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DEPUTY DIRECTOR (TEST & EVALUATION)

**T&E GUIDELINES
FOR COMMAND AND
CONTROL SYSTEMS**

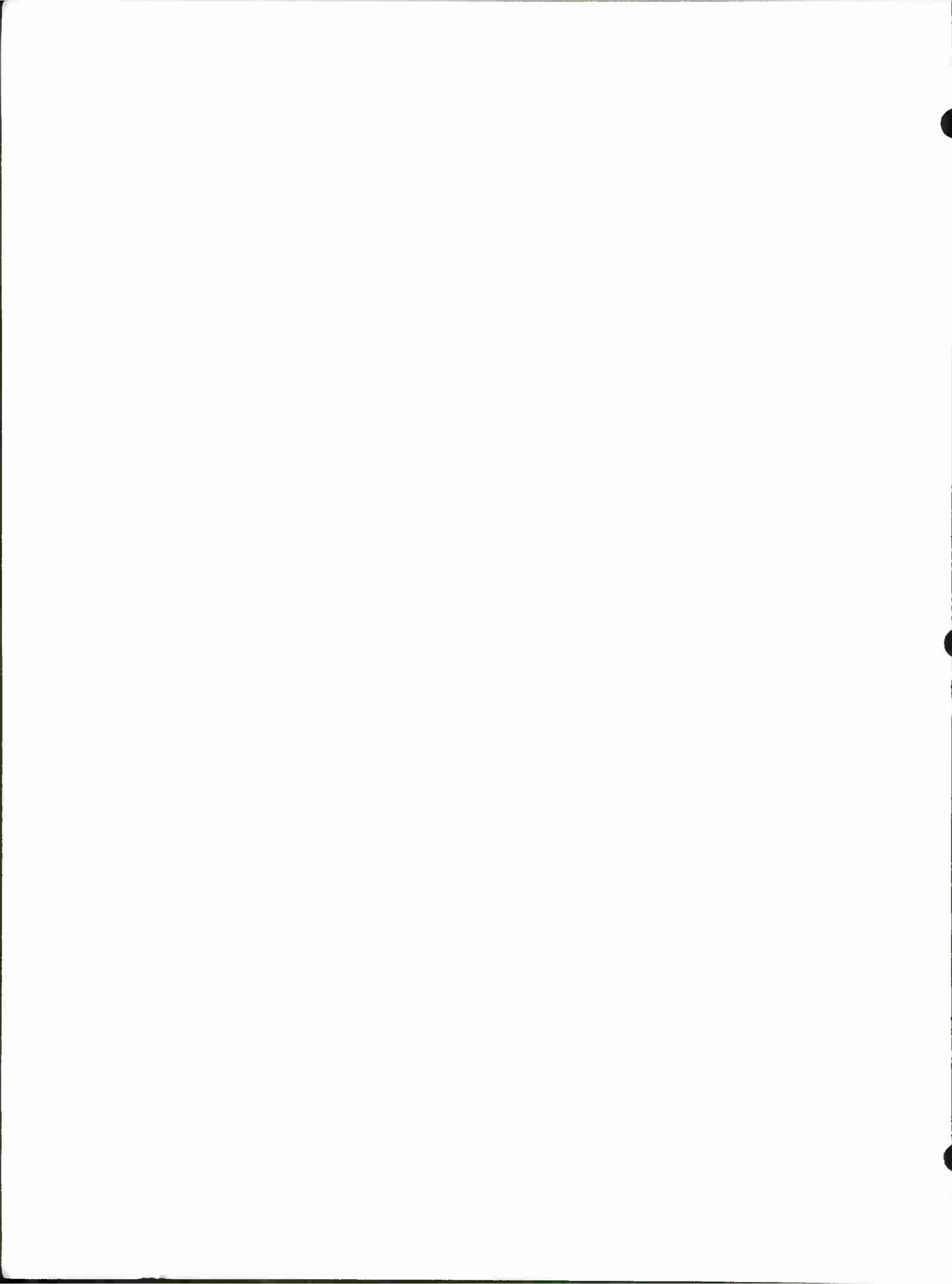
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**OFFICE OF THE DIRECTOR OF
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DEPUTY DIRECTOR (TEST AND EVALUATION)

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AND CONTROL SYSTEMS

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WASHINGTON, D. C.



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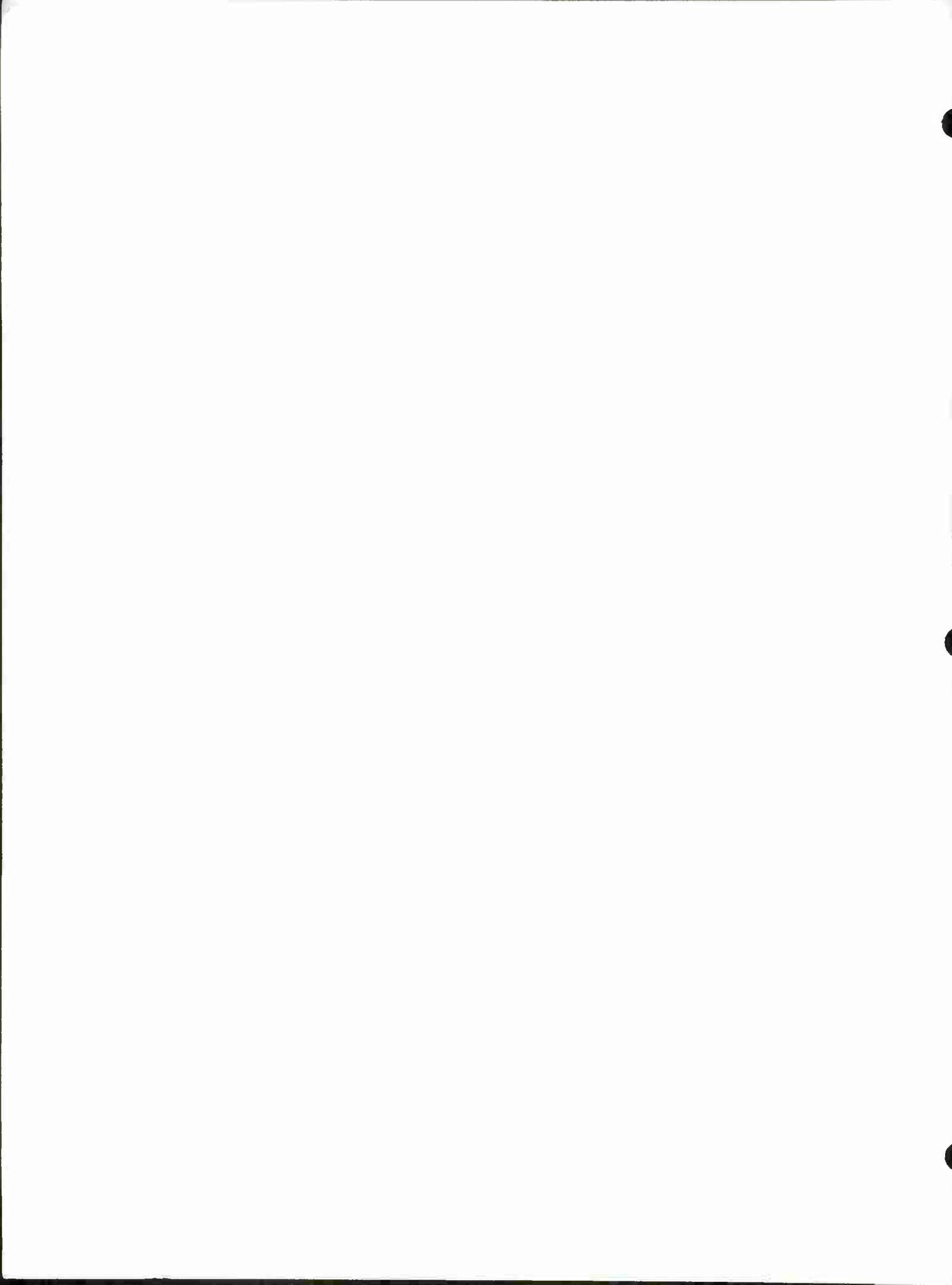
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T&E GUIDELINES FOR COMMON TEST GEAR



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FOREWORD

This report is an outgrowth of the work of the Defense Science Board Task Force on Test and Evaluation, and the checklists herein have been derived from the study of past major weapon system programs.

The T&E expert in reading this volume will find many precepts which will strike him as being too obvious to be included in checklists of this type. These items are included because examples were found where even the obvious has been neglected, not because of incompetence or lack of personal dedication by the people in charge of the program, but because of financial and temporal pressures which forced competent managers to compromise on their principles. It is hoped that the inclusion of the obvious will prevent repetition of the serious errors which have been made in the past when such political, economic and temporal pressures have forced project managers to depart from the rules of sound engineering practices.

In the long run, taking short cuts during T&E to save time and money will result in significant increases in the overall costs of the programs and in the delay of the delivery of the corresponding weapon systems to the combatant forces.

T&E GUIDELINES FOR COMMAND AND CONTROL SYSTEMS

The checklist items presented here are specifically applicable to command and control testing and evaluation. It is suggested that the user of this volume also refer to the Report of the Defense Science Board on Test and Evaluation which contains general checklist items also applicable to this system T&E program. The checklist items presented here are organized into time phases of the acquisition process oriented to the DSARC cycle.

The checklists cover various aspects of the major activities that should be underway during a given time period. Hence, a checklist might cover the (1) evaluation of work that occurred in the previous phase, (2) conduct of tests planned in the previous phase and executed in the subject phase, and (3) plans and other preparatory actions for test schedules to be conducted in a subsequent phase. For reasons such as this, items on some subjects, such as development test plans, may appear in more than one phase. In addition, since the Services and the DSARC have flexibility in deciding how rapidly to progress in the validation phase, there may be cases where the Request for Proposals (RFPs), proposal evaluations, source selections, or contract negotiations may occur after the DSARC approves full-scale development instead of before. For this reason, it is recommended that previous checklists in the Validation Phase be reviewed when entering the Full-Scale Engineering Development Phase. The following are the phases used in this report.

CONCEPTUAL PHASE

The checklist items in this phase are for guidance in evaluating T&E activities during the Conceptual Phase of the acquisition of the system. This phase (often research and exploratory development) precedes the first DSARC milestone and is focused on the development of a system concept that offers high prospects of satisfying an identified military need.

Although not called for in DoD Directive 5000.1 specifically, the objective of this phase should be:

1. To verify that there is a military need for the proposed system.
2. To demonstrate that there is a sound physical basis for a new weapon system.
3. To formulate a concept, based on demonstrated physical phenomena, for satisfying the military need.
4. To show that the proposed solution is superior to its competitors in terms of potential effectiveness, probability of success, probable cost, impact on the U.S. military posture, and development risks.
5. To analyze the technology outlook and the military need to show that it is better to start advanced development now rather than to wait for future technological improvements.
6. To identify the key risk areas and critical issues that need to be resolved before full-scale development is initiated.

The most important product of this phase is the Development Concept Paper (DCP) or its equivalent. The DCP defines program issues, including special logistics problems, program objectives, program plans, performance parameters, areas of major risk, system alternatives, and acquisition strategy.

VALIDATION PHASE

The checklist items in this phase are for guidance in conducting T&E during the Validation Phase (the time between when the DSARC recommends approval of the DCP for the first time and when the DSAPC recommends full-scale development of the system).

While these objectives are not spelled out in the DoD Directive 5000.1, the objectives of the Validation Phase should be to confirm:

1. The need for the selected system in consideration of the threat, system alternatives, special logistics needs, estimates of development costs, preliminary estimates of life cycle costs and potential benefits in context with overall DoD strategy and fiscal guidance.
2. The validity of the operational concept.
3. That development risks have been identified and solutions are in hand.
4. Realism of the plan for full-scale development.

In the pursuit of the above objectives, it is likely that advanced development T&E will be conducted to resolve issues. In some cases, an RFP for full-scale engineering development will be prepared, proposals will be received and evaluated, and contracts negotiated in preparation for seeking DSARC approval for the next phase. Therefore, some checklist items are included to help ensure that this work properly reflects the T&E interests in this and subsequent phases. For example, the RFP must include adequate guidance to ensure that sufficient resources and time are available so that engineering effort can properly support the initial DT&E with hardware, software, technical data, and training.

The primary emphasis of OSD/T&E activities is with items 3 and 4 above. Special attention should be given to the planning of IOT&E activity as it is incorporated in the engineering development contract as well as the DT&E associated with addressing the critical issues and areas of major risk identified in the DCP.

FULL-SCALE ENGINEERING DEVELOPMENT PHASE

The checklist items contained in this phase are for guidance in conducting T&E during the Full-Scale Engineering Development Phase. This includes the major DT&E and the IOT&E conducted prior to the major production decision. By this time, the C&C system is well-defined and is becoming a unique item and, hence, sound judgment must be applied in using these checklist items.

To enter the Engineering Development Phase, the DSARC will have:

- Confirmed the need in consideration of the threat, alternatives, logistic needs, cost, and benefits.
- Identified development risks.
- Confirmed the realism of the development plan.

Given the above, the primary objectives of the DT&E should be to:

1. Demonstrate that the engineering and design and development process is complete and that the design risks have been minimized (the system is ready for production).
2. Demonstrate that the system will meet specifications.

The primary objectives of the IOT&E should be to:

3. Assess operational suitability and effectiveness.
4. Validate organizational and employment concepts.
5. Determine training and logistic requirements.

In addition, the validity of the plan for the remainder of the program must be confirmed by the DSARC before substantial production/deployment will be recommended to the Secretary of Defense.

The level of OSD/T&E activity is highest during this phase. The IOT&E plan must be designed, the tests conducted, and the data analyzed to evaluate the inputs associated with the primary objectives. These tests should not be conducted until the primary objectives of the DT&E have been met. Thus, OSD/T&E activity is required to assess that the DT&E major milestone--the system is ready for production--has been achieved. Close monitoring of the T&E Service activity is required during the latter stages of this phase.

SUBSTANTIAL PRODUCTION/DEPLOYMENT PHASE

The checklist items contained in this phase are for guidance in conducting T&E after the substantial production decision has been made by the DSARC. This includes DT&E and follow-on OT&E to be conducted on the early production items.

To enter the Production/Deployment Phase, the DSARC will have reviewed the program to confirm:

- The need for the system.
- A practical engineering design with adequate consideration of production and logistic problems is complete.
- All technical uncertainties have been resolved and operational suitability has been determined by T&E.
- The realism of the plan.

The primary objective of the DT&E in this phase should be to:

1. Verify that the production system meets specifications.

The primary objectives of the follow-on OT&E should be to:

2. Validate the operational suitability and effectiveness.
3. Optimize organization and doctrine.
4. Validate training and logistic requirements.

At this point, the OSD/T&E activity is similar to that in the previous phase; however, much of the testing is verification that the production system performance is as expected. Hence, most of the items in the previous phase are appropriate to this phase, especially those related to OT&E.

I. CONCEPTUAL PHASE

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The prime objective of the Conceptual Phase of a Command and Control program is to justify the program. The genesis of the program is usually built on a recognized need where existing Command and Control systems have serious deficiencies, cost to modify them adequately would be high, and a more efficient new system is proposed.

The new concept is usually based on studies, IR&D by contractors, evidence of military applications of commercial gear, and other exploratory and advanced development.

The test and evaluation checklist for this Conceptual Phase for Command and Control systems touches on the following subjects:

1. Conceptual Test Philosophy
2. The Importance of Software Testing
3. Software Test Scheduling - Contractors' Facilities
4. Evaluation of Exploratory Development Tests
5. Feasibility Testing for Field Compilers
6. Application Patches
7. Evaluation of Test Plan Scheduling
8. Type Personnel Needs - Effects on T&E
9. Planning for Joint Service OT&E Before DSARC I

1. CONCEPTUAL TEST PHILOSOPHY

T&E planners must understand the nature of Command and Control systems early in the Conceptual Phase.

In a complex Command and Control system a total systems concept has to be developed at the beginning. Total systems life cycle must be analyzed so the necessary requirement for the design can be established. Only with this in hand can targets be established and/or the proper trade-off studies made. Whenever two major systems are to be connected, test and evaluation should make special analysis of the interface(s) and from the systems definition phase and thereafter should test the credibility and durability of the interface(s) and monitor change in the interface(s) for signs of instability of the program(s).

Central control of interfaces and changes to inter-connected systems is also required since systems which interface usually become inter-dependent.

Total systems concept must recognize that C&C systems will evolve/change over their expected life span--due to changes in threat, requirement, and technology and that this may dictate need for flexibility in hardware/software approach. Recognize change as a way of life in C&C systems and plan for it and test for ability to accept change.

The variety of expected users must be understood as well as the expected modifications in operational environment and this must be extended to consider prospective changes due to changes in threat, requirements or technology. Remember that a C&C system is employed for the first time about six years after its initiation and should live for at least six years thereafter. Agreement must be reached between the users (whom the system must satisfy), the operators, the developers and the testers as to what the system is intended to do, and as to the way tests can predetermine ultimate performance.

2. THE IMPORTANCE OF SOFTWARE TESTING

Testers should recognize that software is a pacing item in Command and Control systems development.

The pacing item in most (if not all) automated C&C systems proves to be the software. This is often not recognized by the developer, tester, or the user who are traditionally hardware-oriented. The result is that acceptance of the developmental system from the contractor is in large measure based on compliance with hardware specifications following review of contractor-conducted tests, while software acceptance may all too often be based on limited and selected demonstrations by the contractor. The upshot is that the government accepts a system that has not been tested or demonstrated under "full load" conditions. Having separate hardware and software contractors creates real problems as to who is responsible for insuring that the "system" works--this has plagued C&C systems for years. It is best to have one contractor responsible for overall system integration. If more than one contractor is involved, e.g., separate software and hardware developers, then test plans should be so phased as to require successful software demonstration (e.g., by well conceived emulation or translation)--followed by tests to ensure adequate systems integration--followed by total system test and demonstration prior to government acceptance.

3. SOFTWARE TEST SCHEDULING - CONTRACTORS' FACILITIES

Provision should be made for inclusion of software T&E during each phase of C&C systems' acquisition. Availability of contractors' facilities should be considered.

Test and evaluation should insure that any software products are tested appropriately at the completion of each phase. Software has often been developed more as an add-on than as an integral part of the overall system. Software requirements need the same consideration as hardware requirements in the Validation Phase. Usual practices often do not sufficiently provide for testing the software subsystem concept. Often the facilities available to contractors for software development and verification are critical to schedule and cost.

4. EVALUATION OF EXPLORATORY DEVELOPMENT TESTS

Care should be exercised in evaluating results of tests conducted during exploratory development of Command and Control Systems.

Results of tests conducted during exploratory development and which most likely have been conducted on brassboard, breadboard, or modified existing hardware should be evaluated with special attention to items such as:

- (a) The packaging of the hardware may significantly affect the performance characteristics so that the suggested proof of validation is inconclusive. A case in point is the experimental van-mounted, relatively immobile Tactical Operational System (TOS) for Europe versus the current highly mobile TOS test bed configuration.
- (b) The laboratory type environment in which the hardware was tested may preclude the generation of data needed to validate that the concept and technology approach will be applicable to an operational environment. The close and necessary interaction between the ultimate user and the developer of C&C systems emphasizes this point.
- (c) The tests may not include signals and noise sources representative of those that might be expected in an operational environment. Since C&C systems depend on communication links this point is especially important.
- (d) Software is highly hardware-dependent and in most cases is not transferable from one system to another. For example, software developed for the Army's initial Tactical Operations Systems (TOS) in Europe is not transferable to the current TOS development program. Thus, test results obtained previously have some, but limited, value to the present program.

5. FEASIBILITY TESTING FOR FIELD COMPILERS

Early test planning should allow for simulation of the computer system to test for field use of compilers, where applicable.

If the development plan for a tactical C&C system assumes the use of a compiler in the field, the plan should provide for early DT&E simulation of the computer system to test the feasibility of using the compiler in the field. Appropriate simulations or analyses done early will allow

for computer changes during DT&E that could not be accomplished rapidly enough to avoid disrupting the subsystems and system IOT&E schedule.

6. APPLICATION PATCHES

Early T&E evaluation of procedures for application patches is needed.

In real time C&C systems, early DT&E verification of the procedure proposed for application patches is indispensable. If a compiler is to be used in the field, tests must be made to ensure that enough memory is provided; if the patches are to be provided off line from a remote station, the particular method of communication necessary to specify the patch and to obtain the program must be tested as well. Procedures must be developed and tested to insure accuracy of all "transmitted" program changes.

7. EVALUATION OF TEST PLAN SCHEDULING

Milestones should be event-oriented, not calendar-oriented.

In evaluating the adequacy of the scheduling as given by test plans, it is important that milestones be tied to the major events of the C&C system (meeting stated requirements) and not the calendar. As a result, milestones should be flexible with respect to time. The acquisition process should be based on the achievement of major milestones and sufficient time and resources allowed between these milestones. -For example, flexibility must not be hampered by the contracting mechanism. Contractors should be required to demonstrate successful accomplishment of technical milestones before proceeding to the next phase of development. Remember software testing and retesting takes time. Allow for it.

8. TYPE PERSONNEL NEEDS - EFFECTS ON T&E

A mix of personnel with different backgrounds affecting T&E is required.

Developers, testers, evaluators, operators, and users have quite different backgrounds and needs which affect the T&E of the C&C system. Each has a different approach which has merit and utility at almost all points in the T&E program. A mix of these types are needed throughout the program. Early in the program, the lead emphasis should be from the developer/tester, with strong user input shifting to the evaluator and finally the operator, but at all times all parties and their needs should be coordinated.

9. PLANNING FOR JOINT SERVICE OT&E BEFORE DSARC I

Joint Service Operation Test and Evaluation should be considered for Command and Control systems.

If the operational concept for the new C&C system envisions interoperability with another Service system, then Joint Service Tests should be mandatory and should be planned. An analysis of the impact of this type of testing on time and resources needed in the program should be conducted before DSARC I.

II. VALIDATION PHASE

II. VALIDATION PHASE

The major concerns in this phase are the conducting of issue tests and critiquing of test and evaluation plans for the remainder of the program and particularly in the Engineering Development and IOT&E phase.

The checklist includes:

1. Test Prototypes
2. Test Objectives - Critical Issues
3. Real Time Software - Demonstration of "Application Patches"
4. Independent Software Test-User Group
5. System Error Conditions
6. Test Schedule - Software Debugging
7. Real Time Operating Systems
8. Software Test Analysis
9. System Interfaces
10. Human Factors
11. Degraded Operations Testing
12. Test Bed
13. Software-Hardware Interfaces
14. Reproducible Tests
15. Cost-Effectiveness

The reader should review the checklist items in the previous phase since many of them will be appropriate for this phase.

1. TEST PROTOTYPES

In Command and Control Systems, prototypes must reasonably resemble final hardware configuration from a functional use standpoint.

When high technical risk is present, development should be structured around the use of one or more test prototypes designed to prove the system concept under realistic operational conditions before proceeding to engineering development. It is good to take a risk; however, when an implied commitment to production is involved the technology should be operationally proof tested prior to commencing full-scale development. Avoid the temptation of thinking that anything is "state-of-the-art" until it is working in the field. In C&C systems, the key points to remember are that the prototype must reasonably resemble final hardware configuration from a functional use standpoint and one must assemble a reasonable replica of the total system so that the functions that must be performed by the C&C system can be tested. Often a representative slice of a total system may suffice for the prototype if that slice may be expected to perform all or most of the functions of the total system.

2. TEST OBJECTIVES - CRITICAL ISSUES

In addition to addressing critical technical issues, T&E objectives during the Validation Phase should address the functional issues of a Command and Control system.

It is important to ensure that the technical and operational objectives of the tests to be conducted during the time period from DSARC I to DSARC II address the major critical issues, especially technological issues. In addition to technical issues, the functions of the C&C system must be clearly defined and established through T&E during the Validation Phase. Each test should have a single objective if possible and the objective should be simply stated. A plan for the conduct of the test and the data collection, reduction, and analyses must be in sufficient detail so that one can readily evaluate the performance of the system and whether or not the test objective can be met. A relationship between the identified performance parameters and the test results should be established prior

to the conduct of the test. Further, the set of objectives for each of the tests should be clearly related to the program objectives. When this relationship is not clear, amplifying data should be required. By the end of the systems definition phase, test and evaluation planners should make certain that test criteria are established so there is no question as to what constitutes a test and what performance is attained. These should be agreed to by the developer, the tester and the user.

For example, if the program objective is to validate the concept that the proposed C&C system will result in providing the user with faster, more reliable and complete information upon which to base a decision, then test objectives should be designed to measure these parameters over a variety of scenarios and to evaluate the impact of these parameters on the commander's decision process.

3. REAL TIME SOFTWARE - DEMONSTRATION OF "APPLICATION PATCHES"

Tests of real time Command and Control systems should include demonstrations of interfaces whereby locally generated application patches are brought into being.

Real time software must be designed to permit locally generated "application patches" to cope with peculiar local situations or development of new procedures or threats, while at the same time maintaining the integrity of standardized software or interfaces. Tests of all real time systems should include demonstrations of methods whereby such patches are brought into being within an interval of a few days.

4. INDEPENDENT SOFTWARE TEST-USER GROUP

An independent test-user software group is needed during early software qualification testing.

During early software qualification testing, the tests themselves should be prepared and executed under the direction of an independent test-user group rather than under the control of original programmers who are more concerned with completing the software system development on schedule (with minimal fault free testing).

5. SYSTEM ERROR CONDITIONS

A set of tests needs to be designed specifically to find and verify system error conditions.

During early tests of software programs, a set of tests should be designed specifically to find and verify error conditions. If the system is designed to print out a warning message when incorrect data is fed in, then a series of tests should be run inputting faulty data to verify correct performance.

In the debugging process, a variety of tests should be run to verify algorithm accuracy and to assess operator/user impact on functional applications programs, e.g., formats, operator error. Each program should then be rerun until it executes perfectly. This is particularly significant in light of a tendency during testing to carry the errors forward to the next higher level of testing. This latter approach tends to permit an excessive number of errors to be carried forward into the more difficult test phases.

6. TEST SCHEDULE - SOFTWARE DEBUGGING

At the end of each level of software qualification testing, a schedule provision must be made for incorporating corrections.

In C&C systems it must be recognized that software debugging is time consuming and will require tests and retests during the T&E cycle. Software testing is continuous in that new functions in all likelihood will be added in the T&E cycle, which again should be planned for in the T&E schedule. For example, at the end of each level of software qualification testing, a schedule provision must be made for incorporating corrections and modifying the overall system. The development of complex software systems is simply not sufficiently formalized (as is hardware) to permit a smooth continuous development from concept to implementation. Error correction and design modifications will be required after each level of testing, so schedule provisions should be made in advance. Fixing software bugs needs more time than flow charting and coding. Schedules that

do not take this into account should be rejected unless good technical reasons are given.

7. REAL TIME OPERATING SYSTEMS

Test plans should recognize the difference between an operating system and a real time operating system and be designed accordingly.

When dealing with "real time" situations in Command and Control, weapon assignment, air traffic control, and the like, one should always remember that there is a fundamental difference between OS (operating systems) and RTOS (real time operating systems). The use of OS where RTOS is called for is usually disastrous. This applies with particular emphasis to the high level language and the related compiler when these are not optimized for minimum execution times.

Test plans for RTOS software should be designed to:

- (a) simulate the expected maximum environment from the point of view of traffic, interference, spurious targets.
- (b) Explore simulated displays if the final displays are not available.
- (c) Employ operators who are not so skilled as to make the test invalid for its future operational employment.
- (d) Test for continuity of operations if elements of the system are lost. A real time requirement implies a need for extremely high reliability, usually achievable only through redundant on-line equipment.
- (e) Provide for on-line (background) diagnostic routines.
- (f) Provide for automatic cutover to redundant equipment or some other form of graceful degradation.
- (g) Provide for user notification of faults.

8. SOFTWARE TEST ANALYSIS

Emphasis should be placed on analyzing a reasonable set of software tests rather than on generating a large number of tests.

In developing software for Command and Control systems, it is easier to generate tests than it is to analyze their results. A reasonable set

of tests, carefully constructed, analyzed, and documented often proves more useful than a much larger set of tests performed and analyzed less carefully. Further, sufficient and qualified government and/or contractor resources must be made available to perform the required analyses.

Therefore, planners must ensure that test plans call for a carefully paced software test program with emphasis on analyses of results and that adequate resources are applied to the job.

9. SYSTEM INTERFACES

Critical attention should be devoted to testing interfaces with other C&C systems and to interfaces between subsystems.

In every system but especially in C&C systems, DT&E and OT&E should not only test subsystems and systems, but interfaces as well. Particular attention should be devoted to interfaces with other C&C systems and to the interfaces between sensors (e.g., radars), communications systems (e.g., modems), and the specific processors (e.g., CPU). Interface with information processing C&C systems must also address data element and code standardization problems if data is to be processed on-line.

10. HUMAN FACTORS

In a C&C system human factors must be considered from the earliest prototype designs and testing provided.

In evaluating Command and Control systems, human factors should play a large role and must be considered from the earliest prototype designs. Testing should be conducted to determine the most efficient arrangement of equipment from the human factor standpoint, e.g., displays should be arranged so as to be viewed from an optimum angle whenever possible; adequate maneuvering room within the installation constraints should be allowed considering the number of personnel normally manning the facility; and console-mounted controls should be so designed and located as to facilitate operation, minimize fatigue and avoid confusion. Operators should be able to function in a reasonably comfortable environment (e.g.,

consider lighting levels, temperature, humidity and air exchange controls, chair comfort and noise levels).

11. DEGRADED OPERATIONS TESTING

When the expected operational environment of a C&C system suggests that the system may be operated under less than finely tuned conditions, tests should be designed to allow for performance measurements under degraded conditions.

The system concept and possible implementations must not hinge on the requirements for the system or subsystems to be finely tuned when the expected operational environment suggests that this will not be likely. The system should not degrade significantly as a result of detuning caused from expected operational usage. For example, if the capability to receive data at the processing center is expected to degrade with operational use (and the effectiveness of the system depends on the quality and completeness of the data), then tests of the data transmission capability should be conducted under varying conditions of signal-to-noise ratios to establish sensitivity factors and under varying traffic load conditions to establish saturation factors. The developer and the user should agree on the specification of the acceptable performance envelope.

12. TEST BED

The use of a test bed for study and experimentation with new C&C systems is needed early in the Validation Phase.

Command and Control systems need a test bed starting in the early validation phase for study and experimentation with user input. This test bed is required through the full period of the system design and for continued program maintenance after the system is fielded. The test bed requires a computer with software that works and that the user can understand, and peripherals that are truly an aid to the user. Testing early versions of such systems with user participation in the human acceptability and compatibility environment is important. Test beds should be used especially in the validation phase of systems acquisition

prior to the large scale commitment of resources. Tests should be performed in all typical operational environments to: assess the need for materiel adjustments; provide hard data for cost-effective analyses; gain user acceptance; assess the value of reduced reaction time to a variety of situations; refine software procedures and applications; refine user requirements, and judge the impact of the system on force structure and doctrine.

13. SOFTWARE-HARDWARE INTERFACES

The software-hardware interfaces with all operational back-up modes to a new C&C system should be tested early in the program.

Software-hardware interfaces, particularly in the Command and Control area, should be included as early as practical in all operational modes. Sometimes the operational back-up modes do not get tested until many years after the system is operational. On occasion, surprises have been experienced when these modes were finally tested.

14. REPRODUCIBLE TESTS

Test plans should contain a method for allowing full-load message inputs while maintaining reproducible test conditions.

One of the elements associated with conducting "full-load" tests on automated systems early in the testing cycle is the importance of maintaining a reproducible test. It is extremely difficult (if not virtually impossible) to manually generate a heavy load for a complex C&C system without an unreasonably large test staff and even then, the element of human error is present. Therefore, test plans should contain a method (e.g., tape recorder message input) for allowing full-load message inputs while maintaining reproducible test conditions.

15. COST-EFFECTIVENESS

Field test data is needed during the Validation Phase for input to cost effectiveness analyses of C&C systems.

One of the greatest difficulties associated with proposed automated C&C systems is to demonstrate that they are cost effective. Unlike weapon systems that can graphically show their potential lethality or destructiveness (P_k) on the battlefield, the value of automation in terms of measures of effectiveness is a difficult and elusive problem. It is often not sufficient to show that the automated system can do the job "faster" than the manual system or that more information can be made available to the decision-maker through data processing. Paper studies may provide some answers but comparative hard field data based on realistic scenario-type testing is indispensable. Therefore in testing new tactical automated Command and Control systems during both the Validation and Engineering Development Phases, all typical battlefield scenarios in which the system is expected to operate must be devised and comparative side-by-side tests with the manual or older system conducted. Sufficient repetitions with change of "players" must be allowed to provide for an adequate data base and the human factors influence on the test results.

III. FULL-SCALE ENGINEERING DEVELOPMENT PHASE

III. FULL-SCALE ENGINEERING DEVELOPMENT PHASE

In this phase, the T&E plans developed in the Validation Phase will be refined, and the development testing will be conducted. IOT&E plans will similarly be refined; personnel will be assigned and trained; and finally the testing will be conducted.

The checklist includes:

1. Operational Testing
2. Acquisition Strategy
3. Problem Indications
4. Impact of Software Failures
5. Critical Issues
6. Displays
7. Pilot Test
8. Publications and Manuals
9. Power Sources
10. OT&E Reliability Data
11. Subsystem Tests
12. Communications
13. Maintenance
14. Continuity of Operations
15. Imitative Deception
16. Demonstration of Procedures
17. Government Furnished Equipment and Facilities
18. User Participation in T&E

The reader should review the checklist items in the previous phases since many of them will be appropriate for this phase.

1. OPERATIONAL TESTING

Operational testing may be expensive and time consuming but for C&C systems it is essential.

Operational testing of C&C systems is essential. It is also expensive and time consuming, but the value received is worth its weight in not-delivered systems. Think in terms of:

- (a) Involving operational groups in test planning and in establishing measures of effectiveness, so that the outcome of the tests will be accepted as being operationally significant. Remember, a C&C system will not be used if it proves to be a burden to the user.
- (b) Determining whether the scope of the planned tests will provide sufficient data to justify changes in the eyes of potential users. C&C systems are so closely tied to the needs of the user that changes to accommodate his needs must be expected.
- (c) Comparing the scope of proposed tests against checklists of issues frequently raised at major decision milestones, to assure that the data needed for such decisions will be forthcoming to the extent this is possible from testing alone. For example, a major issue raised in C&C systems is their cost-effectiveness. Proposed tests must include provisions whereby data are collected to assist in determining cost-effectiveness.
- (d) Recognizing in the formulation of test plans that major system decisions are judgments based on a wide range of qualitative considerations, rather than on statistical compilations, and that the outcome and limitations of operational test must be comprehensive and meaningful to the decision makers as well as to the testing community.

2. ACQUISITION STRATEGY

The acquisition strategy for the system should:

- (a) Allow for a sufficient time between the planned end of demonstration testing and major procurement (as opposed to limited procurement) decisions so that there is a flexibility for modification of plans which may be required during the test phases of the program. For instance, because insufficient time was allowed for testing one recent C&C system, the program and the contract had to be modified and renegotiated.

- (b) Be evaluated relative to constraints imposed by:
 - The level of system testing at various stages of the RDT&E cycle.
 - The number of test items available and the schedule interface with other systems needed in the tests, such as aircraft, radars, COMSEC equipment, communications gear, power generators, etc.
 - Support required to assist in the preparation, conduct of the tests and the analysis of test results.
- (c) Ensure that sufficient dollars are available not only to conduct the planned T&E but to allow for the additional T&E which is always required due to failures, design changes, etc.

3. PROBLEM INDICATIONS

It is important to establish an early detection scheme for management to determine when a program is becoming ill.

Establish an early detection scheme for top government and contractor management to determine that a program is becoming ill. At this time there may be a good possibility of recovery. Some of the indications of trouble are:

- The number of software deficiencies is excessive and fixes are not readily identifiable.
- A major component failure such as the central processor.
- Any repetitive failure of a key component or a component which is common throughout the system such as power supplies.
- A revision of schedule or incremental funding that exceeds the original plan. Predicted downstream recovery may not have a realistic basis.

4. IMPACT OF SOFTWARE FAILURES

Prior to any production release, the impact of software failures on overall system performance parameters must be considered.

By the end of the phase, the impact of software errors and failures on overall system availability, mean time between failure (MTBF) and mean time to repair (MTTR) must be known. Testers normally compute these

performance parameters based on hardware test data only and software problems are treated as a separate area. In early testing this may make sense from a data management problem but before any commitment to system production is made, hardware and software results must be integrated to determine overall system performance and suitability. As an example, past experience with both commercial and military ADP systems has shown that system downtime due to software problems has exceeded that of hardware by at least three to one, and that is a conservative figure.

5. CRITICAL ISSUES

IOT&E should provide the answers to some critical issues peculiar to C&C systems.

Some of the critical issues that OT&E of Command and Control systems should answer are:

- Is system mission reaction time a significant improvement over present systems?
- Is a back-up mode provided for use when either airborne or ground system exhibits a failure?
- Can the system be transported as operationally required by organic transport? (Consider ground, air and amphibious requirements).
- Is there a special requirement for site preparation? (For example, survey, antenna siting).
- Can the system be erected and dismantled in times specified? Are these times realistic?
- Does relocation affect system alignment?
- Does system provide for operation during maintenance?
- Can maintenance be performed on site on non-shelterized exposed subsystems during adverse weather conditions, e.g., radars?

6. DISPLAYS

The display subsystems of a C&C system should provide an essential function to the user.

Displays are key subsystems of a Command and Control system. They provide the link that couples the operator to the rest of the system and are therefore often critical to its success. In testing displays and their associated consoles, the following factors should be considered:

- (a) Does the display provide for the selection of a variety of relevant items of information under user control in order to avoid viewer saturation, e.g., overlay?
- (b) Is the information displayed organized to ensure the association of related items and optimum viewing?
- (c) Is the data presented at a rate commensurate with the nature of the problem, e.g., many tactical applications require only relatively static displays?
- (d) Ambient illumination, display size, and size of the materiel displayed.
- (e) Physical layout.
- (f) IOT&E should determine whether the display provides an essential (and cost effective) function for the user or is it in fact nice to have but its function is better performed, for example, manually.

7. PILOT TEST

A pilot test should be conducted prior to IOT&E so that sufficient time is available to make the necessary changes to the IOT&E as dictated by the results of the pilot test.

Before any operational test for demonstration of operational suitability and effectiveness is conducted, a pilot test should be held with the primary purpose of shaking down the test plan, and the data analysis plan. A secondary, but vital purpose should be to provide final training for the test participants. The pilot test should be conducted sufficiently prior to the OT&E so that sufficient time is available to make the necessary changes to the OT&E as dictated by the results of the pilot test. For example, pilot tests for C&C systems may be conducted with reduced communications ranges, with minimal operator manning and with "canned" message inputs.

8. PUBLICATIONS AND MANUALS

It is imperative that all system publications and manuals be completed, reviewed and selectively tested under operational conditions prior to the beginning of overall system suitability testing.

Equipment and software publications, e.g., operating and maintenance manuals are often incomplete and late relative to DT&E and IOT&E. In a Command and Control system that incorporates many separate and sometimes diverse pieces of hardware, the effects of this have serious impact on the overall schedule and effectiveness of the testing. For example, maintenance manuals that are disorganized and incomplete hinder expeditious troubleshooting and interpretation of malfunction indications. Therefore, it is imperative that all equipment and software publications be completed, thoroughly reviewed by the users and selectively field tested by appropriate military users prior to the beginning of overall system suitability testing.

9. POWER SOURCES

Mobile prime power sources are usually provided as GFE and can be a problem area in testing C&C systems.

Essentially all field installations of Command and Control systems require mobile prime power sources which are usually provided as GFE. These equipments should be evaluated using at least the following characteristics:

- Frequency and voltage stability sufficient to meet C&C system requirements.
- Weight and volume
- Logistical support required
- Fuel
 - Availability in field
 - Handling difficulties
 - Weight
- Efficiency
- Noise level
- Ability to operate in all environments.

- Reliability
- Maintenance

Generator outputs should be tested under varying load conditions imposed by the supported system for evidence of surge voltages, spikes or other transients that could affect the power distribution system of the Command and Control facility. The system should also be tested with short term generator outages, i.e., a minute or so. For example, can the system perform during a short term generator outage using battery power?

10. IOT&E RELIABILITY DATA

IOT&E can provide valuable data on the operational reliability of a C&C system which cannot be obtained through DT&E.

Factors such as operator error failures, e.g., using incorrect message formats, and environmentally-induced failures should be looked for in the operational tests and investigated to determine if serious problems are underlying reasons for the failures. Especially important is the procedure used to evaluate the operational reliability of the C&C system as determined by the relatively small amount of, but significant, data obtained through IOT&E and the larger amounts of data on hardware and software design reliability collected through DT&E.

11. SUBSYSTEM TESTS

Every major subsystem of a C&C system should have a successful DT&E prior to beginning of overall system operational testing.

Operational tests designed to demonstrate and assess the operational suitability and effectiveness of the C&C system should not be conducted unless every major subsystem, critical to the primary mission has had a successful DT&E and has been incorporated into the system as intended in service use. If, for whatever reasons this rule is not followed, then at a minimum it is imperative that a substitute subsystem be used which interfaces with the other subsystems in such a way as to not significantly affect their performance. However, the decision to let a major production

contract on the system should not be made until the entire system has been demonstrated to be operationally acceptable to the user.

12. COMMUNICATIONS

C&C systems must be tested in the appropriate electromagnetic environment to determine performance of its communications system.

Communication systems remain a prerequisite element in Command and Control systems. Two categories of communication problems are involved. One is the high data rate computer-to-computer interchange of information and the other is the low bandwidth data link circuits that tie message entry devices to readout devices at remote locations. The former category is very sensitive to such considerations as circuit noise, delay distortion and interference generated either intentionally or unintentionally. The latter is sensitive to ECM, local propagation conditions and mutual interference problems.

Therefore, Command and Control systems must be designed with the hostile combat area in mind and tested, first with electromagnetic analyses and then in an environment that approaches as realistic conditions as possible. For example, if the Command and Control system under development for one service is likely to be used at, with, or near facilities of another service, then it is important this be considered in planning for the test scenarios.

13. MAINTENANCE

In IOT&E, maintenance testing should include:

- A measurement of the adequacy of the maintenance levels and the maintenance practices;
- An assessment of the impact that the maintenance plan has on the operational reliability;
- The accessibility of the major components of the system for field maintenance, e.g., are cables and connectors installed so as to facilitate access.

- Verification that the software design for maintenance and diagnostic routines and procedures are adequate and that the software can be modified to accommodate functional changes.

14. CONTINUITY OF OPERATIONS

IOT&E should provide for an impact assessment of the failure of any subsystem element of a C&C system on overall mission effectiveness.

Continuity of operations is an essential prerequisite of any automated Command and Control system concept. The impact on mission effectiveness of a failure of any subsystem element, especially computer centers, must be assessed. Therefore, IOT&E should be designed to provide the mechanism whereby the assessment can be made. Tests should include employment of back-up systems and ease of transition from one system to another under various interrupt conditions. SOPs for accomplishing the transition should be evaluated.

15. IMITATIVE DECEPTION

IOT&E should provide for tests to assess the susceptibility of the data links of a C&C system to imitative deception.

The digital data links associated with automated Command and Control systems are likely to have a distinctive signature on the battlefield. The possibility of enemy use of imitative deception should be recognized.

16. DEMONSTRATION OF PROCEDURES

Test plans should include a procedural demonstration whereby the tested C&C system works in conjunction with other systems.

In testing C&C systems, it is imperative that the test plans include a demonstration of the procedures whereby a new or modified system works in conjunction with other systems that will or are likely to coexist in the same geographic environment. If a hardware, software, or communication interface is required, the test plans must include these interfaces.

17. GOVERNMENT FURNISHED EQUIPMENT AND FACILITIES

T&E should be concerned about the availability of GFE equipment as specified in the proposed contract.

If there are GFE and other government commitments in the proposed contract, be concerned about the following:

- (a) Can the equipment with required performance be available when required? Examples are COMSEC equipment, generators, communications, shelters, vehicles. In one recent C&C test program, the required generators were not available and the COMSEC equipment design required some redesign of the C&C system interface.
- (b) Can government supported facilities provide the assistance required at the time needed? If not, is it reasonable to construct the required facilities (test ranges, airspace, firing ranges, instrumentation, etc.)? If not, what alternatives are available?
- (c) Avoid contract terms on fixed price contracts that vaguely commit the government. Don't include, "government support as required" or "test facilities will be made available when needed".

18. USER PARTICIPATION IN T&E

The varying needs of the user for a C&C system make it mandatory that he participate in all phases of T&E.

It is imperative that the user participate in all of the T&E phases to ensure that the user needs are represented in the development of the system concept and hardware/software. Initially, the user command should play an advisor role during the feasibility and engineering testing program and gradually assume a more active role in the conduct of the testing programs, as it becomes more and more operational. This should facilitate the necessary communication and interaction between the developing and user command--especially needed during the DT&E and IOT&E phases.

This is especially true of C&C systems where the varying needs of the user must be satisfied. The close coupling of the user to the C&C system necessitates that the system be fully matched to the operator

personnel. One point to remember during OT&E is that the tests must be designed to assess whether the C&C system will be a burden to the user.

IV. SUBSTANTIAL PRODUCTION/DEPLOYMENT PHASE

IV. SUBSTANTIAL PRODUCTION/DEPLOYMENT PHASE

This phase includes follow-on OT&E that is performed after the DSARC decision for substantial production and deployment. It is generally conducted with production hardware. Prior to the major production decision, the DSARC will assess the adequacy of test results to support a decision to proceed with major production and the adequacy of plans and schedules for any remaining testing.

The checklist includes:

1. First Article Testing
2. Test Planners and Evaluators

The reader should review the checklist items in the previous phases, especially Phase III, since many of them will be appropriate to this phase.

1. FIRST ARTICLE TESTING

Conduct first article testing.

The preproduction, first article, testing and evaluation should be designed and conducted to: (1) confirm the adequacy of the equipment to meet specified performance requirements; (2) confirm the adequacy of the software not only to meet current user needs but also to accommodate changing needs; and (3) determine failure modes and rates of the total integrated system. This activity should be followed by FOT&E.

2. TEST PLANNERS AND EVALUATORS

Use the IOT&E personnel in the follow-on OT&E program.

The planners and evaluators for the OT&E of the production system can do a better job if they are initially involved in planning and conducting the IOT&E. The program plan should be reviewed to ensure that the FOT&E people are identified for IOT&E participation and that the personnel system of their service retains identity of these people for use in planning, conducting, and evaluating FOT&E which may not be run until a year or two afterwards. This is especially critical to testing of C&C systems which require a reasonably high degree of training and knowledge of electronics, automatic data processing, communications and especially field operating procedures, tactics and doctrine.

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