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SYSTEM INSTALLATION AND TESTING

TECHNICAL DOCUMENTARY REPORT NO. ESD-TDR-64-167

DECEMBER 1964

F. W. Hopkins

Prepared for

TECHNICAL REQUIREMENTS - STANDARDS OFFICE

ELECTRONIC SYSTEMS DIVISION

AIR FORCE SYSTEMS COMMAND

UNITED STATES AIR FORCE

L. G. Hanscom Field, Bedford, Massachusetts

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ABSTRACT

The type of testing discussed in this report is that which takes place for every field installation to ensure that implementation of system components is accomplished properly and that optimum system performance is obtained. Implementation testing is defined, it is contrasted with other types of testing, its motivation is discussed, and its planning requirements are outlined. This report reveals how designing an implementation testing program in advance is an effective way of ensuring and accomplishing the successful implementation of the system in the field, at each location where its components are installed.

REVIEW AND APPROVAL

Publication of this technical documentary report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

EDWARD M. DOHERTY
Chief, Scientific & Technical
Information Division

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SECTION I

INTRODUCTION

SCOPE

Once the components of a system have been transported from the manufacturer's plant to the emplacement where they will be come part of an operational system, implementation testing will take place. This document attempts to define implementation testing, contrast it with other types of testing, discuss its motivation, and describe the planning required.

CONTRAST WITH OTHER TEST PROGRAMS

Implementation testing takes place for every field installation that is accomplished. It is necessary to ensure that the implementation itself is accomplished properly and that the proper degree of system performance results at the end of the implementation. Implementation testing should not be confused with or act as a substitute for design verification. The latter is a part of the design and development process, and, ideally, it should be completed prior to any field installation. Similarly, implementation testing should not be confused with Category I or Category II testing which is commonly performed on the first article of an electronics system for purposes of design and quality acceptance and collecting certain service data. First article testing, also, should be completed prior to field installation.

THE MOTIVATION FOR IMPLEMENTATION TESTING

Testing is appropriate upon implementation of any system or element of a system whether or not a copy of the same system has been tested previously. The first article of any system of new components must undergo thorough

testing. The second and subsequent articles must also undergo testing although the expectation of failure should be considerably less, and, consequently, the manpower and time programmed should not be as great. The experience of previous testing should yield simpler test methods and diagnostic techniques, and the emphasis might tend toward verification of proper performance rather than discovery of sources of difficulty. It should be noted, however, that if a malfunction does occur on the second article, it is just as important to locate and fix it as in the case of the first article.

Why does a malfunction occur on a second article if thorough testing resulted in a well-operating first article? No matter how thoroughly the specifications for the system were prepared, no matter how conscientious the manufacturer was in the performance of the contract, no matter how well the first article performed during testing, the situation is different with each emplacement.

A technician in installing a piece of equipment may have crossed wires and connected them to the wrong terminals; atmospheric conditions may cause the radar background noise to have different characteristics; the site location and relative location to other sites will be different; and, the logical operation of the system at an adjacent site may be different from any used at the first article test site. In addition, there are normally many unique site adaptation parameters that must be verified for accuracy and suitability, and assurance that insertion of the parameters did not destroy some operation that was previously satisfactory. There are also, normally, several threshold parameters that are not necessarily unique to any particular site, but which must be set correctly at each site and be verified for correct operation.

Implementation testing will take place whether or not it is deliberately planned. One can envision, perhaps, putting components into place according to site-layout drawings, connecting the components according to engineering

drawings, and reading in a computer program previously prepared. The day must come, however, when personnel will seat themselves at operational positions, turn on all power switches, set in adaptation parameters, and expect the system to operate according to plans prepared many years previously and modified continuously up to this day. If no systematic testing has been accomplished prior to this day, the first system implementation test begins then.

THE NEED FOR TEST PLANNING

On delivery of a new system, those concerned are interested in having the system operate at the earliest possible time. The high expectation of failure on the first system trial suggests that the goal of timely delivery of an operating system is achieved with greater likelihood and less cost by planning and conducting a systematic test program in advance, a program which detects areas of malfunction with collection of information that will indicate corrective action or which verifies the absence of malfunction with confidence and measures the actual performance achieved.

Implementation testing should be designed and conducted to answer the following questions:

Does the system as installed meet the specifications?

Does the system, meeting the specifications, allow the job to be done?

How well does the system do this job?

In designing a test program one must, of course, formulate many more detailed questions to be answered for each of the three general questions. With proper design, one can often obtain answers to all three major questions with the same test plan. In testing for the first question, however, one needs to be sure that, if the answer is in the negative, he has obtained sufficient information to allow determination and correction of the deficiency. The answers to

the third question are usually obtained as byproducts to testing specifically designed to cover the first two questions, and can be augmented by collection of information throughout the normal course of operations following delivery.

Proper test design requires comprehensive and realistic planning: among the major areas that should be treated are the total time, the manpower, the instrumentation, and the external resources required. It generally happens that a computer-based air defense system is installed at an existing manual air defense site. It is expected that the radar and other operational resources of that site will be used. Test planning must recognize the need of the operational elements to continue operating. Too often a test plan for installation of a computer-based system will assume that the system manufacturer has use and control of, say, the radar 24 hours a day, 7 days a week. In an operational environment, he will be fortunate to get use of the radar for one hour a day. Test planning should take this into account.

Failure to consider all the pertinent factors in test design usually results in nothing more serious than delays in delivery. Delays in delivery, however, can have serious impact. Contractor manpower costs continue in significant amounts without useful results, and operational commands support manning for two systems over the delay period at significant cost. False impressions based on capability at expected delivery date can generate undue lack of confidence in the system performance of the system untimately delivered.

SECTION II

CONSTRUCTION OF THE TEST PLAN

Let us now try to construct an implementation test plan for a computer-based air defense system. This should be accomplished in accordance with the general objectives of the implementation test program. (see p. 1). Specific questions must be constructed for each of the general objectives.

TEST OBJECTIVES

Tests for Compliance with the Specifications

For the first general objectives, of course, one needs to have the specification before the specific questions can be completed. Some examples can be given, however, to illustrate the type of operations that should be checked.

If a Link-1 message, say S-4, is required to be sent between a pair of adjacent sites, the following series of steps is indicated.

(a) Insure that the telephone lines are installed between the two sites concerned, and that they have the specified characteristics. Of particular concern is the requirement that the specified number of bits per second can be passed from one computer to the other with only the allowable loss of bits.

(b) Insure that the format generated within the sending computer is received in the same format in the other computer. One might make this check, for example, by including, in a sample message format, zeros in all information items except one. That information item, perhaps bits 9 to 12, might be filled with ones. A check of the receiving computer could then be made to see that all ones were received for the information item of bits 9 to 12, and that zeros occurred elsewhere. A complete check of this step might require that all possible combinations of zeros and ones were examined. It should suffice, in most cases, to check only a small sample of

the possibilities. The sample should include examination of the information items which might be most important in operations. Testing for the second and third objectives and, indeed, monitoring of performance during operations, should reveal discrepancies of significance, if any, not uncovered by this specific test.

(c) Insure that the message is generated according to prescribed rules for area, timing, or other criteria. To accomplish this step, one might attempt to crosstell several tracks with the S-4 message by placing these tracks for test purposes at various points within and without the boundaries of the areas for automatic crosstell. At the receiving site, a check can be made to insure that no tracks outside of the area are received and that tracks meeting the other criteria are received within the prescribed area at the rate of message generation, say one per scan, specified.

In examining the generation resulting from other criteria, for example, identity or request for a message from another site, steps should be taken to insure that an identification changing the eligibility of a track for crosstell results in the proper response, and that a request for a message results in the proper message being sent.

(d) Insure that the information content is set properly according to rules and definitions. In some cases, a very simple test is involved. For example, with identification content, one can merely assign successively all the possible identification classifications, and check to see that the correct identification classification is included in each message being crosstold. It is slightly more complex to insure the proper setting of an information item such as data quality. In this case, one must examine the history of tracking, looking at the external factors that determine data quality. If the data conditions are, in fact, poor, the data quality transmitted should be poor; and, in a similar fashion, if the data quality transmitted is good, then the data history on the track concerned should, in fact, be good.

(e) Insure that the information is interpreted and used properly at the receiving site. The best example here is, again, that of data quality. At the receiving site there are, presumably, some conditions under which crosstold information of good quality tracks should be incorporated, other conditions under which crosstold data of poor quality tracks should be incorporated, and, perhaps, some conditions under which only part of the information received

should be used. The check then must insure that the information is properly decoded and that it is used in accordance with the rules for the conditions existing at the receiving site at the time of receipt. Thus, the examination must be concerned not only with the message itself, but with the conditions at the receiving site.

Testing of the sort indicated in this section can easily get out of hand if one tries to insure correct operation under every possible situation. It is important for efficiency, confidence, and saving of time in the total implementation process to perform this kind of testing for at least a few of the commonly expected situations so that obvious malfunctions installation errors, or data processing errors can be eliminated before proceeding to a higher level of testing. A continuous search for faults of this nature should be made, as a byproduct, for other situations encountered during high-level test programs.

Another illustration of a check to see that the system as installed meets the specifications might be the following: if the tracking logic includes, say bifurcatious tracking, one should check to see that a secondary track is formed if and only if the prescribed history of data correlation is achieved; that a secondary track becomes a primary track if and only if the proper history of data correlation is achieved; and finally, that the excess track is dropped if and only if the proper history of data correlation is achieved. A check of this nature requires detailed examination, in a few representative situations, of the data correlation and the process of the tracking equations. An examination of this sort at each site being implemented, using live radar information, can be accomplished in a fairly simple manner, and may save much time and effort in subsequent tests to evaluate tracking capability, say, on maneuvering aircraft.

Although the specifications for the system may not always prescribe tolerances on the registration of target information between two adjacent radar sites, they probably should. (Registration is defined here to mean the degree to which two separate sites can report a single target in such a fashion that, after coordinate conversion, the location reported matches that computed at the other site.) Whether the specifications indicate a tolerance for the discrepancy in position reported or not, tests should be conducted to measure the separation and to uncover the errors responsible for significant separation, if any. The types of errors commonly responsible for

excessive separation are errors in (1) coordinate conversion data processing, (2) the coordinates of site location in one computer or the other or both; (3) common alignment of radars to true north; or, finally, (4) in the range timing of one or another radar. In addition, faulty height information on test targets, if contained in one computer or the other, may cause apparent registration errors and, hence, should be guarded against.

Although the tests that are normally conducted to measure registration errors require a fair amount of test control, data reduction and analysis, the results of this analysis ordinarily indicate, in a straightforward manner, the correction necessary to improve the registration. In addition, incorporating at least two steps into the test process can increase the confidence in achieving successfult registration at an early time. The two principal steps would be a static test wherein stationary targets are passed from one site to another and back again to detect obvious errors in the implementation of the coordinate conversion function, and a series of tests on a live target aircraft to measure the actual separation.

Finally some of the most significant but trivial tests that can be accomplished to meet the first general objectives are mentioned. These consist of pushing each button at a console and generating each display at each console to see if the buttons cause the specified computer responses and if the displays contain the proper information. In many test programs, this is the extent to which planned checkout takes place. Invariably, tests of a more sophisticated nature of the sort indicated above subsequently manifest themselves as being necessary. They can then be accomplished only with great difficulty, and waste results because of lack of planning and conduct in an orderly fashion.

All the checks that should be made to verify that the system is properly installed have not been covered. A review of the specifications for any particular system should indicate the important checks to be made before going on to further testing. In addition, it is always advisable to continue looking for deviations from specifications as subsequent testing takes place. This can be done in a planned fashion so that once the more important checks have been made, the remainder can be accomplished simultaneously with performance testing without any expectation of seriously affecting subsequent test conduct. In fact, if performed simultaneously

with subsequent testing, one might find that the system operating with the error still allows the job to be done and, hence, there is no need to correct the deficiency.

Tests to Verify Performance

The second general objective is to determine whether or not the system with its deficiencies removed still allows the mission to be accomplished. To answer this question, of course, one needs to think about the job the system is trying to accomplish. For an air defense system, the principal task is to deny access to enemy aircraft over friendly territory. Ultimately, the objective is to destroy the enemy aircraft before they can launch weapons that might damage or destroy elements of the environment that are being protected. Current air defense systems have two principal means of destroying enemy aircraft: the surface-to-air missile, and the manned interceptor.

First in the order of discussion is the surface-to-air missile (SAM). The guidance and control of a SAM is not normally the responsibility of the ground environment of concern. The SAM control units must be provided with sufficient target information so that a SAM can be guided to the target at close to its maximum range in the direction from which the enemy penetration is taking place. The measure of success, therefore, should be the timeliness with which information of target position can be transmitted with sufficient accuracy so that the missile target tracking radar can lock-on to the target aircraft. The question which must be answered then is this: can the ground environment assign targets to the SAM units in sufficient time and with sufficient accuracy so that the missile can destroy the hostile aircraft with its nominal probability of kill? The specific test measurements should be made against criteria determined by the operational environment and by the desired probability of kill.

With respect to the manned interceptor, the task of the ground environment is to place the interceptor in such a position that its own weapons system can destroy the target with a high probability of kill. The measure of success of the ground environment then is the ability to place the interceptor on a heading so that it can have optimum or near optimum crossing angle, displacement from the target, and altitude separation for attaining the objective of completing the intercept as far forward in the direction of enemy penetration as feasible. Thus, the ground environment must be able to get the interceptor off the ground quickly to give it a course toward the target so that fuel and time will not be wasted in gaining a position on an attack heading such that the intercpet can be accomplished. Normally, the desired tactics and profiles and conditions under which each of these may be used are specified. For each tactic and, when designated, each profile, the task is to insure that the interceptor is placed on a specified heading within a specified tolerance, at a specified altitude within specified tolerance, at a certain distance from the target within a specified tolerance, with a reasonable time or distance of target penetration, again, within a specified tolerance.

Assuming that the system can satisfactorily designate targets to the SAM units and that they can satisfactorily guide interceptors to a position where they can kill targets, the remaining measure of success of the ground environment is whether or not it can determine the presence and location of all hostile targets and choose among these the ones which should be committed to each available weapon. Ideally, the ability of the target to penetrate an environment completely is accomplished only by deficiencies in our weapons inventory or deployment or by an allowable deviation from a 100 per cent kill probability.

To insure that a system is good, there are several tests that should be passed successfully as necessary steps toward accomplishing ultimate success.

The first of these is detection of the target aircraft. The system should obviously be able to detect the presence of all aircraft that are within the radar coverage specified for the environment during the entire time that the aircraft are in this coverage. The system should be able to track each of these targets with the same track and track number in a continuous fashion throughout the time that they are in the radar coverage of the total environment. The system should allow identification of each of these targets and maintain this identification so long as it is valid and so long as the target is being tracked. The system should allow determination of altitude of the target with sufficient accuracy so that the intercepts can be accomplished successfully. The system should allow determination to be made in a timely fashion of what targets should be taken under fire and what weapons should be used against targets so indicated. Each of these tests should be measured against criteria which provide for reasonable tolerance but still allow the desired system kill probability to be achieved.

Ideally, one might produce a mathematical model with various threat situations that would allow statistical determination of the tolerance to be placed on each of these steps so that the desired system capability can be achieved, assuming each of these steps meet the assigned criteria. In practice, a criteria for each of these steps is determined arbitrarily based on judgement of what seems reasonable for the equipments involved, the environmental characteristics, and needs of operational personnel. Whether or not the criteria are determined arbitrarily, they should still be established, and tests should be conducted to see that the system as installed meets these criteria. When it does, and only when it does, can it be said that the system has been installed successfully.

Consider, for example, one specific test that should be conducted for determining success of target maneuvers in a system with bifurcatious tracking. For implementation testing, several target aircraft should be flown in straight-line courses, followed by maneuvers of certain magnitude at a certain rate. The criteria designed arbitrarily might be that the target should be tracked successfully throughout a certain percentage of each type of maneuver, that it should stabilize on a new straight-line heading within a certain tolerance within a certain time, and that during each straight leg the track should remain with the aircraft in the sense that the velocity is that of the aircraft within a specified tolerance, and the position is that of the aircraft radar data within a specified tolerance for a specified percentage of time and with a specified maximum amount of operator correction actions. During a test for system capability, it must be remembered that operators are part of the system and that they are provided with actions to correct situations with which the automatic data processing equipment cannot contend. If this test can be passed satisfactorily and repeatedly, and if the tolerances are satisfactory to achieve the desired system capability, then it can be said that with respect to this particular step the system as installed and meeting specifications as prescribed does the job for which it was intended. If it does not pass the test, then either there is still a hidden error not uncovered during previous testing, or the specifications were not adequate to allow the job to be done. Both of these situations commonly occur. However, by planning and conducting a competent test program with the first objectives, and by preparing the system specifications in a thorough and detailed fashion, the chance of success in passing a test of this kind is considerably enhanced with a corresponding increase in confidence in the system delivered and saving in cost and time in the total implementation effort.

Tests to Evaluate Performance

The third general objective is to determine how well the system does the job for which it was bought. In our previous testing, the principal objective was to assure that system performance met desired criteria. Assume, as a desired criteria for tracking continuity that the track should be within 5 per cent of aircraft position 90 per cent of the time that the aircraft is within radar coverage of the environment, while maintaining the same track number and identification throughout. The measurements may actually indicate that for 95 per cent of the time the track heading is within 2 per cent, the track speed within 10 knots, and the track position within 1-1/2 miles of the corresponding parameters of the aircraft. This information is useful. It can be obtained as a direct byproduct of testing for the second general objective, and can be collected repeatedly after system operations begin. It can be useful to operational personnel to understand better the system capabilities, and it can be useful to detect subsequent degradation of system performance. For, in spite of the specifications or the previously determined criteria of success, deviation from higher performance sustained over some period of time indicates that some unnecessary malfunction has been introduced into the system. This malfunction can then be located and corrected to return the system to its proven capability of higher level of performance.

TEST FACILITIES

In addition to specifying each of objective for the test program and the method of analysis for each objective, the test plan should treat other important topics: the internal facilities of the ground environment to be used for each test, and the external facilities required for each test indicating the coordination necessary.

Internal Facilities

Internal facilities break down into four categories. The first should be an identification of the normal operating facilities, for example: consoles, computer programs, and sensor devices that need to be utilized in each test.

The second category consists of recording equipment and other test instrumentation necessary to collect information that is not necessarily a part of normal operations, but which is essential for the test program. This may, in fact, include additional display equipment and radio equipment for control of test aircraft and safety monitoring. It will also include recording devices indicating specific information to be recorded so that the necessary data for test analysis is available. In a computer-based system, recording devices planned should normally include not only photographs and manual logs, but also digital recording of information contained in the computer stores so that specific data processing situations can be reconstructed. Some of the examples given before suggest recording of Link 1 messages as transmitted and as received, recording of specific positions of data correlating with specific tracks, recording of track positions and velocity, and recording of operator actions, to suggest a few. Operator actions can, perhaps, be recorded by manual logs; the other information is almost unavailable except through recording of digital data in computer storage. In any event, the specific information to be obtained by the various means of instrumentation should be determined by examination in terms of the intended method of analysis of each test objective, and by assuring that the information necessary for the analysis is obtained by some means and that the necessary test equipment is available for the test program.

The third category consists of normal operator personnel required to participate in the program for each test.

The fourth category consists of normal operator personnel required for test conduct and safety operations in addition to the operating personnel.

External Facilities

The external facilities which should be indicated in the test program include the test aircraft, use of manual facilities as necessary for monitoring purposes, coordination with air traffic control facilties for test purposes, participation of SAM units for test purposes, and others. The extent to which these are required during the test program should also be indicated by review of a method of analysis for each objective. Again, it is important that the requirements in this area be understood and established well in advance so that the people who must provide the support have an opportunity to plan for it adequately.

TEST RESULTS

The application of test results is an important part of planning an efficient test program. First of all, it may be determined that the results of some particular test are not applicable. If possible, this should be determined before the test is conducted. Second, preplanning the application of the results should decrease the elapsed time between the conduct of a test and the correction of a deficiency, if any. For example, with a test of radar registration, a test may be planned well, conducted, the errors measured, and the existence of a significant separation, due to a faulty site location parameter, discovered. Thus far the program has proceeded in accordance with the plan. Obviously, the next step is to determine the correct parameter and insert it into the appropriate computers. There should be a plan for accomplishing this as a part of the test program so that as soon as the error is determined, the correction can be implemented. Similarly, if a large amount of information is

obtained on the performance of the system in various functions, the information should be provided in a consolidated and useful fashion to the operator personnel who might benefit from understanding the system capabilities. The information will not be of much use if it is retained, say, only in a contractor's files. A plan for compilation and distribution of the test information in a useful way well in advance is an important part of a test program.

PHASING PLAN

Finally, the test plan should include relative schedule or phasing information which indicates the scope of effort and extent of resources required throughout the test program. This should be done even if at the time of preparation the starting date of implementation is not known. The schedule should be based on an examination of each of the test objectives, on the amount of personnel and other resources available in the test program, on a certain expectation of failure (particularly in the early phases), a certain elapsed time for correction of deficiencies uncovered, a reasonable expectation of availability of operational facilities, and a reasonable rate of aircraft support. The last items must consider other aircraft obligations, aircraft abort rates, and the likelihood of simultaneous availability of both the aircraft and the ground environment under test.

Determination of the phasing and the resources required is likely to reveal that the total test effort is quite large. Adequate personnel and other resources to accomplish the effort will likely be available only if the requirements are known well in advance of the need. A well-coordinated, well thought out realistic schedule can have major benefits in the efficient use of personnel and other resources and can, consequently, save time and money and increase total confidence in the system.

SECTION III

CONCLUDING REMARKS

Ideally, test planning is a part of the total system design. The system design should be directed to yield the desired performance. The latter should be specified in such a way that one can determine whether or not it has been achieved. Thus, the specific test objectives are basically constructed. The test instrumentation is often an integral part of the operational system equipment and program. It needs to be treated as part of the total system design considering access to essential data, the large overlap with system training requirements, and the needs of operational exercises.

This program has been discussed in terms of implementation testing mostly from a testing point of view. The intent is not to suggest that testing should be done just for its own sake. In fact, unless it can be demonstrated how results of a test are going to be useful to the system, the test should not be conducted. In a sense, the testing described is, in fact, the implementation of the system. Designing a program of this sort in advance is a way of ensuring and accomplishing the successful implementation of the system in the field, at each location where its components are installed.

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