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T AND E GUIDELINES FOR AIRBORNE ECM SYSTEMS

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DEPUTY DIRECTOR (TEST & EVALUATION)

T&E GUIDELINES FOR AIRBORNE ECM SYSTEMS

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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.

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T&E GUIDELINES FOR AIRBORNE ECM SYSTEMS

The checklist items presented here are specifically applicable to airborne ECM 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.

These checklist items are generally applicable to the following classes of airborne ECM equipment:

- Active jammers carried on dedicated ECM aircraft.
- Airborne passive reconnaissance and warning systems.
- Active jammer pods carried by tactical aircraft.
- Active jammers carried internally on strategic aircraft.
- Deceptive repeater jammers carried both internally and in pods on tactical or strategic aircraft.

However, not every checklist item will be applicable to all of the above classes of ECM systems. Thus, the user must use judgment in applying them to a particular type of ECM system.

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 objectives 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 DSARC 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 ECM 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

The prime objective of the Conceptual Phase of an airborne ECM program is to provide sufficient data for intelligent decisions regarding DCP approval and program establishment. Program justification is usually built on the recognition of a growing threat or a new need; existing ECM equipment is shown to have serious deficiencies that cannot be modified adequately at an acceptable cost, and a more efficient new system is proposed. The new concept is usually based on studies, IR&D by contractors, and progress in various exploratory and advanced developments.

The test and evaluation checklist for this conceptual phase of the development program touches on the following subjects:

1. Preliminary Studies
2. Total Test Program
3. Critical Issues in the DCP
4. State-of-the-Art or Manufacturing Risks
5. OT&E Preliminary Planning
6. Facilities Requirements for OT&E
7. Consideration of Joint Testing
8. T&E Plans
9. Test Plans for Subsystems and Interfaces

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1. PRELIMINARY STUDIES

Analytic and empirical studies should be conducted prior to DSARC I to ensure that the range of critical performance characteristics has been specified.

Each performance characteristic so specified should be measurable through bench and laboratory or full-scale testing. The test plan and the number of tests should be prepared so that meaningful results and conclusions can be drawn (at suitable confidence limits if necessary). If a given accuracy for locating an enemy radar or for measuring the azimuth direction is specified, testing at one or two frequencies in two different reasonable environments may satisfy the requirement for meaningful test results. Testing in advanced development should be planned to explore the detection and localization performance characteristics over a broad range of environments so as to provide insight into system performance over the expected operational range and not just at a single point.

Also, when applicable, the testing should be planned to find out if the accuracy provided by the detection and localization system is adequate for directing the active ECM.

2. TOTAL TEST PROGRAM

Prior to DSARC I, all the phases of the test program should be addressed so that the approximate total costs and development schedules include consideration of all likely activities in the overall program.

In an airborne ECM program, these might include the cost for range support during the R&D effort, new test range instrumentation of facility requirements, the cost of the OT&E program (both IOT&E and follow-on OT&E including test gap closing provisions), and the cost of special tests, such as anechoic chamber tests and tests against actual or simulated enemy electronics in as realistic an environment as possible.

3. CRITICAL ISSUES IN THE DCP

In evaluating the initial DCP (or its equivalent) for an airborne ECM system, it is important to ensure that the tests to be conducted during the period from DSARC I to DSARC II address the major critical issues.

These should include a vulnerability to home-on-jamming, crosstalk between antennae, performance in very dense electronic traffic, receiver sensitivity, repeater time delay, and other critical issues that may be identified in the DCP. 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 for the data collection, reduction, and analyses must be in sufficient detail so that one can readily evaluate the performance of the equipment and whether the test objective can be met. A clear relationship between the identified performance parameters and the test results should be established prior to the conduct of the test. For instance, in a reconnaissance system or in a deceptive or active jamming system, performance may not be an immediate consequence of test results but must be calculated from information, not always reliable, on the emitter effective radiated power (ERP) antenna pattern and receiver design.

Further, the set of objectives for each of the tests should be clearly related to the program objective as defined in the DCP. When this relationship is not clear, amplifying data should be required.

4. STATE-OF-THE-ART

Ensure that the state-of-the-art issues are addressed before full-scale development and that new manufacturing techniques are subjected to special test attention whenever they are introduced so that side effects will not adversely impact the test and production programs.

New state-of-the-art or new manufacturing techniques that were not adequately tested rank very high as reasons for major development problems.

For example, if development of a new electronic component is needed for successful airborne ECM performance, component development should be initiated long enough before the ECM development contract is signed to reduce the component development risk to an acceptable level. For instance, in data processing equipment (including software algorithms) that compute the characteristics of an enemy weapon or device, memories of the several types required for effective ECM performance should be available and should have been tested before DSARC II is reached.

5. OT&E PRELIMINARY PLANNING

Before DSARC I the general nature of the schedule for the OT&E plan should be addressed.

In general, the OT&E plan should include ECM engagements in the environments in which the new system is expected to operate. Airborne ECM testing may be addressed in several phases, such as:

(a) One-on-one testing against existing U.S. radars and available simulators of the assumed threat.

(b) Single aircraft testing in a multiple defensive radar environment.

(c) Multiple aircraft testing in a multiple defensive radar environment.

(d) Comparative testing of the new ECM system with existing systems to estimate the increased capability.

Test range and resource requirements should be estimated, and, if interservice testing is contemplated, preliminary plans for such testing should be coordinated with the cooperating service.

6. FACILITIES REQUIREMENTS FOR OT&E

Before DSARC I ECM test facilities and instrumentation requirements to conduct operational tests should be identified, along with a tentative schedule of test activities.

The applicability of the test ranges, the adequacy of the facilities and instrumentation, and the availability (at the appropriate time) of real or simulated enemy radiators should be verified. Insofar as possible alternative approaches (different ranges, etc.) and instrumentation improvements needed should be specified. Of prime importance are the identification of constraints to be placed on the test because of range, instrumentation, and target availability. If these factors are found to cause significant doubt on the meaningfulness of the test data because of a lack of operational realism, the steps necessary to assure meaningful data should be identified and planned before inclusion in the DCP.

7. CONSIDERATION OF JOINT TESTING

If joint testing is recommended, an analysis of its impact on time and resources needed in the program and the additional resources needed to execute the joint tests should be conducted before DSARC I.

Joint service operational test and evaluation may be critical for an airborne ECM system, especially if new concepts are being implemented. Emphasis in ECM joint tests should include investigation of the impact on the effectiveness of the ECM system of such aspects as communication, radar acquisition, and localization, effectiveness assessment, and counter-countermeasures associated with victim radar operator learning.

8. T&E PLANS

Prior to DSARC I, sufficient material should be generated to allow for an evaluation of the overall T&E program.

As part of this, a detailed test and evaluation plan for those tests to be conducted prior to DSARC II to validate the concept and hardware approach to the weapon system should also be developed. The plan must include statements of:

(a) The critical issues and the overall purpose of the test
Example: In an ECM system, the output power of a jammer is usually a critical design parameter and, consequently, will typically be a critical issue in the test and evaluation program. Other issues might be vulnerability to HOJ, performance in a multiple emitter environment, receiver sensitivity, repeater delay time, etc.

(b) The operational requirements
Example: The test plan should be compared with the specific operational requirements; every major element of the test plan should bear a logical relationship to the operational requirements.

(c) The major test objectives.

(d) The schedule of test milestones

(e) The major resources required

- Test environment, facilities, and instrumentation
Example: Testing of airborne ECM systems usually requires special test facilities (e.g., large anechoic chambers, sensitive instrumentation, etc.); every major

system design parameter which is to be tested must be identified with the appropriate test facilities and instrumentation. If this cannot be done, then the validity of the test plan should be questioned.

- Operational environment, especially real or simulated defensive radars.

(f) The organizations which will conduct the test program

(g) The analysis and evaluation approach
Example: It will always be desirable to consider how the data from the test program will be analyzed and evaluated. This simple procedure will often reveal discrepancies between the analysis planned and the data to be taken.

9. TEST PLANS FOR SUBSYSTEMS AND INTERFACES

Ensure that the broad program plan assembled before DSARC I includes testing plans for all the proposed subsystems and interfaces in the ECM system.

In particular, electromagnetic compatibility tests should be scheduled early in an anechoic chamber with ECM equipment and other electronic systems in place on the aircraft. For instance, in an active jammer ECM system, one can never predict all the possible interference problems that may exist between the various on-board systems over the system operating band width. This fact serves to emphasize the need for anechoic chamber (or equivalent) testing for the purpose of establishing system compatibility.

II. VALIDATION PHASE

During the Validation Phase, the issues of the DCP will be addressed. In many cases, tests of advanced developments will be necessary to demonstrate proof.

It is also likely that the proposed system and the proposed contract will be defined through competitive industry efforts. In some cases, where funding is successfully defended for a program before it is formally approved for full-scale development, it is likely that the service would come to the DSARC at the end of the Validation Phase with a program defined and a contract negotiated and ready for government signature.

The major T&E concerns in this phase are the conduct of DCP issue tests, planning for the conduct of test and evaluation in the remainder of the program, and the relationship of contract terms to T&E.

The checklist covers:

1. Subsystem Interactions
2. Feasibility Test Design
3. Data Recording
4. Tests as Prerequisites for Program Phasing
5. Impact of Incentives on Performance Envelope Exploration
6. Importance of Performance Envelope "Corners"
7. Government Furnished Equipment
8. Sample Size for Reliability
9. Realism of Test Configuration
10. Software T&E
11. Effects of Look Through Rates on ECM Effectiveness
12. Modulation Technique

The reader should also refer to the checklist items in the Conceptual Phase since many of those items will also be applicable to the Validation Phase.

1. SUBSYSTEM INTERACTIONS

The test plans should address all of the critical subsystem interactions.

Specifically, these include the interfaces between the ECM pods and other essential electronic systems, the ground support equipment, and the command, control, and communications (C^3). For example, if the jammer system support and maintenance equipment can not be easily operated and maintained by service personnel, then it will not be possible to keep the ECM in proper operating conditions and, as a result, the jamming performance, system reliability, and in-commission availability will be seriously degraded.

2. FEASIBILITY TEST DESIGN

The design of the set of tests to demonstrate system feasibility prior to DSARC II should be based on a building block concept.

High technical risk items should be tested early with subsequent tests incorporating more of the hardware until the complete system concept has been demonstrated as feasible. For example, if the high risk item is a high power tube, then the demonstration of tube performance should be conducted prior to a demonstration of the transmitter system.

3. DATA RECORDING

Insofar as possible, data recorders should be used in all flight testing to minimize dependence on crew memories.

The pilot and crew are usually busy flying and navigating the aircraft so that it is not normally possible for them to give attention to the details of the jammer system performance. For example, expecting the crew to remember prime power status at the instant the transmitter tube failed is unreasonable.

4. TESTS AS PREREQUISITES FOR PROGRAM PHASING

Major tests must be accomplished and the ECM system feasibility adequately demonstrated before the system is allowed to move to the next phase of the acquisition process.

For example, before the system is allowed to go into the IOT&E phase, major development tests should be complete; before the full-scale production phase is entered, the IOT&E of the total airborne ECM system should have been successfully performed; prior to deployment of the system to the user, successful completion of the acceptance testing of the initial production items must have occurred.

5. IMPACT OF INCENTIVES ON PERFORMANCE ENVELOPE EXPLORATION

Review the test and evaluation plan to ensure that the contract incentive fee criteria will not constrain the developer from exploring the full performance envelope.

For example, the contract should not penalize the contractor for marginal performance in relatively unimportant regions of the envelope. On the other hand, performance specifications should call for demonstration of successful jamming of simulated threat radars by the test article under other than ideal conditions.

6. IMPORTANCE OF PERFORMANCE ENVELOPE EXPLORATION

Contract requirements and incentives should not be based on tests in extreme corners of the theoretical performance envelope unless there is a high payoff for such performance.

For example, considerable extra test effort, time, and money might be spent on getting completely satisfactory jamming performance against a search radar that cannot be used readily in an air defense role. Thus a contract that blindly specifies that the ECM characteristics must be fully satisfactory throughout the performance envelope may lead to a design with cost-effectiveness less than desired.

7. GOVERNMENT FURNISHED EQUIPMENT

Ensure that GFE items are adequately integrated into the T&E program.

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

(a) Can the gear with required performance be available when required?

(b) Can government-supported facilities provide the assistance required at the time needed? If not, is it reasonable to construct the required facilities (test range, instrumentation, building, 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."

8. SAMPLE SIZE FOR RELIABILITY

In order to provide reasonable confidence in the reliability of an ECM system, a large test sample size or a long test period will generally be required.

A study of the tradeoffs among sample size, test duration, and the confidence level should accompany a reliability testing plan. If, for some reason, the sample size or test duration is less than desired, which is the normal situation, a plan for showing how the reliability goals are to be demonstrated must be prepared. Attention must be given to how reliability is to be demonstrated often with only limited resources.

9. REALISM OF TEST CONFIGURATION

Test conditions during validation testing should be determined by the primary objectives of that test, rather than by more general considerations of realism, etc.

Whenever, in the interest of obtaining advanced engineering data, a non-tactical non-operational configuration is required for testing, the results of the tests should not be challenged by the fact that the configuration was not tactical or operational. For example, if in the development of an airborne ECM system, problems with the surveillance receiver preclude adequate azimuth information, it may be desirable to use an artificial target locator as an aid to testing other aspects of the system.

10. SOFTWARE T&E

Test and evaluation should ensure that software products associated with the ECM and data processing subsystems are tested appropriately during 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 sub-system concept. Often the facilities available to contractors for software development and verification are critical to schedule and cost. Failure to thoroughly check out the software on several ECM programs resulted in inability to properly classify certain emitters.

11. EFFECTS OF LOOK-THROUGH RATES ON ECM EFFECTIVENESS

Simulation tests (computer or breadboard) of the proposed look-through jamming techniques should be conducted to predict the effects of the look-through rates on the threat radars.

The scan rates, dwell time, and PRF of all the threat radars should be considered in the simulation.

12. MODULATION TECHNIQUE

The modulation techniques must be investigated early in the validation of the ECM concept.

Modulation techniques are critical for determining how effective the jammer Effective Radiation Power will be in defeating the victim radar, and consequently simulation tests (computer and/or breadboard) of the proposed modulation concepts and techniques should be prerequisites to DSARC II. A prediction of what the victim radar operator will see on his display should be made.

III. FULL-SCALE ENGINEERING DEVELOPMENT PHASE

In this phase, which includes both DT&E and IOT&E (the OT&E conducted prior to the major production decision), the T&E plans developed in the Validation Phase will be refined and the R&D testing will be conducted. In some cases, the development contract will be signed in the early part of this phase. For this reason the contractual considerations listed under validation are repeated below.

The T&E checklist for the development/IOT&E activities treat:

1. Technical/Maintenance Data Package
2. Use of Non-Tactical Components
3. Untried Materials
4. Disaggregation of Reliability and Performance Evaluations
5. Tests of Entire Jamming Pod
6. Electronic Compatibility
7. Command and Control System Tests
8. Testing of Exciter and Transmitter
9. Passive Detection System (PDS) Testing
10. PDS Accuracy Tests
11. Transmitter Testing
12. Effective Radiated Power Tests
13. Modulation Technique Tests
14. Look Through Jamming Technique Test
15. Observer and Umpire Actions
16. Temperature Cycling Tests Versus Electrical Characteristics
17. System Interfaces in IOT&E

The reader should also refer to the previous checklist items since many of them will also be applicable to this phase.

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1. TECHNICAL/MAINTENANCE DATA PACKAGE

Prior to the decision to go into full-scale production of an airborne ECM system, a complete technical/maintenance data package should be prepared and tested to ensure that the system can be maintained.

The testing of this package should be considered as an essential part of DT&E and also as an essential prerequisite to the IOT&E of the system. Criteria for successful demonstration of this package should be established in both types of tests.

2. USE OF NON-TACTICAL COMPONENTS

When testing is delayed because of the non-availability of critical subsystem components, off-the-shelf interim components should be used as substitutes until the proper components are available.

As long as the off-the-shelf components can be substituted acceptably within a defined range of interest, the rest of the system can be tested, thereby facilitating the progress of the test program. Clearly, this cannot be continued indefinitely, but it should serve to reduce the hindering influence of long lead time components that are not available on time. Selected tests may have to be repeated when the proper component is available.

For example, it may be possible to perform electromagnetic interference (EMI) testing with a transmitter of sub-standard output power if it is capable of providing the necessary signal for proceeding with EMI testing.

3. UNTRIED MATERIALS

If untried materials are employed anywhere in an airborne ECM system or its components, there should be special development tests to determine the ability of these materials to withstand environmental conditions expected.

For example, if a new potting compound is used in the electrical system, it should be exposed to the heat and humidity expected in the use of that system. This test should be done prior to any system demonstration involving large-scale testing.

4. DISAGGREGATION OF RELIABILITY AND PERFORMANCE EVALUATIONS

Reliability and performance evaluations of an airborne ECM system should be segregated into phases.

To do this one should break down the system activity into at least the following phases or aspects:

- threat detection and localization performance
- data processing and display (hardware and software)
- automatic jammer assignment (in multiple threat environment)
- manual jammer assignment
- jammer performance (by frequency band and modulation techniques)
- deception ECM performance (including look-through)
- communication ECM performance.

Analysis of the appropriate test data on this basis should provide more insight into performance than composite, less revealing analyses.

5. TESTS OF ENTIRE JAMMING POD

Engineering flight tests should be conducted on the entire jamming pod as soon as possible.

Test bed aircraft should be used for early flight testing, where the transmitter mounting configuration and antennae pointing directions relative to the aircraft can be carefully selected to ensure that realistic measurements can be made. These flight tests should be flown over a calibrated test range so that ERP measurements can be made. During these tests, it is important to record the critical data so that pilot memory is not required.

6. ELECTRONIC COMPATIBILITY

T&E is required to determine that all major elements of the ECM system are compatible and can operate simultaneously without degrading the system performance.

Special attention should be placed on the effects of spurious side bands generated by the active jammers which may interfere with on-board or other friendly radars, communications, doppler navigation, and IFF equipments. When two or more different kinds of ECM jamming systems are to be used simultaneously (such as a pulse-to-pulse deceptive jammer and a primary jammer) compatibility of the two must be demonstrated. Anechoic chamber tests, followed by flight tests, should precede IOT&E.

7. COMMAND AND CONTROL SYSTEM TESTS

The ECM operator's on-board command and control subsystem should be tested to demonstrate its ability to accept the threat data from the passive detection system and display the data to the operator, provide computer-aided threat analysis, compute the threat parameters and classify them, and provide the operator with computer-aided control.

Specifically, demonstrate that the computer hardware and software meet specifications, including cold start at minimum voltage levels. Demonstrate the classification algorithms, the radar parameter identification algorithm, and other control algorithms and show compatibility between the operator, the computer-aided modes, and the manned modes. Ensure that friendly emitters can be distinguished from threat signals.

Demonstrate that the interfaces between the ECM operator's command and control subsystems are compatible, that is, perform inter-connecting cable compatibility tests between the command and control subsystems. Demonstrate that the RF, IF, and video isolation requirements are adequate and that video, RF, IF, and transient noise do not couple from line-to-line.

8. TESTING OF EXCITER AND TRANSMITTER

DT&E should be conducted in an anechoic chamber with the exciter and the transmitter to verify performance.

These tests should demonstrate the compatibility between the exciter and the transmitter as well as proving that the modulation techniques can be transmitted through the transmitter/antenna combination without degradation.

Prior to this, the modulation techniques should have been incorporated into the exciter design and verification tests performed to demonstrate proper operation, examining factors such as the frequency stability drift rate and linearity of the exciter.

9. PASSIVE DETECTION SYSTEM (PDS) TESTING

Tests are required to measure the capability of the passive detection system (PDS) to detect the enemy radiations, measure their angle of arrival, and determine their frequency.

Specifically, measurements are required of the gain, bandwidth, axial ratio, and patterns of the PDS antennas, including the radome effects; and sum and difference channel balance of the receiver over the operating bandwidth. The PDS receivers should be tested to demonstrate that sensitivity, dynamic range, linearity, and frequency measurement requirements have been met; that the frequency search scan rates are compatible with the look-through jamming rates; and that the tracking systems do operate at the specified minimum signal.

10. PDS ACCURACY TESTS

A full-scale test in an anechoic chamber, to demonstrate accuracy of the passive detection system, should be performed prior to any operational testing.

The receivers should be balanced after installation on the mock-up, the actual aircraft structures should be incorporated, and the simulated emitter should be moved around so that accuracy as a function of azimuth, elevation, frequency, and polarization can be determined. This test should be followed by a flight test to demonstrate the PDS accuracy and sensitivity.

11. TRANSMITTER TESTING

Development testing and evaluation of the ECM transmitters should provide for measurements of the output power (into a dummy load) to gain a preliminary, partial assessment of the performance of the transmitter.

Measurements are also required of the operating bandwidth, the instantaneous bandwidth, the linearity, and the energy in spurious side bands (the out-of-band distribution of radiated signals). Prior to full system DT&E, it should be demonstrated that the transmitter cooling system is adequate (at altitude and full power), and that the transmitter power supply will work properly using aircraft prime power source and is compatible with the power amplifier chain.

12. EFFECTIVE RADIATED POWER TESTS

Development test and evaluation should be conducted to determine and verify the jammer effective radiated power (ERP).

These tests should involve both antenna and transmitter measurements. Relative to the antenna, RF circuit tests measurements should be made on (a) antenna patterns, (b) axial ratio and gain (including radome effects), and (c) RF losses including rotary joint and radome. These measurements must be made in an anechoic chamber for all scan angles and at all aircraft mounting stations. As part of these tests the capability of the antenna to handle full rated power must be demonstrated.

13. MODULATION TECHNIQUE TESTS

Perform flight tests against threat simulators to demonstrate the system effectiveness of the modulation techniques.

These flight tests will need to be run at a secure test range. Final verification of the effectiveness of the modulation by means of system flight testing may require hardware changes to correct problems. This is costly, so getting it right the first time is important.

14. LOOK-THROUGH JAMMING TECHNIQUE TESTS

Flight tests against threat simulators should be performed to demonstrate the effectiveness of the look-through jamming technique.

A multi-threat environment will provide the most difficult test of the look-through jamming technique.

Look-through jamming which is accomplished by turning off the active jammer transmitter may be preferable to the use of receiver desensitizing or spatial isolation. The latter is considered a high risk approach and when used will require careful testing to prove its effectiveness.

15. OBSERVER AND UMPIRE ACTIONS

Test conduct should not be influenced by the actions of the observers and umpires.

These people can provide important clues to the participants of operational suitability testing and in that way lessen the validity of the test. For example, in situations where air/ground duels are to be conducted, observers who look where they have been briefed the jammer aircraft will approach might inadvertently tip-off the direction of approach to the radar operating crew on the ground. Similarly concentrations of observers at a certain location may clue the air crews where to search first for the ground targets.

16. TEMPERATURE CYCLING TESTS VERSUS ELECTRICAL CHARACTERISTICS

When performing vibration, shock, altitude and temperature cycling tests, measurements of the electrical characteristics should be taken before and after each environmental test phase.

Such tests should be conducted separately on the antenna RF circuit, the transmitter, the exciter, etc. Further, such tests should be conducted on the combined antenna/RF plumbing/transmitter/exciter hardware.

Special attention should be devoted to temperature cycle test results since they will help identify components and structural interface problems. Specifically, the temperature cycling tests should simulate the expected temperature environments with respect to the numbers of and peak excursions of the cycles.

17. SYSTEM INTERFACES IN IOT&E

Whenever possible, the IOT&E (as well as the follow-on OT&E) of an airborne ECM should be planned to include any other systems which have a technical interface with the new system.

For example, ECM equipment should be tested on all the existing aircraft for which it has been programmed, and the interface with the pertinent C^3 should be tested. Whenever more than one system is involved, specific attention should be directed to the interfaces of the systems, especially the display and control subsystems.

IV. SUBSTANTIAL PRODUCTION/DEPLOYMENT PHASE

The primary T&E activity in this phase is follow-on OT&E, although acceptance and reliability testing and necessary additional DT&E are also required. Follow-on OT&E is that OT&E performed after the DSARC decision for substantial production and deployment, and is the first OT&E conducted with production hardware.

The checklist items for this phase cover:

1. Testing of Operational Modes; Evaluation of New Threats
2. Personnel Briefing in Testing

The reader should also refer to the previous checklist items since many of them will also be applicable in this phase.

1. TESTING OF OPERATIONAL MODES; EVALUATION OF NEW THREATS

The follow-on OT&E plan should include tests of any operational modes not previously tested in IOT&E.

All operational modes, including backup modes, should be tested in the follow-on OT&E because the software interface with the production hardware system should be thoroughly evaluated. Otherwise, small easy-to-fix problems could seriously impair overall system performance under adverse conditions.

The test phase should be extended if necessary to evaluate system adequacy in the face of new threats that become known late. The follow-on OT&E activity and the continuous operational testing that usually follow system deployment must be coordinated to make most effective use of resources in testing new operational modes and in testing responses to new threats.

2. PERSONNEL BRIEFING IN TESTING

In operational testing and evaluation of airborne electronic countermeasure systems against ground based radars, the ECM test operators should not know the locations of the ground radars or when the radars are in various operational modes.

Likewise, the operators of equipment to be jammed should not be briefed on the precise time, flight plan, or ECM mode to be tested. As part of the test, operationally configured aircraft groups should be used against expected operationally deployed ground radar systems; hence, many-on-many type testing is required to demonstrate the operational utility and effectiveness of the ECM requirement.

Such operational testing will require larger ranges and/or instrumentation in areas where the use of jamming equipment will not seriously interfere with unrelated local commercial and government electronic equipment, (such as T.V., radio, radar approach control, etc.). Constraints imposed on the OT&E by lack of such a range should be critically analyzed to determine the overall impact on the evaluation of the system.