of the test.

The performance measures applied will be as used in the minitestbed evaluation, refined on the basis of that experience, and developed as required to satisfy the requirements of the larger exercise.

9. FIELD CONCEPT EVALUATION

The evaluation of the field concept evaluation will be based on the experience of the previous evaluations, in terms of both use of measures and the tasks and behaviours that are measured. These will be refined and developed as required to cater to the increased size of the exercise.

TEST METHOD

DEVELOPMENT OF PERFORMANCE CRITERIA

Evaluation has been defined as the means by which the performance of hardware, procedures and personnel are observed as a system, to verify that the system and its components will do what they are supposed to do (Meister and Rabideau, 1965). This implies a comparison of the performance that is observed with the standards that define what is expected.

For the testbed evaluation, that standard dictates the approach to the conduct of the evaluation. There are no objective personnel performance criteria inherent in the subject matter, however, (e. g. the ability to correctly handle 15 messages per hour), and performance standards are not objective and specifiable. Arbitrary criteria must be established, therefore. Instead of testing being relative to a criterion, it must be relative to a norm, or accepted level of performance against which observed performance will be compared.

The norm against which the testbed performance will be compared will be a set of performance standards based on measures taken in a manual exercise using similar test participants. Particularly, the scenario, scope, size, phase of war and the concept of operations of the exercises should be the same. The questions asked will thus be in terms of whether the tasks were performed more effectively with automated aiding than in the manual system, rather than in terms of were they performed to an absolute standard of acceptance with automated aiding.

The measures that are developed for the testbed evaluation must be used first for an evaluation of a manual exercise of a similar complexity to the one to be used in the testbed evaluation. The results of that manual evaluation will form the baseline data for testbed performance evaluation.

TEST PARTICIPANT IDENTIFICATION

Test participants must be identified by appropriate characteristics, such as MOC, skill level, and training, to ensure that they are representative of the eventual user population. Distribution of the following qualities in the test sample shall be similar to the population distribution, within selection constraints. That is, the brigade that has been identified for providing test subjects may have personnel that are representative of the personnel in the other brigades in terms of these criteria. By chance, they may provide a selected sample that are not representative in some important aspect. Given the limitations imposed on the availability of personnel, it should be known to what extent the subjects are, or are not representative of the user population, and in what aspects.

1. Physical dimension: ranges of heights and weights of test participants shall be specified, and, where practicable, should not be too unrepresentative the range of 5th to 95th percentiles of applicable features of the user population. Determination shall be made of specific bodily dimensions of importance for item use, such as reach or seated height

2. Sensory acuity: all test participants should have had a recent (within last 12 months) test of vision and audition where vision or audition are deemed critical to the test function. Minimum standards shall be stated for each of these sensory modalities, depending on an analysis of the requirements of the tasks to be performed.

3. Experience and training: all test participants should have an acceptable number of years in a given military specialty, and have the appropriate training and experience in the command post environment.

Attitude and motivation is not an overriding issue when military subjects are used, since they are subject to orders. However, they should be given an explanation of why they are participating in the evaluation, and why their performance is important.

CONTROL OF PROCEDURES

Participants in the evaluation are to perform according to standard procedures, based on agreed standard military operating procedures and the requirements of the evaluation. However, flexibility in experimenting with novel or personal methods or work procedures could be allowed in moderation under controlled conditions. These procedures are to be issued by the test evaluator as instructions during the training sessions preceding the tests. This approach ensures more valid inferences being drawn from test results with regard to representative users.

When competitive items are being compared in the evaluation, the following conditions will apply:

1. Personnel operating the competitive items should have comparable training, that is, personnel should be cross-trained on the alternatives. To

minimize the effects of time of operation, the evaluation of the alternatives should be conducted simultaneously, facilities permitting. Otherwise, they should be evaluated at similar times of day under the same environmental conditions. To further minimize sources of variability, the items should be tested again by switching the personnel from item A to item B, in a predetermined counter-balanced order, not simple alternation (ABBA rather than ABAB).

2. All test participants should be tested on alternative items, and under each test condition. The total group of test participants will be divided at random into subgroups, and the order of allocation of test items to groups will be counter-balanced across groups as is feasible within the constraints of the exercise.

3. Test project personnel should review these plans before conduct of the evaluation to ensure that factors that could reduce the validity and reliability of the results have been eliminated. A careful review must be made at this time to determine whether the test conditions to be employed and the test design will provide unbiased data.

IDENTIFICATION OF OPERATOR TASKS

Consideration must be given in the preparation of the test to identifying what is to be tested (identification of objectives and critical issues for testing), how the test is to be conducted, and what criteria are to be used.

The tasks that are to be analyzed must be identified by the human factors engineer and the test planner by a walk-through of the activities performed for specific functions, using the actual equipment, and in conjunction with an experienced operator of the equipment. All critical tasks would be recorded at this stage. A walk-through involves the performing of tasks sequentially in an analytical manner to identify potential human factors problems in equipment design, environmental effects, and system performance; to evaluate characteristics of test participants (bodily dimensions, skills); to assess types of tests and measurements to be used; to generate data requirements; and to identify facilities and instrumentation required. Much of this information can be gained by a prior assessment of the manually operated system. Operator tasks will be identified with more validity during the mini-testbed evaluation trials for definition in the evaluation of the testbed proper.

TASK CRITICALITY

Task criticality is analyzed to identify tasks that are critical or that must be included in the evaluation. Tasks can be classified as high criticality, moderate criticality or low criticality, and all high and moderate criticality items are included in the evaluation. The criticality scaling dimensions are as follows:

1. High criticality. A task is judged to be of high criticality if its performance, or failure to perform it properly, results in hazardous or unsafe conditions, which in terms of a command and control information system would involve a major tactical error, or loss of important resources,

2. Moderate criticality. A task is judged to be of moderate criticality if its performance, or failure to perform it properly, results in (a) immediate or ultimate degradation of the system or its components, or immediate cessation of the operation, (b) reduced usability or inefficient performance of a major component of the equipment, or (c) unnecessary difficulty or significant loss of time to the operator.

3. Low criticality. A task is judged to be of low criticality if its performance, or failure to perform, has no effect on the performance of the information system. It may result in minor inefficiencies in the use of system resources or in irritation to users of the system. (Perkins,J. C. et al, 1977)

The relevance of these criteria to an information system in the battlefield is as valid as to weapons systems or vehicles. The result of the performance of a task is more immmediate and direct with such equipments, whereas with the information system similar effects can be obtained on the equipments due to their activity being determined by control directives based on inadequate or innacurate information.

PERFORMANCE REQUIREMENTS

When the critical tasks and task sequences have been identified, an analysis shall be performed to identify performance requirements associated with the critical tasks. This shall answer the following questions:

1. Who performs the task?

2. What performance criteria apply to the task

(time, rate etc)?

3. Are controls and displays involved?

4. What information input is required from other personnel?

5. What commands are required from other personnel?

6. What potential errors are associated with the task?

7. How does the evaluator know that an error has occurred?

8. What environmental conditions (climate, technical, or equipment) may influence task performance?

9. What conditions specific to the operation will affect task performance (body size, clothing, skill level)?

TEST PROCEDURES

The selection of test procedures that are used depends on the type of test and the item being tested. There are two types of human factors engineering tests that can be employed in the evaluation:

1. Design Tests. These are directed towards measuring and assessing the human engineering technical aspects of the equipment and its design characteristics.

   The technical characteristics include the mechanical, thermal, atmospheric or illumination environments created by the item or under which the item must be operated and maintained.

   The design characteristics include the physical dimensions of the item components which are used by the operator, such as controls, labels, displays, communications equipment, doors, handles, optics, seats, documents or any other elements of the item which are handled, controlled, adjusted, avoided, moved, read, communicated or contacted by personnel during use of the item. The design characteristics will be assessed initially in the critical design review to be conducted by the project personnel prior to formal testbed evaluation, in order to establish the initial acceptance of the system for testing.

2. Performance Tests. These are concerned with determining the adequacy of the man-machine interface, and the performance capability of the operator when using the item.

   Performance can be assessed by direct measurement or can be inferred. Direct measurement of performance producing objective, quantitative measures of man-machine system performance capability must be used. Qualitative data alone are insufficient for evaluating personnel. When inferred, or subjective measurement is used, it can be either described analytically or can be obtained from test participants by means of questionnaires or interviews.

   To provide data when direct measurement is not possible, and to supplement direct measurements, performance analyses can be conducted, to identify system performance problems. Examples of these are error likelihood analysis, workload analysis, team interaction analysis and training effectiveness anaysis.

The selection of particular tests within these categories depends on the type and complexity of the item being tested.

CRITICAL DESIGN REVIEW

The critical design review will be conducted by the project personnel after initial delivery of the first workstations, both for the mini-testbed and, as required, for the testbed. The purpose of this review is to assess the acceptability of the structure and functioning of the workstations for use in subsequent evaluation trials. The factors applicable to this type of review are:

1. Design characteristics

   Purpose. To evaluate the items and item components in the workstation for acceptable physical dimensions and placement.

   Relevant tasks include the application of the criteria for controls, displays, labels, workspace and communications as outlined in the section below on Design Tests: Design characteristics.

2. Working position.

   Purpose. To evaluate the normal working position for ease of entry and exit for both normal and contingency conditions.

Relevant Tasks include stepping into and out of the workstation, taking/leaving seat, and moving to/from standing operator position.

3. Station Configuration.

Purpose. To evaluate the design of components and procedures for ease of preparing the station for use.

Relevant tasks include selection of modes of operation, integration with other operators, establishing command links, making connections, following procedures, communicating and interacting with the support system.

4. Checkout.

Purpose. To evaluate the configuration for ease and reliability of verifying operational readiness and existing status of various components.

Relevant tasks include checking control settings, checking data return quality, checking data return format, checking lines and verifying operational readiness.

5. Information Aquisition/Interpretation

Purpose. To evaluate the output of the system for the ability of the user to understand fully the information presented.

Relevant tasks include obtaining/monitoring continuous data, obtaining/ monitoring discrete data, obtaining/monitoring status data, obtaining verification data, identifying/isolating problems and assessing requirement to modify operations.

6. Adjust Operations

Purpose. To evaluate the system for ease of use of those components that contribute to operational readiness.

Relevant tasks include indicating system change requirements, adjusting to changed system configuration, inputing discrete commands, monitoring computer/ communications systems.

DESIGN TESTS: TECHNICAL CHARACTERISTICS

Environmental conditions cannot be controlled to any significant degree during field exercise. However, measures must be taken to establish the operating values of the environmental conditions in the workplace of the test participants. It is known that performance can be adversely affected by changes in these conditions, or by the values of these factors being outside of an acceptable range.

The performance of the test participants can change or deteriorate due to changes in environmental factors, that are not controllable, during the mini-testbed and testbed trials. The recorded values of these factors will permit the evaluator to assess whether observed performance changes were due to environmental factors or to some aspect of the testbed design, and also to annotate performance records to the effect that environmental conditions were known to have deviated from acceptable limits.

1. LIGHTING

Workspace lighting shall be assessed using standard procedures made available to the test project personnel, to ensure that criterion levels are maintained throughout the different evaluation periods. The lighting test will not require the use of test participants. The test evaluator will acquire illumination levels falling on selected workspace areas, and brightness values of displays. He will perform comparisons of obtained light values with criteria denoting minimum allowable levels.

The test evaluator will identify all areas in workstations where lighting could be a problem. Different light sources will be identified for assessement, and potential glare problems from high levels of direct or reflected light will be identified.

The test evaluator will measure light levels using a photometer, according to a test plan, under conditions of maximum and minimum illumination where light intensity is controllable. For consoles, several readings should be made in approximately one foot increments in a grid pattern over the surface to be assessed. The illumination readings will be recorded on a data sheet reflecting the same grid pattern. Readings shall be made in low and daylight conditions of ambient light.

To measure the brightness levels of displays a spot brightness meter shall be used. Several areas within each display shall be measured to identify hot spots or areas of non-uniform luminance.

The data will be in the form of illumination values of light falling on a surface or area (in foot candles), and the brightness levels of illuminated displays (in foot lamberts).

2. NOISE

The effects of noise on performance can be

1. direct when the noise field adversely affects the test participant's ability to perform his tasks.

2. indirect in that noise generally leads to fatigue which in turn can result in performance decrement.

The assessment of noise will be made to ensure that noise levels produced in a test condition do not impact on speech intelligibilty nor constitute an annoyance, but do meet aural non-detectability criteria.

Criterion levels for both steady state and impulse noise shall be made available to the test evaluator, and shall be used as a reference against which test measurements can be compared.

1. Steady state noise is a periodic or random variation in atmospheric pressure at audible frequencies. The duration of the variation exceeds one second, and it may be intermittent or continuous.

2. Impulse noise is a short burst of acoustic energy consisting of either a single impulse or a series of impulses. The rise to peak pressure and the slower decay to ambient pressure of a single impulse occur within one second.

In the testbed, the primary area of concern is steady state noise in areas occupied by test participants. Tests shall employ microphones having an essentially flat response at grazing incidence (90°) and a flat frequency response between 20Hz and 18kHz. Sound level meters shall be used that conform to the requirements for Type I as specified by ANSI S1.4. Octave band filter sets used shall conform to the requirements for Type E Class II as specified by ANSI S1.11. Magnetic tape recorders used shall have a flat frequency response from 20Hz to 18kHz (+/-2dB).

Noise measurement generally involves sampling and recording noise intensities over the frequency range under representative operational conditions. The obtained noise measurements are then compared with the noise limits criteria. This procedure will ensure that noise conditions are within acceptable ranges for all test conditions of the testbed.

The data recorded shall include the following:

1. Test conditions

2. Test site

3. Meteorological data (temperature, humidity, barometric pressure)

4. Nomenclature, model and serial number, and manufacturer of all instruments used

5. Test personnel

6. Microphone locations

7. Sound levels in dB(A), dB(C), and in each octave band.

8. Noise contour data (distances and directions from the equipment at which 85dB(A) is measured.

3. TEMPERATURE, HUMIDITY AND VENTILATION

Since no controls will be provided for the regulation of temperature, humidity and ventilation conditions in testbed workplaces, measurements will be taken of actual conditions during test periods.

While the effects of temperature variations on human performance and physiology are not thoroughly understood, certain temperature states have been demonstrated to have detrimental effects. Continued work effectiveness is compromised with increasing complexity of the task and by added mental strain if temperatures remain at a high level.

Additionally, the combined effects of temperature, humidity and ventilation produce effects that are different from those produced by each factor individually. An evaluation of one factor must therefore give consideration to the other factors, and their values.

The data collected shall be as follows:

1. Dry bulb temperature at one location within the workplace for approximately each 5 square feet of floor space.

2. Humidity at the same location within the workplace.

3. Air flow rate and volume at the same location.

These measurements can be obtained by the use of thermometers, humidity sensors and air flow rate sensors.

DESIGN TESTS: DESIGN CHARACTERISTICS

The specification of standards for the design of workplace items in the testbed is included as a guide to the evaluator in his assessment of the testbed functions.

It is not the function of the evaluation to assess the degree to which the testbed conforms to these human engineering standards. The extent to which they are not met can be used as background information in evaluating the performance, opinions and attitudes of test participants towards use of the testbed features.

This listing of the relevant factors in the design of workplace items should be used as a guide by the evaluator in determining what factors will likely influence performance and attitudes during test performance, and so what factors should be probed in observations, questionnaires and interviews. The evaluation of the mini-testbed will be valuable in determining these items.

1. CONTROLS

Control are components used to activate and modify the equipment power source and to modulate the operating element.

Areas of concern in controls design are

1. location and arrangement, including the relationship between the control and its associated display, functional relations between controls, sequential control operations, orientation to operator, and uniformity of push-buttons in keyboards.

2. force and clearance requirements, as detailed in Annex A, Table IX.

3. visibility, as it contributes to the operator's ability to see the control clearly, including location, size, shape, colour, contrast, field of view, viewing distance, reflectance and illumination.

4. operating procedures, as outline in MIL-STD-1472, paragraph 5.4 (attached as Annex A).

2.DISPLAYS

Displays are components that provide visual and auditory information to the operator concerning the status of operation, and can provide positive indication of developing or potential malfunction.

Areas of concern in displays design include

1. location and arrangement of displays relative to the orientation of the operator, at a viewing distance of 33-70 cm.

2. visibility, including angle of display to line of sight, allocation of most frequently used display sources in optimal visual zone, adequate contrast and luminance, and prevention of reflections.

3. conditions of use, such as display precision and response, quality of information displayed, minimizing of the requirement to decode information, absence of trademarks or irrelevant information from display surface, uniformity of coding techniques, and accessibility of material from printers and plotters.

Specifications will be in accord with MIL-STD-1472, paragraph 5.2 as appropriate (attached at Annex B).

3. LABELS, MARKINGS

Labels provide technical guidance in the form of schematics or instruction plates, make the operator aware of hazards, and give special guidance or instructions.

Labellling and markings criteria will be applied as outlined in MIL-STD-1472, paragraph 5.5 (attached as Annex C).

4. WORKSPACE

This is the area within which the test participant operates the equipment. It includes space for controls, displays, optics, electronic devices, as well as standing areas, consoles and seats. Storage for task-related and personal items is incorporated.

Areas of concern for evaluation of the workplace include

1. location and arrangement, including placement of displays in relation to work surfaces, placement of controls with respect to displays and work surfaces, profile and dimensions of consoles, seating design, and work surface design.

2. clearances, including knee clearance for seated operator, seat adjustment ranges, and adequate personal work space envelope.

3. visibility, including reflections of items in display screens, total workspace viewing angles, and illumination.

4. conditions of use, including environmental conditions, safety considerations and possibility of personal injury.

5. operating procedures, including suitable accessible storage for manuals and worksheets, worksurfaces for placement of reference manuals, and suitable labeling and instructions.

General specifications for workspace design will be in accordance with MIL-STD-1472, paragraph 5.7 as appropriate, (attached as Annex D).

5. COMMUNICATIONS

This refers to devices and techniques for communicating information among test participants within the workspace, and between these personnel and individuals externally located. It is recognized that the communications devices used in the evaluations may not be representative of those to be used in an operational system. The degree to which the communications devices used influence the perfromance or attitudes of the evaluation subjects should be noted, however.

Areas of interest include

1. location and arrangement, including availabilty of microphones, headphones and headsets, accessibilty of volume and gain controls, and adjustments for earphones and headsets.

2. clearance, including unobstructed reach to communications controls.

PERFORMANCE TESTS

Performance assessment provides data that bear directly on the issue of operational effectiveness, rather than the assessment of equipment design. The initial aim is the obtaining of gross measures at critical points in the system. If these indicate deficiencies within an identified sub-element, then additional performance measures are examined to isolate procedural, coordination or communication problems.

The test scenario should sample a broad range of activities performed at the workstation. The primary measure of interest is the adequacy of the task output. Conventional measures are time, accuracy and completeness, supported by stated operational requirements or performance standards. These measures can be obtained in large part from objective records of system output. When adequate standards are not obtained by the test participant, as indicated by these objective records, diagnostic measures are required to identify the nature of the difficulty. These diagnostic measures may be obtained from additional records of control activation times, errors, ommisions, or from direct observation of test participant performance and from test participant interviews.

Questionnaires and interviews shall be carefully prepared and administered to gather valid and reliable data reflecting personnel opinions and insights concerning man-machine system performance capability, and military utility and acceptance. These give opinions, attitudes and preferences of the users who have experience with the item, and also supplement and clarify information derived from observations and measurements.

1. OBJECTIVE MEASURES

Criteria must be established for the collection of objective, quantitative data to measure personnel performance. This includes the issue of how much data should be collected. With too little data it is not possible to form valid conclusions about performance. Collecting too much data is inefficient, since, although the required data are available, it may prove difficult to isolate and extract those data from the total amount collected.

It is possible to collect data on all the actions taken by every test participant in the evaluation trials while using the data system. At an extreme level, every time that he hits a key or uses any other data manipulation device (tablet or roll ball), the action can be recorded and the time of the action noted. Subsequent interpretation of these data can indicate correct responses, errors committed, and frequency of use statistics for various functions and services.

The value of these data should be judged in advance, to see how meaningful they will be in assessing the value of the automated aids provided. An assessment will also have to be made as to the cost to the system in terms of overheads to record all these data and to store them for future recall and analysis.

To reduce the load on the system, and to make the interpretation of the data more meaningful, selection must be made as to the operator functions that will be recorded during the test. This is a judgment that must be made by the test evaluator in terms of the value of the available data, files and facilities to someone performing the duty role under examination. Guidance as to the main data types of interest is given in Heckman et al (1979), paragraph 3.12, based on the results of the Exercise Talfos series.

Almost all personnel performance measures fall into one of three general categories:

1. accuracy or errors

2. duration of responses

3. reaction time to perform an action

and these must be applied to the tasks being performed and the equipment being operated.

The data collected, therefore, will be concerned with accuracy, duration, reaction time, frequency of occurrence, and the amount and quality achieved. For example, if the value of the index of messages was to be assessed, records would be made of each reference to the index, the time of each such reference, and the action that was taken subsequent to that reference (i. e. what he did on the basis of that information). For the graphics display, records might be maintained of which data elements were called up for display while a Sitrep was being prepared, that is, what information is useful in graphic form for completion of this task.

Status information should be recorded in snapshot form, by recording the values of specific items on a periodic basis. For example, the length of the message queues for the different precedence levels can be sampled on a 5-minute basis.

Time Measures

(a) Reaction time measures.
Reaction time measures should be taken to indicate the time taken for a test participant to perceive an event, or to initiate an action in response to an event.

Their main value is in determining how quickly the test participant can react to programmed events. The following points must be noted:

1. reaction time data should only be collected when it has been determined that they will be of use for the evaluation.

2. the reaction time data will only be meaningful if a time requirement exists, or a reaction time criterion is available. That is, there has to be a standard against which the data are compared, in order to assign meaning for the evaluation.

3. there may be an application for team as opposed to individual reaction time data. This type of measure depends on the accumulation of individual reaction times, together with team interaction factors.

4. the test participant's response may be covert, that is, a perceptual rather than an observable response. It may be difficult to record, therefore.

5. if a reaction time measure is used, the precision of the measurement must be appropriate to the nature of the task being measured.

(b) Duration measures.
Duration measures should be taken to indicate the total time required to complete a task.

The main value of duration measures is when there is a maximum duration that is considered to be acceptable for a task. This can relate to both individual and to team performance. When acceptable time durations are not met, excessive demands may be being made at some point in the procedure. When they are met, it may be at a cost in terms of decreased accuracy.

An application for duration measures is determination of what percentage of time the test participant spends on individual functions when he is performing several functions concurrently or sequentially (for example, receiving a message, logging it, extracting information from it, and entering the data in the system, can be recorded by duration of each function).

Accuracy Measures

Measures of the accuracy, or the converse, the errors committed in task performance is the most commonly used and the most useful measure of personnel performance. Accuracy can be measured in tasks that include the following:

1. observing and identifying stimuli or occurrences
2. estimating distance, direction or time of movement of objects
3. detecting a change in events over time
4. recognizing a signal in a high target density background
5. recognizing an out of tolerance condition
6. positioning a control
7. reading displays
8. selecting among alternatives
9. making a coordinated series of movements
10. communicating

The following points should be noted with respect to accuracy measures:

1. the maximum number of permissable errors should be estimated, and the significance of errors stated in terms of system efficiency
2. there will be both errors of comission (performing a non-required action or an action incorrectly) and of omission (failure to perform an action).
3. accuracy data can be diagnostic of inadequate system design or of inadequate personnel training
4. analysis of error data relates to both error frequency and to the types of errors made
5. errors that are made but are subsequently corrected by the test participant should not be counted as errors unless they degrade task performance significantly until corrected.

For error analysis, therefore, there must be a statement prior to the evaluation that clearly outlines the number of errors allowable, and the types and criticality of errors to be assessed. Errors that have no impact on overall performance, or are trivial in nature should not be recorded. Without some prior guide as to the criticality of errors and their value as data, the test observers will not be able to recognize performance inadequacies and to note that errors are being made.

The recording of errors will be achieved in several ways. Some of the error data will be logged automatically in the computer as part of the workstation activity record. The preferable technique for manual error logging is to use an operating procedure as a template. Task performance is checked against the procedure as each action is accomplished. Actions that do not conform to the template are noted at that point on the procedure sheet.

For relatively unstructured tasks this procedure may comprise a list of general functions rather than specific actions, and only major gross actions required to carry out these functions noted. At this level, the observer has to be more cognizant of the task requirements, and be more able to observe the task details and to note errors in specific actions.

The data recorded should include the nature of the error, error amplitude if appropriate, and where in the system operation the error occurred. Frequency of errors of each type will be computed at a later stage. Additionally, accuracy will be assessed apart from error data by contrasting the number of tasks successfully completed against the number attempted.

Frequency of Occurrence Measures

Frequency measures of personnel performance give a tabulation of personnel actions over time, or during some specific phase of the operation. The main value of such data is to explain other data that have beeen collected, rather than standing alone as a performance measure. By itself, it explains nothing. Relative frequency of errors may assist in explaining a problem that has been noted with a data entry device, for example. Commonly, frequency measures are carried out on personnel actions, errors, verbal reports or maintenance actions.

Measures of Amount Achieved

Given that a certain level of performance must be acieved on a task, performance measures indicate the degree of achievement relative to that criterion. An example is the number of messages that are processed from the total number that are sent to a terminal. The previously noted measure of accuracy, i.e. the percentage of tasks that are successfully completed, is another example. The value of this measure is largely descriptive rather than analytical. It can be used in conjunction with other measures to improve understanding of personnel performance. A related concept is the amount consumed, since there is always a cost associated with attaining a product. The measure of amount consumed in the command post task may be man-hours, computer system resources or communication system time.

2. INFERRED MEASURES

When the measures that are employed depend on human judgment, that is, when the test participant or observer is the measuring instrument, there is inevitable inaccuracy and inconsistency. This type of measurement will involve the recognition of the behaviour to be recorded, determination of the relevant characteristics of that behaviour, and the recording of the relevant data. Interpretation, and so error, is involved at each of these stages.

In practical terms, all measures of personnel performance cannot be objective, and, indeed, any evaluation is incomplete if subjective data are not gathered together with objective data, since they provide information unobtainable by other means. There is value to be derived from the careful use of inferred measures. These include observation, the questionnaire, the interview, and the use of rating scales, checklists and critical incident reporting. It should be noted that qualitative, subjective measures such as these cannot be scaled nor combined with other subjective data. They cannot stand alone, but must be used to support or explain the meaning of quantitative data.

Observation

Observation of subject activity during evaluations provides increased objectivity, but requires a large pool of experienced, trained human factors specialists to act as observers, since an observer is required at each subject workstation.

Project officers can observe more effectively from the military procedures standpoint, but in most cases must be trained to observe behaviour analytically. Observation is not merely seeing, but also includes analysis and interpretation by the selection of relevant task characteristics. It is this selectivity, with associated inaccuracies and omissions of observation that can be identified as a key issue in the use of this measurement technique (Selltiz et al, 1959).

If observation is conducted by remote means, such as by videorecording, the presence of the camera may act as a reminder of, and add to the artificiality of the situation. The cost of the equipment for data collection by such remote observation in a large system could be quite considerable. The time required and the professional staff dedicated to the reduction of this form of data is often unacceptable.

There are several problems associated with the use of human observers:

1. There is a lack of reliability resulting from random observation of events and selective perception on the part of the observers. Establishing formal procedures can alleviate this to a degree, but personal interest or training can still influence how the observer observes.

2. The mere presence of the observer can alter the performance of the test participants from what it would otherwise have been.

3. There is a risk that the observer may not notice important actions, such as erroneous responses, if the test participant's body blocks the observer's view of his actions. If events occur concurrently or in rapid succession, the observer may be unable to detect them all. He may then focus on a sub-set of events, or alternatively only report in a gross undetailed manner.

4. It is usual for an observer to have a certain status or role in the organization that precludes him from observing the behaviour of the more senior participants. The captain will find it difficult to properly observe the general.

5. An observer allocated to observe a specific group tends to become involved with the group, identifying himself as a member of the group. In the process he loses objectivity.

6. The process of observing implies that the observer must passively wait for the occurrence of particular events. The most interesting events, or the events that will be most informative about performance may not occur during the time span of the observation.

These limitations to the observation technique are not sufficient, however, to eliminate it from use. The natural setting, the amount of information that can be obtained on a wide range of items, and the relative unobtrusiveness of the technique makes it a useful and valuable method of data collection. The problems should be recognized, however, and their effects minimized as much as possible.

The procedure for individual observation of personnel performance can be:

1. describe what events or test participant responses occurred, what happened, who did it, and with whom.

2. determine the frequency of system events or test participant responses

3. determine the accuracy (or errors) with which these events or responses occurred

4. form conclusions and judgments about performance quality

Questionnaires

The questionnaire involves a series of structured questions presented to test participants in order to sample their opinions, attitudes and preferences concerning test facilities or procedures. Participants are usually required to rate the item along some dimension ranging from extremely positive to extremely negative. The major advantage of the questionnaire is that it can be administered to a group of test participants simultaneously, while in addition it elicits responses while placing a minimum demand on the test participant. The major disadvantage is that only those issues that have been determined in advance by the test evaluator as being important are sampled.

(a) Preparation of Questionnaires.
Questionnaire items should be based on a prior human factors analysis by specifically addressing each potential problem area which the analysis identifies. The responses to the questionnaire will then tend to confirm or reject initial assessments, and may indicate potential practical solutions to identified problems.

(b) Validity.
Validity implies that the questionnaire is measuring what

it is intended to measure. Frequently it is assumed that the questions are asking, and so giving data on one issue, when in fact the answers are about something else, since the subjects give a different interpretation to the question than was intended.

A major point is the establishing of content validity for each question. The designers of questionnaires often assume that the way they have phrased questions is correct because they understand them. The subject, however, may not give answers in the frame of reference intended, since he may misunderstand the wording, may confuse the point with some other, or may answer in an unexpected sense. It is important, therefore, to pre-test the questionnaire to ensure that the questions are meaningful and understandable, and to provide information on any problems in content, presentation or procedures that may have been overlooked to this point. The pretest should be conducted on personnel similar to the test subjects, and the data that is gathered should be used only for the purpose of questionnaire refinement.

(c) Question Construction.
Questionnaire items must be developed with care. Firstly, the length of the questionnaire should be as short as possible while covering the required topics. Secondly, the questions should be such as to elicit answers that will be of value in assessing the item rather than providing background information. Thirdly, the phrasing of the question must not bias the answer in one direction or the other. Finally, the questions must be as clear and concise as possible.

Questions must be constructed in such a way that they ask only one question on a defined and specific point, so that the answer can be interpreted correctly. That is, compound questions must be avoided.

The recommended format for questions is the presentation of fixed alternatives from which the subject selects his response, while giving him the option of appending a short explanation if he so wishes. The use of free-answer questions is not recommended, although they offer some advantages such as being undirected, and eliciting a wide variety of responses. They also provide a richer background of opinion on which to base conclusions. Their main application, however, is in situations where the issues are unclear and formulation of specific questions difficult. These advantages are outweighed by the possibility that the opinions presented are being influenced by the observer. The administrative problems involved in analysis of the information given to free-answer questions are alone severe enough to make them unusable.

In designing questions, it must be ensured that the subject can in fact provide the information that is requested. If not, he may answer anyway, from a position of ignorance. This does not imply that the respondents to the questionnaire are not knowledgable about the task, but rather that they are being asked to report on their own behaviour or attitudes from memory. They may not have noted these items in enough detail to report adequately at a later time.

(d) Administration.
The time when the questionnaire is administered during the evaluation is important. If it is given too early, the subjects may not have had enough experience to give meaningful answers. If it is given too late, the risk is run that the subjects adapt to system deficiencies before their opinions are noted.

Interviews

(a) Interview Structure.
The interview provides a maximum amount of information in terms of insights and acceptability estimates. It may be administered on an individual basis, and so takes a lot of time to administer, depending on the number of interviewers and interviewees. It may be administered to a team, with one interviewer interviewing several interviewees as a group, in order to identify team interaction factors. The interview should always be conducted at the end of the test trial.

The interview cannot be used as an unstructured, open-ended discussion period between the test participant and the observer. In order to ensure that the topics discussed by different participants are comparable, and also that the problem areas identified by the test evaluator are considered, the interview must follow a structured interview guide, containing a set of questions which are asked of each participant.

The structured interview guide comprises a series of questions selected on the basis of their relative importance for the item assessment. The same series of questions are presented to each participant, nomally in the same order.

A sample list of items for the interview can be:

1. what did he do while performing the task?

2. why did he perform as he did?

3. what knowledge does he have about principles and

information that should have guided his task performance?

4. what test conditions affected his task performance most, and why?

5. how well did he think he performed?

6. with what tasks did he experience the most difficulty?

7. in team operation, how was responsibility assigned?

8. what effect did specific features of the system design or function have on his performance?

9. what comments does he have to make on any aspect of the test or on his performance?

(b) Interviewers.
Interviews can be conducted by the project officers or by human factors specialists. Unfortunately there are limitations in both approaches.

The project officer is familiar with the operational requirements and procedures, but is not trained in the techniques of interviewing. The main objections to the use of interviews are relevant here. Interviews are claimed to produce inaccurate information due to bias in judgment related to the interviewer's response to the interviewee's appearance, manner, or other personal characteristics. In the testbed situation, this bias can be augmented by attitudes towards the interviewee as an individual known personally or by reputation, to his MOC that is different from that of the interviewer, or to regimental differences.

The human factors specialist is skilled in interview techniques, but will not be so aware of the military aspects of the situation. The interviewer, however, need only know the general task procedures, without being as proficient in the task as the test participant. The specialist will not be alert to deviations from accepted standards of procedure and technique as would the project personnel.

Ideally, all test participants in the evaluation should be interviewed, but the staff required to conduct such a number of interviews is beyond the resources of this evaluation. Some compromise may be found between the need from a comprehensive series of interviews and the number of interviewers available by identifying a selected sample of key subjects from each unit or sub-unit who could provide the necessary data.

The basic requirements for interviewers are:

1. Experience in establishing rapport with the person interviewed

2. Being alert to partial hints from the person interviewed

3. Being able to initiate new channels of communication within the format of the stuctured interview guide.

(c) Guidelines.
A series of guidelines for interviewing is as follows :

1. Decide in advance what is to be accomplished in the interview. This entails the clear understanding of what the aim of the testbed evaluation is, and what the individual's role in it is. On this basis, the interview can attempt to find out the attitudes of the individual towards the total system, and to his role in it. He can also be prompted to state how well he thinks the situation was designed to permit him to do what he had to do.

2. Know the interviewee. The interviewer should know in advance who he will be talking to, what his operational background is, and what his role was in the evaluation. Rapport suffers when the interviewee is treated like one of a faceless crowd.

3. Appointments must be made in advance for each interview. The attitude of the interviewees towards the interview situation can be negative and uncooperative if there is an appearance of lack of organization.

4. Provide for privacy during the interview session, and establish clearly that all records made from the interview are coded for analysis only, and are otherwise anonymous.

5. Try to discount personal prejudices, and to take the interviewee's point of view. Essentially, this means being ready to listen to what is said, and interpret it in the way it was intended, and not on the basis of personal perceptions.

6. Allocate enough time for the interview to be conducted thoroughly, but keep it moving, avoiding

irrelevant topics. Approximately 20 minutes is a good average length for the interview session, since after 30 minutes interviewees will tend to become fatigued.

7. Use an interview guide or schedule as a basis for the structure of the interview. Each person interviewed should be treated in as similar a manner as possible, and should be given standard conditions within which he provides information. The interviewer can best avoid omitting items from the discussion, or from introducing unique items by following a guide or loosely structured schedule, listing the topics that should be covered in the interview.

8. At the close of the interview, note casual remarks that provide additional information or new leads. Individuals tend to follow the lead of the interviewer up to this point, trying to do what is requested of him. When he realizes that the procedure is coming to an end, he is likely to offer comments that he was unable or unwilling to offer within the structure of the interview proper.

Critical Incidents Measures

A critical incident is an unusual event that occurs during system operation and that shows some positive or negative feature of the system. It generally refers to some task-related action taken, or not taken by the test participant. An example is a procedure that is set up to be used in the event of some set of conditions occurring. It may then be noted by an observer that an incident occurs invoking the set of conditions, but the test participant being observed fails to adopt the procedure.

The critical incident is assumed to be significant, but unusual, and to reflect test participant performance. The method of recording the critical incident is a narrative, and an interview may be required with the test participant in order to clarify the details of the event.

Rating Scales

Ratings can be made by an observer, by a team supervisor, by peers or by the test participant as a self-report rating. Ratings assign a number to a subjective assessment so that it can be treated quantitatively, but that process does not make the measurement more accurate nor more valid.

Ratings should only be used when an objective measure of performance assessment cannot be applied, or when such a measurement would be too costly or impractical. The limitations noted for the observational technique apply to ratings, insofar as an individual is the measuring instrument.

The graphic rating scale is the most popular. Commonly it is a straight line combined with descriptors that represent the values of the variable being scaled. The line can be segmented into units or can be continuous, although a continuous line has been found to be preferable in many cases. Examples of rating scales that could apply to the evaluation are attached as Annex E.

Descriptive terms that are used should be short, simple and unambiguous, and should be obviously consistent with the attribute being rated. Good/bad or desirable/undesirable descriptors should be avoided.

It should be noted that observers rating other personnel tend towards leniency with those they know, and are subject to a halo effect by rating a quality as unjustifiably high if other qualities were found to be high. There is also a central tendency, that is, a tendency for raters to bunch ratings in the middle range of the line, avoiding the extremes.

Checklists

A checklist is a series of statements describing test participant performance, the equipment configuration and the system operation. The statement provides a standard against which the item is compared, to allow a judgment to be made as to whether it is or is not as stated.

A common application is the assessment of relatively static system features, as in a human engineering checklist of the man-machine interface. It is not as useful for the measurement of performance, since performance is essentially continuous and checklists are binary. The use of checklists will be most appropriate, therefore, in the critical design review stage. It can be applied during the evaluation as a method of monitoring workstation and environmental conditions to note deviations from the normal, established conditions of the test.

The limitations in the use of the checklist should be noted. The checklist statement states the required condition, and the response is that this condition does or does not exist. No intermediate state can be noted. Therefore the statement must be limited in its application, must be precise and should refer to a single item. A statemnt such as 'controls are simple and easy to operate' raises the question as to the meaning of 'simple' and of 'easy to operate'. It also does not allow for the situation where all the controls except one are deemed easy to operate.

Checklist data are descriptive. They can only guide the test evaluator to the characteristics that may require improvements.

TACCDAS TESTBED MEASURES OF EFFECTIVENESS

In order to adequately assess the performance of the personnel using the TACCDAS Testbed, measures of human performance effectiveness have been generated as a guide for the test evaluator.

1. Evaluate the operational effectiveness and suitability of the TACCDAS Testbed, through its integrated hardware, software, procedures and personnel, to support the operations activities of receipt, evaluation, correlation, analysis, display, storage, retrieval, production and dissemination. These activities are conducted in support of command post personnel in accomplishing the mission of providing complete, accurate, and timely information in support of Brigade operations.

2. Evaluate the capability of the TACCDAS Testbed to provide effective automated assistance to command post personnel in the performance of their duties.

   For example;
   Proportion of enemy sighting reports tthat reach CP and are displayed
   Time taken to issue orders and direction
   Time taken to issue direction by trace/overlay
   Time taken to prepare and distribute movement orders
   Time delay in determining friendly force status
   Time delay in determining enemy losses
   Number of information reports available to all system users

3. Determine, through systematic interviews with project management, scientific and technical support personnel, and systems operators the overall operating adequacy of the system from a command/management point of view, in terms of procedures - bottlenecks, shift changes, work

flow

For example:

1. Amount of duty officer time devoted to clerical duties, which detracts from his ability to supervise and control the CP, and to advise the commander and other staff cells.

2. Currency of master battle map, which should reflect near real-time information.

3. Reliability of master battle map, possibly in terms of the amount of information that is available to a HQ that is displayed in that HQ.

4. Determine system throughput in total, and for each CP cell, in terms of number of messages logged, number of data base transactions, and number of final actions posted per unit of time.

   Data messages are seen to be short, generally formatted, with specific items of information, and requiring specific procedures to be followed. Since the rate is largely determined by enemy activity, their processing determines how well the commander is informed.

5. Determine by comparative analysis the relative improvement provided by the TACCDAS Testbed for report composition in terms of time saved, accuracy, and completeness achieved. Determine overall flexibility of format and ease of manipulation of data withion the report.

6. Determine by observation and interview the overall adequacy of the non-digital data base in terms of type and amount of documents provided and their usability.

7. Evaluate the technical coverage, accuracy and usability of all user manuals, technical orders, and position handbooks in their support of the operation and maintenance of the Testbed.

8. Determine the capability of the TACCDAS Testbed to provide automated support to generate and maintain a digital and non-digital data base file that can be manipulated both manally and automatically so as to maintain currency and effectiveness in support of the primary mission.

9. Determine the efficiency of data base maintenance

in terms of personnel required and man-hors expended for the basic updating and purging functions.

10. Determine the adequacy of the data base structure in terms of elements to be deleted or added to facilitate performance of CP personnel.

11. Determine the requirement for, and feasibility of an automated update capability with respect to certain files of data.

12. Determine the adequacy of system and application software in its operating environment. Identify and catalogue all deficiencies and discrepancies for further testing and/or corrective action.

13. Evaluate the degree to which performance of CP personnl is adversely affected by various types of system degradation, with resulting reconfiguration, input/output loading, and/or partial loss of automated assistance capability.

14. Determine TACCDAS communications interface requirements

    User opinion on:
    requirement for intercom
    number and types of radios/remotes
    number and types of telephones
    possible enhancements to communications (types of microphones,headsets,alarms).

    The communications loading during peak periods is mostly a system rather than performance measure, but is related to user performance insofar as it influences the ability to pass information in a timely manner.

15. Determine whether human engineering, biomedical, and safety objectives have been implemented effectively in the design and fabrication of the TACCDAS Testbed workstations.

16. Determine the space adequacy within the shelters for storage of equipment, personal gear, and for the storage and use of maps.

17. Evaluate the maintanability and reliability of the TACCDAS Testbed as supported by spares, test and fault isolation equipment to permit continuous operations.

18. Determine the ability of military personnel to assemble and disassemble, connect, interconnect

and disconnect the terminal equipment, and to initiate operations.

19. Obtain data and observations to support recommendations concerning the number, type and skill level of personnel required for effective operation and maintenance of the Testbed.

20. Obtain data and observations to support recommendation concerning the type, length and content of specific training required for TACCDAS operating personnel. Identify any contractor-provided training that will facilitate the development of military courses.

21. Determine the cost of ownership of a TACCDAS configuration with regard to manpower requirements to operate and maintain it, with manuals, support equipment, test equipment, spares, training and data base conversion.

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ANNEX A

To

TACCDAS Testbed Human Factors Evaluation

MIL-STD-1472 para 5.4

CONTROLS

5.4.3.1.3 Keyboards -

5.4.3.1.3.1 Application - Arrangements of push buttons in the form of keyboards should be used when alphabetic, numeric or special function information is to be entered into a system.

5.4.3.1.3.2 Layout and Configuration - The key configuration and the number of keys are directly dependent upon the predominant type of information to be entered into the system. The major forms that keyboards can take, which aid in the entry of such information, are given below:

a. Numeric Keyboard: The configuration of the keyboard which shall be used to enter solely numeric information should be a 3 x 3 + 1 matrix with the zero digit centered on the bottom row.

b. Alpha-Numeric Keyboard: Keyboard configurations for applications which require the entry of alphabetic and some numeric information shall conform to MIL-STD-1280. For some applications the entry of data varies from primarily alphabetic to primarily numeric. For these applications two alternatives are suggested. The first being to provide a keyboard of the type shown in Figure 2, page 16, of MIL-STD-1280 (where there is no separation between alphabetic and numeric characters); and the second to provide a separation to emphasize the two separate functions, with the numeric keyboard located to the right of the standard keyboard.

5.4.3.1.3.3 Dimensions, Resistance, Displacement, and Separation - The control dimensions, resistance, displacement and separation between adjacent edges of the pushbuttons which form keyboards shall conform to the criteria in Table IX. For a given keyboard these criteria shall be uniform for all individual keys. For those applications where operation while wearing (trigger finger) arctic mittens is required, the minimum key size shall be 0.75 inch (19 mm). Other parameters are unchanged from those of bare-handed operation (see Table IX).

5.4.3.1.3.4 Slope - All nonportable keyboards should have a slope of between 15 and 25 degrees. The preferred slope is 16 to 17 degrees. The slope of a portable device can be varied according to the preference of the operator.

TABLE IX. KEYBOARDS

	Dimensions: Diameter D* Bare-handed	Dimensions: Diameter D* Arctic mittens**	Resistance: Numeric	Resistance: Alpha-numeric	Resistance: Dual Function
Minimum	0.385"	0.75"	3.5 oz	0.9 oz	0.9 oz
Maximum	0.75"		14.0 oz	5.3 oz	5.3 oz
Preferred	0.5"	0.75"			

	Displacement: Numeric	Displacement: Alpha-numeric	Displacement: Dual Function	Separation (between adjacent key tops)
Minimum	0.03"	0.05"	0.03"	0.25"
Maximum	0.19"	0.25"	0.19"	
Preferred				0.25"

	Dimensions: Diameter D* Bare-handed	Dimensions: Diameter D* Arctic mittens**	Resistance: Numeric	Resistance: Alpha-numeric	Resistance: Dual Function
Minimum	10mm	19mm	1N	250 mN	250 mN
Maximum	19mm		4N	1.5 N	1.5 N
Preferred	13mm	19mm			

	Displacement: Numeric	Displacement: Alpha-numeric	Displacement: Dual Function	Separation (between adjacent key tops)
Minimum	0.8mm	1.3mm	0.8mm	6.4mm
Maximum	4.8mm	6.3mm	4.8mm	
Preferred				6.4mm

*See Figure 9
**Trigger finger type

TABLE VII. MINIMUM SEPARATION DISTANCES FOR CONTROLS

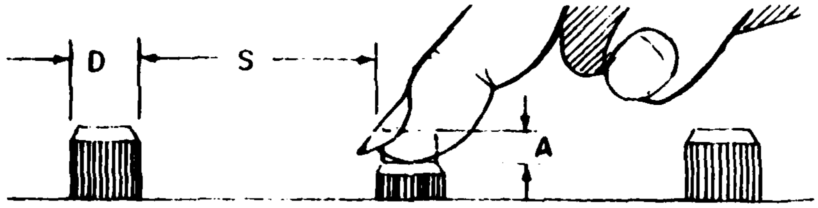
	TOGGLE SWITCHES	*PUSH-BUTTONS	CONTINUOUS ROTARY CONTROLS	ROTARY SELECTOR SWITCHES	DISCRETE THUMBWHEEL CONTROLS
TOGGLE SWITCHES	SEE FIG 11	0.5"(13 mm)	0.75"(19 mm)	0.75"(19 mm)	0.5"(13 mm)
*PUSHBUTTONS	0.5"(13 mm)	SEE FIG. 9	0.5"(13 mm)	0.5"(13 mm)	0.5"(13 mm)
CONTINUOUS ROTARY CONTROLS	0.75"(19mm)	0.5"(13 mm)	SEE FIG 6	1.0"(25 mm)	0.75"(19 mm)
ROTARY SELECTOR SWITCHES	0.75"(19 mm)	0.5"(13 mm)	1.0"(25 mm)	SEE FIG 3	0.75"(19 mm)
DISCRETE THUMBWHEEL CONTROLS	0.5"(13 mm)	0.5"(13 mm)	0.75"(19 mm)	0.75"(19 mm)	SEE FIG 5

*For pushbuttons not separated by barriers

All values are for one hand operation. Distances are measured in inches and are measured from edge to edge of each control.

TABLE VIII. ADVANTAGES AND DISADVANTAGES OF VARIOUS TYPES OF CODING

	TYPE OF CODING					
ADVANTAGES	LOCATION	SHAPE	SIZE	MODE OF OPERATION	LABELING	COLOR
Improves visual identification.	X	X	X		X	X
Improves nonvisual identification (tactual and kinesthetic).	X	X	X	X		
Helps standardization.	X	X	X	X	X	X
Aids identification under low levels of illumination and colored lighting.	X	X	X	X	(When trans-illuminated)	(When trans-illuminated)
May aid in identifying control position (settings).		X		X	X	
Requires little (if any) training; is not subject to forgetting.					X	
DISADVANTAGES						
May require extra space.	X	X	X	X	X	
Affects manipulation of the control (ease of use).	X	X	X	X		
Limited in number of available coding categories.	X	X	X	X		X
May be less effective if operator wears gloves.		X	X	X		
Controls must be viewed (i.e., must be within visual areas and with adequate illumination present).					X	X



	DIMENSIONS: Diameter D		RESISTANCE		DISPLACEMENT: A
	Fingertip Operation	Thumb or Heel of Hand Operation	Fingertip Operation	Little Finger Operation	Thumb or Finger Operation
Minimum	0.385" (10mm)	0.75" (19mm)	10 oz (2.8N)	5 oz (1.4N)	0.125" (3mm)
Maximum	0.75" (19mm)		40 oz (11.0N)	20 oz (5.6N)	1.5" (38mm)

	SEPARATION: S		
	Single Finger Operation	Single Finger Sequential Operation	Operation by Several Fingers
Minimum	0.5" (13mm)	0.25" (6mm)	0.5" (13mm)
Preferred	2.0" (50mm)	1.00" (25mm)	0.5" (13mm)

Figure 9. PUSHBUTTONS (FINGER OR HAND OPERATED)

ANNEX B

To

TACCDAS Testbed Human Factors Evaluation

MIL-STD-1472 para 5.2

VISUAL DISPLAYS

5.2 VISUAL DISPLAYS -

5.2.1 General - Visual displays should be utilized to provide the operator with a clear indication of equipment or system conditions for operation under any eventuality commensurate with the operational and maintenance philosophy of the system under design.

5.2.1.1 Display Illumination - When the degree of dark adaptation required is not maximum, low brightness white light (preferably integral), adjustable as appropriate, shall be used; however, when the maximum degree of dark adaptation is required, low brightness red light (greater than 620 nm) shall be provided. Where multiple displays are grouped together, the displays shall have brightness uniformity so that all appear of equal brightness across the range of full ON to full OFF.

5.2.1.2 Information -

5.2.1.2.1 Content - The information displayed to an operator shall be limited to that which is necessary to perform specific actions or to make decisions.

5.2.1.2.2 Precision - Information shall be displayed only to the degree of specificity and precision required for a specific operator action or decision.

5.2.1.2.3 Format - Information shall be presented to the operator in a directly useable form. (Requirements for transposing, computing, interpolating, or mental translation into other units shall be avoided.)

5.2.1.2.4 Redundancy - Redundancy in the display of information to a single operator shall be avoided unless it is required to achieve specified reliability.

5.2.1.2.5 Combined Information - Information necessary for performing different activities (e.g., operation and troubleshooting) shall not simultaneously appear in a single display unless they are comparable functions requiring the same information.

5.2.1.2.6 Display Failure Clarity - Displays shall be so designed that failure of the display or display circuit will be immediately apparent to the operator.

5.2.1.2.7 Display Circuit Failure - Failure of the display circuit shall not cause a failure in the equipment associated with the display.

5.2.1.2.8 Unrelated Markings - Trademarks and company names or other similar markings not related to the panel function shall not be displayed on the panel face.

5.2.1.3 Location and Arrangement -

5.2.1.3.1 Accuracy - Displays shall be located and designed so that they may be read to the degree of accuracy required by personnel in the normal operating or servicing positions.

5.2.1.3.2 Access - Ladders, supplementary lighting, or other special equipment should not be required in order to gain access to or to read a display.

5.2.1.3.3 Orientation - Display faces shall be perpendicular to the operator's normal line of sight whenever feasible and shall not be less than 45° from the normal line of sight (see Figure 1). Parallax shall be minimized.

5.2.1.3.4 Reflection - Displays shall be constructed, arranged, and mounted to prevent reduction of information transfer due to the reflection of the ambient illumination from the display cover. Reflection of instruments and consoles in windshields and other enclosures shall be avoided. If necessary, techniques (such as shields and filters) shall be employed to insure that system performance will not be degraded.

5.2.1.3.5 Vibration - Vibration of visual displays shall not degrade user performance below the level required for mission accomplishment (see para 5.8.4.2).

5.2.1.3.6 Grouping - All displays necessary to support an operator activity or sequence of activities, shall be grouped together.

5.2.1.3.7 Function and Sequence - Displays shall be arranged in relation to one another according to their sequence of use or the functional relations of the components they represent. They shall be arranged in sequence within functional groups whenever possible to provide a viewing flow from left to right or top to bottom.

5.2.1.3.8 Frequency of Use - Displays used most frequently should be grouped together and placed in the optimum visual zone (see Figure 2).

5.2.1.3.9 Importance - Very important or critical displays shall be placed in a privileged position in the optimum projected visual zone or otherwise highlighted.

5.2.1.3.10 Consistency - The arrangement of displays shall be consistent in principle from application to application, within the limits specified herein.

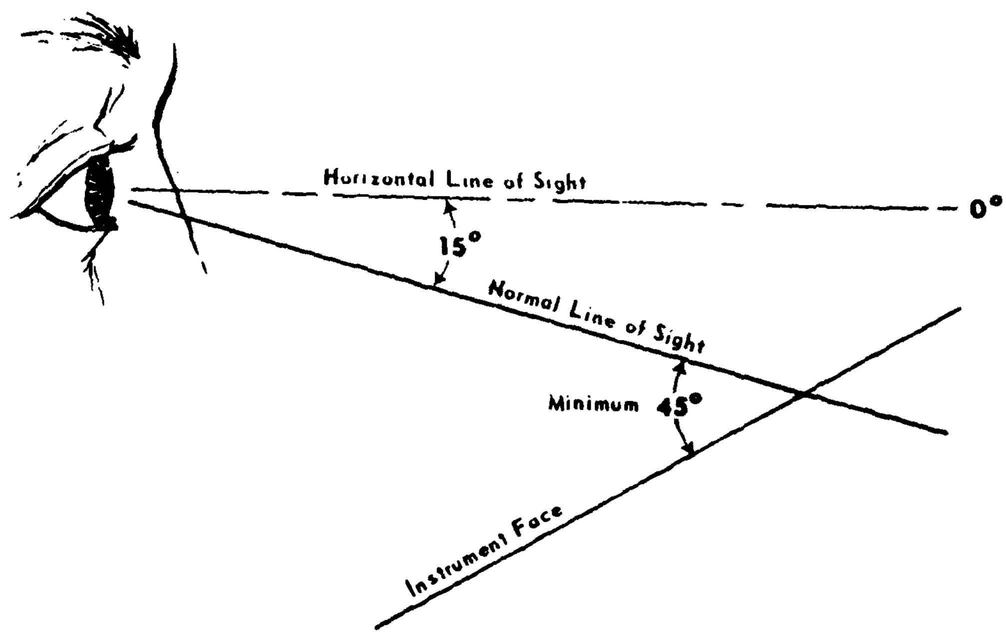


Figure 1. LINES OF SIGHT

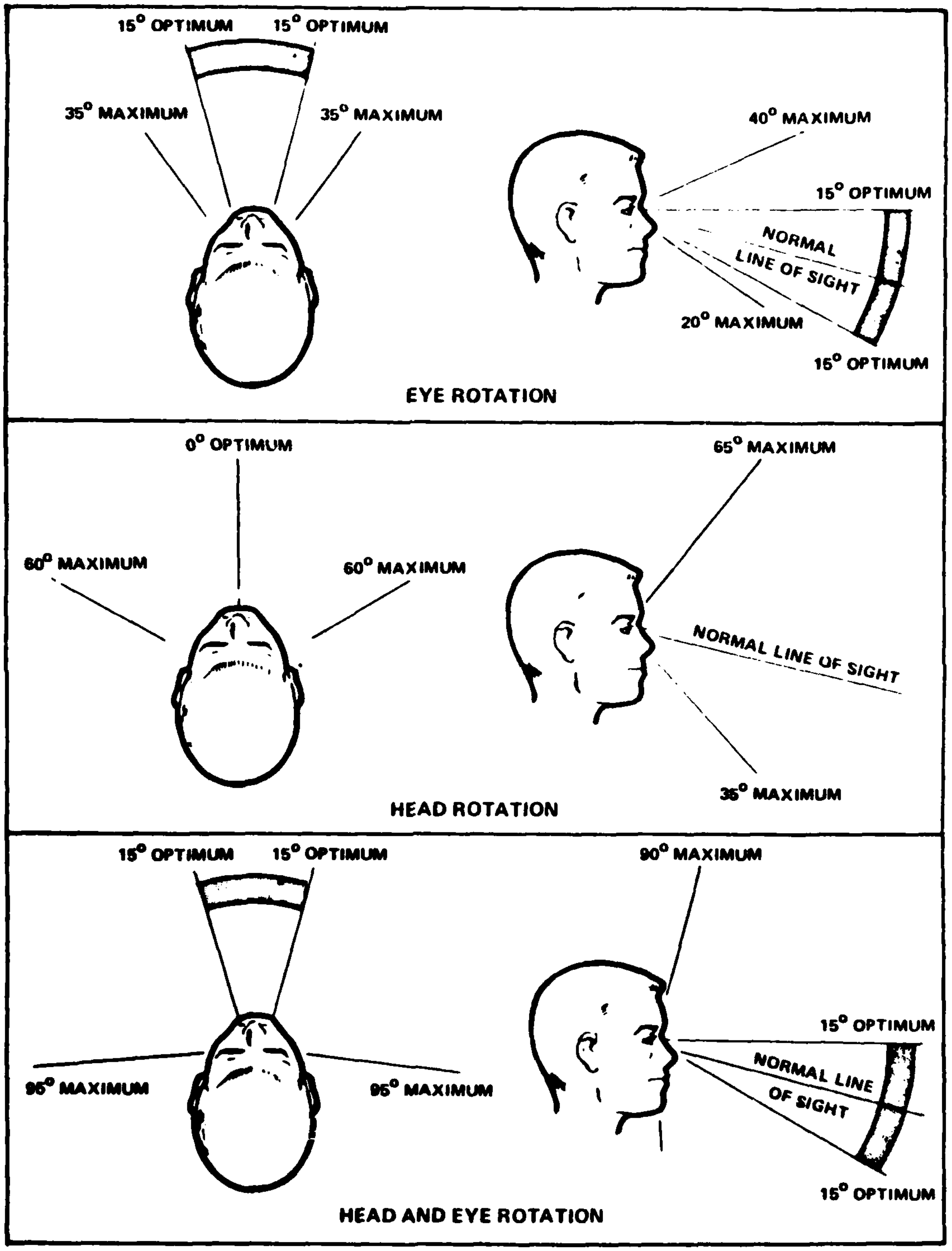


Figure 2. VERTICAL AND HORIZONTAL VISUAL FIELD

5.2.4 Cathode Ray Tube (CRT) Displays -

5.2.4.1 Signal Size - When a target of complex shape is to be distinguished from a nontarget shape that is also complex, the target signal should subtend not less than 20 minutes of visual angle and should subtend not less than 10 lines or resolution elements. Image quality shall be consistent with the operator's needs.

5.2.4.2 Viewing Distance - A 16-inch (410 mm) viewing distance shall be provided whenever practicable. When periods of scope observation will be short, or when dim signals must be detected, the viewing distance may be reduced to 10 inches (250 mm). Design should permit the observer to view the scope from as close as he may wish. Displays which must be placed at viewing distances greater than 16 inches (410 mm) due to other considerations shall be appropriately modified in aspects such as display size, symbol size, brightness ranges, line-pair spacing and resolution.

5.2.4.3 Screen Luminance - The ambient illuminance shall not contribute more than 25% of screen brightness through diffuse reflection and phosphor excitation.

5.2.4.4 Faint Signals - When the detection of faint signals is required and when the ambient illuminance may be above 0.25 FT-C (2.7 lux), scopes shall be hooded, shielded, or recessed. (In some instances, a suitable filter system may be employed, subject to approval by the procuring activity.)

5.2.4.5 Luminance Range - The luminance range of surfaces immediately adjacent to scopes shall be between 10% and 100% of screen background luminance. With the exception of emergency indicators, no light source in the immediate surround shall be brighter than scope signals.

5.2.4.6 Ambient Illuminance - The ambient illuminance in the CRT area shall be appropriate for other visual functions (e.g., setting controls, reading instruments, maintenance, etc.) but shall not interfere with the visibility of signals on the CRT display.

5.2.4.7 Reflected Glare - Reflected glare shall be minimized by proper placement of the scope relative to the light source, use of a hood or shield, or optical coatings or filter control over the light source.

5.2.4.8 Adjacent Surfaces - Surfaces adjacent to the scope shall have a dull matte finish. The reflectances of these surfaces shall be such that the resultant luminances will be consistent with the criteria established above.

5.2.4.9 Electronically or Optically Generated Displays - Electronically or optically generated displays shall conform to MIL-STD-884.

5.2.5 Large-Scale Displays

5.2.5.1 Design - The design of large-scale displays intended for group observation shall conform with the basic visual criteria in other paragraphs of this standard, and the additional requirements below. Also, see 5.2.6.6.

5.2.5.2 Legibility - The height-to-width ratio, stroke width, size, and spacing of display symbols shall be such that all characters will be legible at the maximum viewing angle and distance (minimum of 15' arc).

5.2.6 Other Displays

5.2.6.1 General

5.2.6.1.1 Types - Where applicable, direct-reading counters, printers, plotters, flags, optical projection displays and light emitting diodes (LEDs) should be considered.

5.2.6.1.2 Applications - The selection of the above types of displays for various applications should be based on the following specific criteria as well as the criteria in Table III.

5.2.6.3 Printers -

5.2.6.3.1 Application - Printers should be used when a visual record of data is necessary or desirable.

5.2.6.3.2 Form of Information - Printed information shall be presented in a directly usable form with minimal requirements for decoding, transposing, and interpolating.

5.2.6.3.3 Insertion and Removal of Materials - Printers shall be designed to provide for quick and easy insertion and removal of printing materials.

5.2.6.3.4 Take-up Provision - A take-up device for printed material shall be provided.

5.2.6.3.5 Supplies - A positive indication of the remaining supply of printing materials (e.g., paper, ink, and ribbon) shall be provided.

5.2.6.3.6 Annotation - Where applicable printers should be mounted so that the tape may be easily annotated while still in the recorder.

5.2.6.3.7 Printed Tapes - The information on the tapes shall be printed in such a manner that it can be read directly when it is received from the machine without requiring the cutting and pasting of sections of tape.

5.2.6.3.8 Visibility - The printed matter shall not be in any way hidden, masked or obscured so that direct reading cannot be easily and accurately accomplished.

5.2.6.3.9 Illumination - The printer shall be designed with internal illumination if the printed matter is not completely and easily readable in the operational ambient illumination planned for the printer.

5.2.6.3.10 Contrast - A minimum of 50% luminance contrast shall be provided between the printed material and the background on which it is printed.

5.2.6.4 Plotters -

5.2.6.4.1 Use - Plotters should be used when a visual record of continuous graphic data is necessary or desirable.

5.2.6.4.2 Visibility - Plotting points shall be readily visible and shall not be obstructed by the pen assembly or arm.

5.2.6.4.3 Contrast - A minimum of 50% contrast shall be provided between the plotted function and the background on which it is drawn.

5.2.6.4.4 Take-up Device - A take-up device for extruded plotting materials shall be provided when necessary or desirable.

5.2.6.4.5 Job Aids - Aids (e.g., graphic overlays) shall be provided when an operator is required to interpret graphic data, but such aids shall not obscure or distort the data.

ANNEX C

To

TACCDAS Testbed Human Factors Evaluation

MIL-STD-1472 para 5.5

LABELING

5.5 LABELING -

5.5.1 General -

5.5.1.1 General Requirements - Controls, displays, and any other items of equipment that must be located, identified, read, or manipulated shall be appropriately and clearly labeled to permit rapid and accurate human performance. No label will be required on equipment or controls whose use is obvious to the user (e.g., aircraft control stick).

5.5.1.2 Label Characteristics - The characteristics of the labeling to be used shall be determined by such factors as:

a. The accuracy of identification required

b. The time available for recognition or other responses

c. The distance at which the labels must be read

d. The illumination level and color characteristics of the illuminant

e. The criticality of the function labeled

f. Consistency of label design within and between systems.

5.5.1.3 Prototype and Production Equipment Labels - Labels for both prototype and production equipment shall meet the criteria specified herein. Labels for production equipment shall be designed to meet the criteria specified for the duration of equipment use. Since frequent design changes may be anticipated in prototype equipment, labels for such equipment shall be designed so that they may be simply and easily affixed, altered, and removed.

5.5.2 Orientation and Location -

5.5.2.1 Orientation - Labels and information thereon should be oriented horizontally so that they may be read quickly and easily from left to right. Vertical orientation shall be used only when labels are not critical for personnel safety or performance and where space is limited. When used, vertical labels shall read from top to bottom.

5.5.2.2 Location - Labels shall be placed on or very near the items which they identify, so as to eliminate confusion with other items and labels. Labels shall be located so as not to obscure any other information needed by the operator. Controls shall not obscure labels.

5.5.2.3 Standardization - Labels shall be located in a consistent manner throughout the equipment and system.

5.5.3 Contents -

5.5.3.1 Equipment Functions - Labels should primarily describe the functions of equipment items. Secondarily, the engineering characteristics or nomenclature may be described.

5.5.3.2 Abbreviations - Standard abbreviations shall be selected in accordance with MIL-STD-12, MIL-STD-411, or MIL-STD-783. If a new abbreviation is required, its meaning shall be obvious to the intended reader. Capital letters shall be used. Periods shall be omitted except when needed to preclude misinterpretation. The same abbreviation shall be used for all tenses and for both singular and plural forms of a word.

5.5.3.3 Irrelevant Information - Trade names and other irrelevant information shall not appear on labels or placards.

5.5.4 Qualities -

5.5.4.1 Brevity - Labels shall be as concise as possible without distorting the intended meaning or information and shall be unambiguous. Redundancy shall be minimized. Where the general function is obvious, only the specific function shall be identified (e.g., frequency as opposed to frequency factor).

5.5.4.2 Familiarity - Words shall be chosen on the basis of operator familiarity whenever possible, provided the words express exactly what is intended. Brevity shall not be stressed if the results will be unfamiliar to operating personnel. For particular users (e.g., maintenance technicians), common technical terms may be used even though they may be unfamiliar to nonusers. Abstract symbols (e.g., squares and Greek letters) shall be used only when they have a commonly accepted meaning to all intended readers. Common, meaningful symbols (e.g., % and +) may be used as necessary.

5.5.4.3 Visibility and Legibility - Labels and placards shall be designed to be read easily and accurately at the anticipated operational reading distances, vibration/motion environment, and illumination levels, taking into consideration the following factors:

a. Contrast between the lettering and its immediate background

b. Height, width, stroke width, spacing, and style of letters and numerals

c. Method of application (e.g., etching, decal, and silk screen)

d. Relative legibility of alternative words

e. Specular reflection.

5.5.4.4 Access - Labels shall not be covered or obscured by other units in the equipment assembly.

5.5.4.5 Label Life - Labels shall be sharp, have high contrast, and be mounted so as to minimize wear or obscurement by grease, grime, or dirt.

5.5.4.6 Label Background - Label color shall contrast with the equipment background specified in 5.7.9. No special background for the label shall be provided without approval by the procuring activity.

5.5.5 Design of Label Characters -

5.5.5.1 Black Characters - Where the ambient illuminance will be above 1 ft-C (11 lux), black characters shall be provided on a light background.

5.5.5.2 Dark Adaptation - Where dark adaptation is required, the displayed letters or numerals shall be visible without interfering with night vision requirements. Where possible, markings shall be white on a dark background.

5.5.5.3 Style - Style of label characters shall conform to MIL-M-18012, where consistent with 5.5.5.4, 5.5.5.5, 5.5.5.7, and 5.5.5.8, herein. Labels shall be prepared in capital letters, except that extended copy (e.g., instructions) shall be in lower-case letters.

5.5.5.4 Letter Width - The width of letters shall preferably be 3/5 of the height, except for the "I", which shall be one stroke in width, and the "M" and "W", which shall be 4/5 of the height.

5.5.5.5 Numeral Width - The width of numerals shall preferably be 3/5 of the height, except for the "4", which shall be one stroke width wider, and the "1", which shall be one stroke in width.

5.5.5.6 Wide Characters - Where conditions indicate the use of wider characters, as on a curved surface, the basic height-to-width ratio may be increased to 1:1 in accordance with MIL-M-18012.

5.5.5.7 Stroke Width, Normal - For black characters on a white (or light) background, the stroke width shall be 1/6 of the height.

5.5.5.8 Stroke Width, Dark Adaptation - Where dark adaptation is required or legibility at night is a critical factor, and white characters are specified on a black background, the stroke width of the characters shall be from 1/7 to 1/8 of the height (i.e., narrower than specified for normal daytime vision).

5.5.5.9 Character Spacing - The minimum space between characters shall be one stroke width.

5.5.5.10 Word Spacing - The minimum space between words shall be the width of one character.

5.5.5.11 Line Spacing - The minimum space between lines shall be one-half character height.

5.5.5.12 Label Size vs Luminance - The height of letters and numerals shall be determined by the required reading distance and luminance. With a 28-inch (700 mm) viewing distance, the height of numerals and letters shall be within the range of values in Table X for "low" and "high" control-display luminance conditions.

5.5.5.13 Character Height and Viewing Distance - For general dial and panel design, with the luminance normally above 1 ft-L (3.4 cd/m^2), character height should approximate the values given below for various distances:

Viewing Distance	Height
a. 20 inches (510 mm) or less	0.09 (2.3 mm)
b. 20 - 36 inches (510 - 910 mm)	0.17 (4.3 mm)
c. 36 - 72 inches (910 mm - 1.830 m)	0.34 (8.6 mm)
d. 72 - 144 inches (1.830 - 3.660 m)	0.68 (17 mm)
e. 144 - 240 inches (3.660 - 6.100 m)	1.13 (29 mm)

5.5.6 Equipment Labeling -

5.5.6.1 Assemblies, Components, and Parts -

5.5.6.1.1 General Requirements - Each assembly, component, and part shall be labeled with a clearly visible, readable, and meaningful name, number, or symbol.

5.5.6.1.2 Location - The gross identifying label on an assembly or major component shall be located:

a. Externally in such a position that it is not obscured by adjacent assemblies or components

b. On the flattest, most uncluttered surface available

c. On a main chassis of the equipment

d. In a way to minimize wear or obscurement by grease, grime, or dirt

TABLE X. LABEL SIZE VERSUS LUMINANCE

MARKINGS	HEIGHT*	
	BELOW 1 ft-L ($3.4\ cd/m^2$)	ABOVE 1 ft-L ($3.4\ cd/m^2$)
For critical markings, with position variable (e.g., numerals on counters and settable or moving scales):	0.20–0.30" (5 – 7.5 mm)	0.12–0.20" (3 – 5 mm)
For critical markings, with position fixed (e.g., numerals on fixed scales, controls, and switch markings, or emergency instructions):	0.15–0.30" (3.8 – 7.5 mm)	0.10–0.20" (2.5 – 5 mm)
For noncritical markings (e.g., identification labels, routine instructions, or markings required only for familiarization):	0.05–0.20" (1.3 – 5 mm)	0.05–0.20" (1.3 – 5 mm)

*Values assume a 28-in. (710 mm) viewing distance. For a distance, D, other than 28 in. (710 mm), multiply the above values by D/28 in. (D/710 mm).

ANNEX D

To

TACCDAS Testbed Human Factors Evaluation

MIL-STD-1472 para 5.7

WORKSPACE DESIGN REQUIREMENTS

5.7 GROUND WORKSPACE DESIGN REQUIREMENTS -

5.7.1 General -

5.7.1.1 Kick Space - All cabinets, consoles, and work surfaces that require an operator to stand or sit close to their front surfaces shall contain a kick space at the base at least 4 inches (100mm) deep and 4 inches (100mm) high, or greater to allow for protective or specialized apparel.

5.7.1.2 Handles - Handles on cabinets and consoles shall be recessed whenever practicable, to eliminate projections on the surface. If handles cannot be recessed, they shall be designed such that they shall neither injure personnel nor entangle clothing or equipment.

5.7.1.3 Work Space - Whenever feasible, free floor space of at least 4 feet (1.220 m) shall be provided in front of each console. For equipment racks that require maintenance, free floor space shall be provided in accordance with the following criteria, whenever feasible.

5.7.1.3.1 Depth of Work Area - The distance from the front of the rack to the opposite surface or obstacle shall be no less than 42 inches (1.070 m).

5.7.1.3.2 Lateral Work Space - The minimum lateral workspace for racks having drawers shall be as follows (measured from drawers in the extended position):

a. For racks having drawers weighing less than 45 pounds (20.4 kg): 18 inches (460 mm) on one side and 4 inches (100 mm) on the other.

b. For racks having drawers weighing over 45 pounds (20.4 kg): 18 inches (460mm) on each side.

5.7.1.3.3 Storage Space - Adequate and suitable space shall be provided on consoles or immediate work space for the storage of manuals, worksheets, and other materials that are required for use by the operational or maintenance personnel.

5.7.1.4 Panel Slope - For normal console operation, the slope of the control-display panel surface shall begin at the level of the console shelf.

5.7.2 Standing Operations -

5.7.2.1 Work Surface - Convenient work surfaces to support job instruction manuals, worksheets, etc., shall be provided for standing operators. Work benches and other work surfaces shall be 36 ±0.5 inches (915 ±15 mm) above the floor, unless otherwise specified.

5.7.2.2 Display Placement, Normal - Visual displays mounted on vertical panels and used in normal equipment operation shall be placed in an area between 41 inches (1.040 m) and 70 inches (1.780 m) above the standing surface.

5.7.2.3 Display Placement, Special - Indicators that must be read precisely and frequently shall be placed in an area between 50 inches (1.270 m) and 69 inches (1.750 m) above the standing surface.

5.7.2.4 Control Placement, Normal - All controls mounted on a vertical surface and used in normal equipment operation shall be located in an area between 34 and 74 inches (860 mm and 1.880 m) above the standing surface.

5.7.2.5 Control Placement, Special - Controls requiring precise or frequent operation and emergency controls shall be mounted between 34 and 57 inches (860 mm and 1.450 m) above the standing surface and no further than 22 inches (560 mm) laterally from the centerline.

5.7.3 Seated Operations -

5.7.3.1 Work Surface Width - A lateral workspace of at least 30 inches (760 mm) wide and 16 inches (400 mm) deep shall be provided whenever practicable.

5.7.3.2 Work Surface Height - Desk tops and writing tables shall be 29 to 31 inches (740 to 790 mm) above the floor, unless otherwise specified.

5.7.3.3 Writing Surfaces - Where a writing surface is required on equipment consoles, it shall be at least 16 inches (400 mm) deep and should be 24 inches (610 mm) wide, when consistent with operator reach requirements.

5.7.3.4 Seating -

5.7.3.4.1 Compatibility - Work seating shall provide an adequate supporting framework for the body relative to the activities that must be carried out. Chairs to be used with "sit" consoles shall be designed to be operationally compatible with the console configuration.

5.7.3.4.2 Vertical Adjustment - Provision shall be made for vertical seat adjustment from 16 to 21 inches (400 to 525 mm) in increments of no more than 1 inch (25 mm) each.

5.7.3.4.3 Backrest - A supporting backrest that reclines between 103° and 115° shall be provided. The backrest shall engage the lumbar and thoracic regions of the back, and shall support the torso in such a position that the operator's eyes can be brought to the "Eye Line" with no more than 3 inches (75 mm) of forward body movement.

5.7.3.4.4 Cushioning - Where applicable, both the backrest and seat shall be cushioned with at least 1 inch (25 mm) of compressible material and provided with a smooth surface.

5.7.3.4.5 Armrests - Unless otherwise specified, armrests shall be provided. Armrests that are integral with operators' chairs shall be at least 2 inches (50 mm) wide and 8 inches (200 mm) long. Modified or retractable armrests shall be provided when necessary to maintain compatibility with an associated console and shall be adjustable from 7.5 to 11 inches (190 to 280 mm) above the compressed sitting surface.

5.7.3.5 Knee Room - Knee and foot room that equals or exceeds the following minimum dimensions shall be provided beneath work surfaces:

a. Height: 25 inches (640 mm). If a footrest is provided, this dimension shall be increased accordingly.

b. Width: 20 inches (510 mm)

c. Depth: 18 inches (460 mm).

5.7.3.6 Display Placement, Normal - Visual displays mounted on vertical panels and used in normal equipment operation shall be placed in an area between 6 and 48 inches (150 mm and 1.220 m) above the sitting surface.

5.7.3.7 Display Placement, Special - Indicators that must be read precisely and frequently shall be placed in an area between 14 and 37 inches (360 and 940 mm) above the sitting surface, and no further than 22 inches (560 mm) laterally from the centerline.

5.7.3.8 Warning Displays - For "sit" consoles requiring horizontal vision over the top, critical visual warning displays shall be mounted at least 22.5 inches (570 mm) above the sitting surface.

5.7.3.9 Control Placement, Normal - All controls mounted on a vertical surface and used in normal equipment operation shall be located in an area between 8 and 35 inches (200 and 890 mm) above the sitting surface.

5.7.3.10 Control Placement, Special - Controls requiring precise or frequent operation shall be mounted between 8 and 30 inches (200 and 760 mm) above the sitting surface.

5.7.4 Unusual Positions - Anthropometric data for the design and sizing of workspaces involving reaching, stooping, squatting, kneeling, crawling, or prone positions are presented in Table XVII and illustrated in Figure 23. Fifth and 95th percentile values are given for various body dimensions in both inches and centimeters. Since these data represent nude body measurements, suitable allowances must be made for heavy clothing or protective equipment when required. In no case shall clearance dimensions be less than the 95th percentile values shown in Table XVII.

TABLE XVII. MALE ANTHROPOMETRIC DATA FOR WORKSPACES

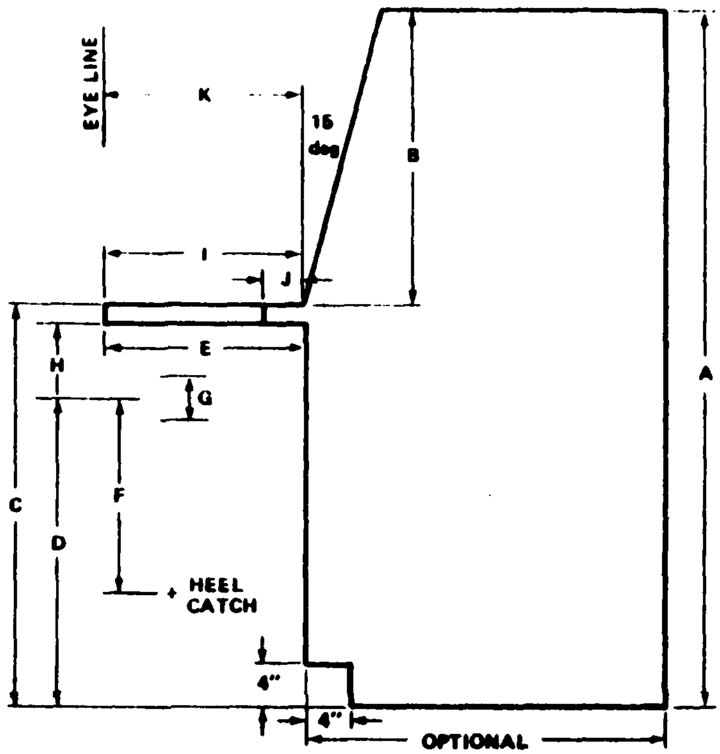
	5TH PERCENTILE		95TH PERCENTILE	
	INCHES	CENTIMETERS	INCHES	CENTIMETERS
1. OVERHEAD REACH HEIGHT	78.6	199.6	87.6	222.5
2. MAXIMUM OVERHEAD REACH HEIGHT	83.3	211.6	93.6	237.7
3. OVERHEAD REACH BREADTH	13.6	34 5	15.9	40.4
4. OVERHEAD REACH, ONE ARM	76.8	195.1	88.5	224.8
5. MAXIMUM BODY DEPTH, STANDING	10.1	25.7	13.0	33.0
6. MAXIMUM BODY BREADTH, STANDING	18.8	47.8	22.8	57.9
7. BENT TORSO HEIGHT	46.3	117.6	55.9	142.0
8. BENT TORSO BREADTH	16.3	41.4	19.1	48.5
9. SQUATTING HEIGHT	40.8	103.6	47.0	119.4
10. MAXIMUM SQUATTING BREADTH	18.8	47.8	25.7	65.3
11. TORSO-TO-KNEE DEPTH, SITTING	12.1	30.7	16.5	41.9
12. HAND-TO-HAND BREADTH, SITTING	13.3	33.8	19.6	49.8
13. KNEELING HEIGHT	48.2	122.4	54.4	138.2
14. KNEELING LEG LENGTH	24.3	61.7	28.7	72.9
15. KNEELING POSITION HEIGHT	29.7	75.4	34.4	87.4
16. KNEELING POSITION LENGTH	37.6	95.5	48.1	122.2
17. CRAWLING POSITION HEIGHT	26.2	66.5	30.5	77.5
18. CRAWLING POSITION LENGTH	49.3	125.2	58.2	147.8
19. PRONE POSITION HEIGHT	12.3	31.2	16.4	41.7
20. PRONE POSITION LENGTH	84.7	215.1	95.8	243.3
21. HORIZONTAL LENGTH	66.0	167.6	73.9	187.7
22. HORIZONTAL LENGTH, KNEES BENT	55.1	140.0	62.0	157.5
23. ARM REACH, SUPINE	26.4	67.1	32.2	81.8
24. BENT KNEE HEIGHT, SUPINE	18.2	46.2	21.1	153.6

TABLE XVIII. STANDARD CONSOLE DIMENSIONS

TYPE OF CONSOLE	MAXIMUM TOTAL CONSOLE HEIGHT FROM STANDING SURFACE	SUGGESTED VERTICAL DIMENSION OF PANEL (INCLUDING SILLS)	WRITING SURFACE SHELF HEIGHT FROM STANDING SURFACE	SEAT HEIGHT FROM STANDING SURFACE AT MIDPOINT OF G	MAXIMUM CONSOLE WIDTH (NOT SHOWN)
	A	B	C	D	
1. SIT (W/VISION OVER TOP)*	47.5 in. (1.210 m)	22 in. (560 mm)	25.5 in. (650 mm)	18 in. (460 mm)	44 in. (1.120 m)
	54.0 in. (1.370 m)	22 in. (560 mm)	32 in. (810 mm)	23 in. (580 mm)	44 in. (1.120 m)
	58.0 in. (1.470 m)	22 in. (560 mm)	36 in. (910 mm)	28.5 in. (725 mm)	44 in. (1.120 m)
2. SIT (W/O VISION OVER TOP)	51.5 in. (1.310 m)	26 in. (660 mm)	25.5 in. (650 mm)	18 in. (460 mm)	36 in. (910 mm)
	58.0 in. (1.470 m)	26 in. (660 mm)	32 in. (810 mm)	23 in. (580 mm)	36 in. (910 mm)
	62.0 (1.570 m)	26 in. (660 mm)	36 in. (910 mm)	28.5 in. (720 mm)	36 in. (910 mm)
3. SIT-STAND (W/STANDING VISION OVER TOP)	62 in. (1.570 m)	26 in. (660 mm)	36 in. (910 mm)	28.5 in. (720 mm)	36 in. (910 mm)
4. STAND (W/VISION OVER TOP)	62 in. (1.570 m)	26 in. (660 mm)	36 in. (910 mm)	NA	44 in. (1.120 m)
5. STAND (W/O VISION OVER TOP)	72 in. (1.830 m)	36 in. (910 mm)	36 in. (910 mm)	NA	36 in. (910 mm)

*THE RANGE IN "A" IS PROVIDED TO ALLOW LATITUDE IN THE VOLUME OF THE LOWER PART OF THE CONSOLE; NOTE RELATIONSHIP TO "C" AND "D".

NOTE: All dimensions based on male data.



KEY	DIMENSIONS	INCHES	(mm)
A	MAXIMUM TOTAL CONSOLE HEIGHT FROM STANDING SURFACE	SEE TABLE XVIII	SEE TABLE XVIII
B	SUGGESTED VERTICAL DIMENSION OF PANEL, INCL SILLS		
C	WRITING SURFACE: SHELF HEIGHT FROM STANDING SURFACE		
D	SEAT HEIGHT FROM STANDING SURFACE AT MIDPOINT OF "G"		
E*	MINIMUM KNEE CLEARANCE	18	(460)
F*	FOOT SUPPORT TO SITTING SURFACE **	18	(460)
G*	SEAT ADJUSTABILITY	5	(125)
H*	MINIMUM THIGH CLEARANCE AT MIDPOINT OF "G"	6.5	(165)
I	WRITING SURFACE DEPTH INCLUDING SHELF	16	(400)
J	MINIMUM SHELF DEPTH	4	(100)
K	EYE LINE-TO-CONSOLE FRONT DISTANCE	16	(400)

*NOT APPLICABLE TO CONSOLE TYPES 4 AND 5 OF TABLE XVIII.

**SINCE THIS DIMENSION MUST NOT BE EXCEEDED, A HEEL CATCH MUST BE ADDED TO THE CHAIR IF "D" EXCEEDS 18" (460 mm).

(NOTE: ALL DIMENSIONS BASED ON MALE DATA)

Figure 24. STANDARD CONSOLE DIMENSIONS KEY

ANNEX E

To

TACCDAS Testbed Human Factors Evaluation

RATING SCALE EXAMPLES

uncomfortable		comfortable
l..		l

Comfort Rating Scale (continuous scale)

extreme discomfort	great discomfort	moderate discomfort	slight discomfort	no discomfort
l..........	l.............	l.............	l......	l

Comfort Rating Scale (segmented scale)

ANNEX F

To

TACCDAS Testbed Human Factors Evaluation

OBSERVATION REPORTING CHECKLIST

TASK STEP	ERROR AND CONSEQUENCES
1.	....
2.	....
3.	....
4.	....
5.	....

Sample Observation Reporting Checklist