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SAMSO-TR-68-63

AD827975

09365-6004-R0-00

Final Technical Report

(U) TEST PLANNING FOR IN-PLACE HARDNESS DEMONSTRATION

Volume II
METHODOLOGY

Air Force Contract F04694-67-C-0134

Prepared By
TRW Systems Group
Redondo Beach, California

15 February 1968

Prepared For
Department of the Air Force
Headquarters, Space and Missiles Systems Organization
SMNP-1
Air Force Systems Command
Norton Air Force Base, California

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UNCLASSIFIED ABSTRACT

This study has developed a test program plan for demonstrating the in-place hardness of an advanced ballistic missile weapon system. A test requirements analysis methodology was devised, utilizing a systems approach, to examine a WS-120A system baseline design with respect to a given weapons effects environment criteria, define the testing required to assure hardness of each system element, trade off applicable simulation techniques, and recommend a series of test concepts. These concepts were then logically combined into efficient and cost-effective in-place hardness demonstration test programs for the launch facility and launch control facility.

This report has been divided into five volumes and classified as follows:

Volume I	Study Report Summary (Unclassified)
Volume II	Methodology (Unclassified)
Volume III	Test Requirements Analysis (Secret, RD)
Volume IV	Test Program Plan (Unclassified)
Volume V	Selected LF Subsystems Test Plan (Unclassified)

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FOREWORD

(U) This document is the final technical report of the Test Planning for In-Place Hardness Demonstration Study submitted to SAMSO/NAFB in January 1968. This study was conducted by the Systems Support Group, Science and Technology Department of TRW Systems Group, Redondo Beach, California, for the Space and Missile Systems Organization, Air Force Systems Command, Norton Air Force Base, California, under Contract No. F04694-67-C-0134, dated 1 June 1967.

(U) The study effort covered by this report was initiated in June 1967 and completed in February 1968. The United States Air Force management control for this task was provided by Mr. C. B. Totten, SMNP-1. Technical direction was provided by Mr. S. Italia and Mr. C. R. Smith, Weapon Systems Division, Aerospace Corporation, San Bernardino Operation.

(U) Mr. C. K. Stein was TRW Systems Group's project engineer for this study and was responsible for attaining its overall objectives. Mr. J. P. Bednar (TRW) and Mr. J. Karagozian (consultant) were co-authors of the Final Technical Report.

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(U) This technical report has been reviewed and is approved.

Charles B. Totten

Charles B. Totten
Project Officer
Resources, Planning and Programming Division
Directorate of Civil Engineering

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1. INTRODUCTION

1.1 PURPOSE

The purpose of this Methodology Volume of the test planning for the In-Place Hardness Demonstration Technical Report is to describe the procedures used and the judgments made during the course of the study in the development of a test program plan. The procedures contained herein will enable the reader to follow and understand the pattern of evaluations made and the considerations used in evolving each individual test in the total spectrum of recommended testing.

1.2 SCOPE

The methodology described in this volume was developed during the test planning for the In-Place Hardness Demonstration Study and was used with a proposed WS-120A system design baseline and weapons effects environment criteria. The methodology was developed to be insensitive to changes in the baseline design and the weapons effects environment criteria so that normal program changes could be introduced without loss of continuity or effectiveness of the overall test requirements analysis. Although the methodology was developed for in-place hardness testing, it could be used effectively for airborne hardness test planning, and, with some modifications, it would be a valuable tool for use in the preparation of system development test program plans for any type of complex system. The methodology described herein, implemented, becomes the test requirements analysis.

1.3 IN-PLACE HARDNESS DEMONSTRATION TEST PLANNING PHILOSOPHY

The philosophy applied to this test planning study includes the following basic elements:

a) Plan to test throughout the weapon system development cycle, but with emphasis on the early stages, so that hardness is assured prior to system deployment

b) Utilize a systems approach to examine the total weapon system in the overall weapons effects environment

c) Plan to conduct many relatively simple tests and supplement them with a few complex (and costly) ones

d) Plan a series of interrelated tests in which the cumulative results will build confidence in hardness as the series progresses until completion, at which time confidence in hardness is as high as it can be without the benefit of atmospheric nuclear tests.

In-place hardness demonstration tests are considered to be those tests that confirm or provide data that increases confidence in the hardness of the system element tested. These tests will normally utilize prototype systems as test articles. However, in some cases it may be necessary to require testing that is more in the nature of development testing (using subscale models, engineering models, etc.). Development testing will be called for only in the event that it is a necessary prerequisite to a subsequent demonstration test.

The in-place hardness of a system can be demonstrated to some degree at every stage of the system development cycle. With careful and early planning, a spectrum of testing can be identified that will assure hardness of certain elements very early in the development stage, thus providing a strong data base upon which to design (or redesign, if necessary) interacting system elements. Examination of the total system piece by piece will allow the identification of system elements that lend themselves to early testing. It will also identify those systems that are more complex and, thus, would more logically be tested later in the development program. The hardness demonstration tests can follow much the same pattern as system development tests; that is, to evaluate the system elements in their simplest form first; then, as the components are combined, more complex testing is conducted. This method provides a test data base that accumulates as each test is conducted until hardness is assured. It also provides an inherent insensitivity to design changes in that the redesigned components or subsystems may be re-evaluated with simple tests rather than requiring retesting of a large complex system to assure hardness.

The basic philosophy discussed here is reflected in Figure 1-1 and in the detailed methodology discussions presented in the following sections. It must be emphasized that the Hardness Demonstration Test Program as depicted in Figure 1-1 is the summation of sequential tests on subsystems up to the complete facility, and no one test demonstrates hardness completely.

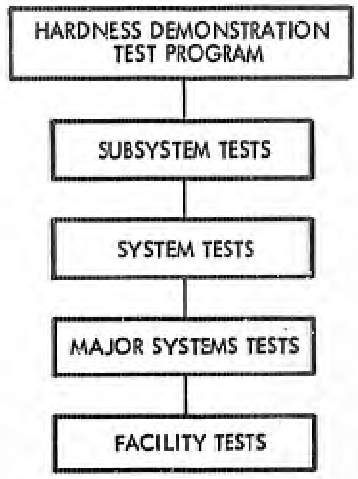

Figure 1-1. Summation of Sequential Tests

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2. SYSTEM DESCRIPTION

The first task to be accomplished in the test requirements analysis is the definition and description of the system under study. It is important that the system be described in a manner that is simple, clear, and concise, since all subsequent tasks will be accomplished with reference to the system elements defined here.

2.1 ESTABLISHMENT OF THE SYSTEM BASELINE CONFIGURATION

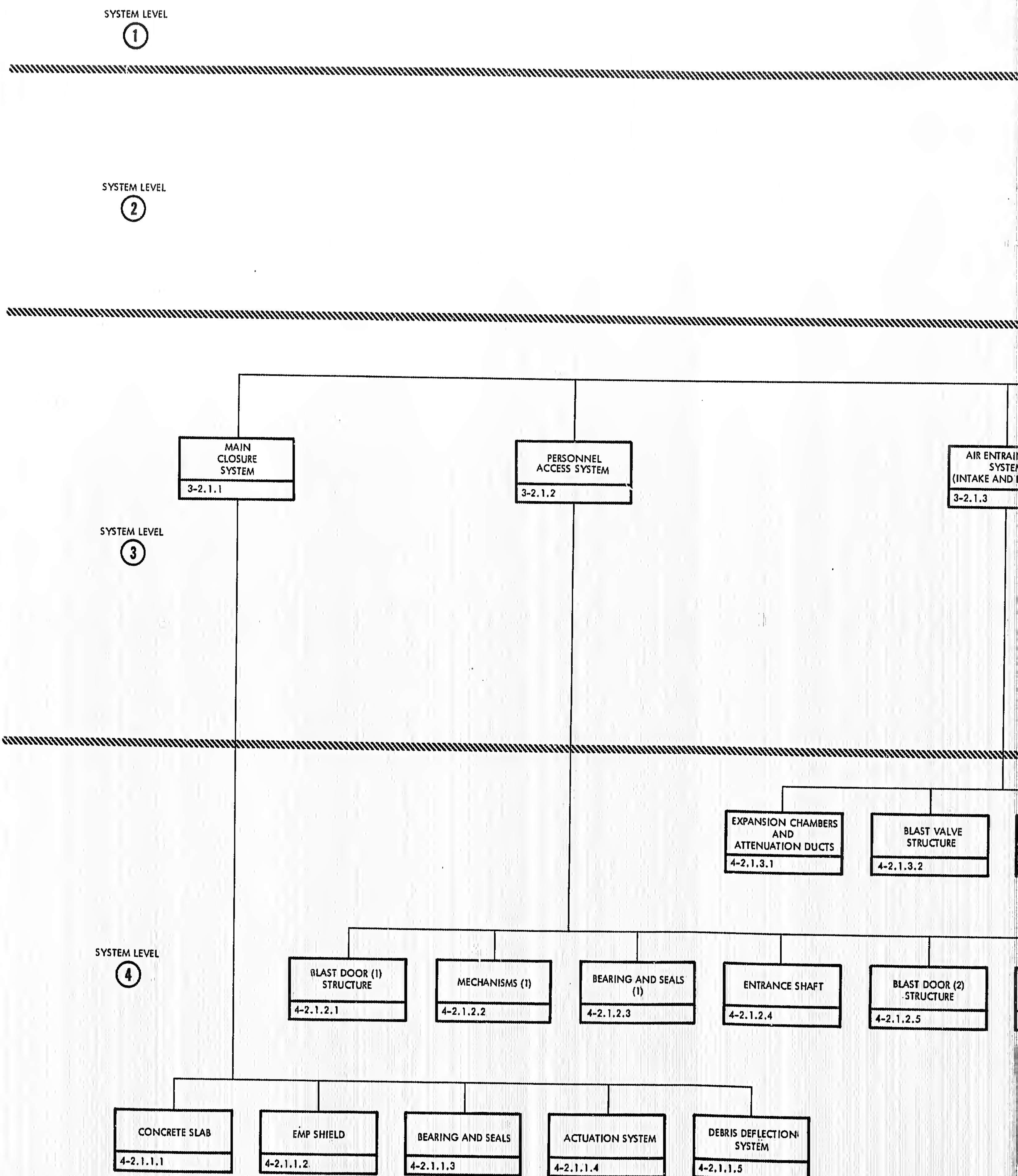
The baseline configuration of the system that is presented as a study input may lack the detail required to conduct a successful test requirements analysis. Therefore, assumptions based on past experience with similarly configured weapons systems must be made to supplement the given baseline data. These assumptions are usually made to identify the subsystems or components of a given system.

The system description must also identify just those system elements that are meaningful or critical to the hardness and vulnerability problem. These elements will either be the missile and launch essential equipments that are sensitive to an attenuated weapons effects environment, or the elements that are functional in protecting the sensitive system elements from the free field weapons effects environment.

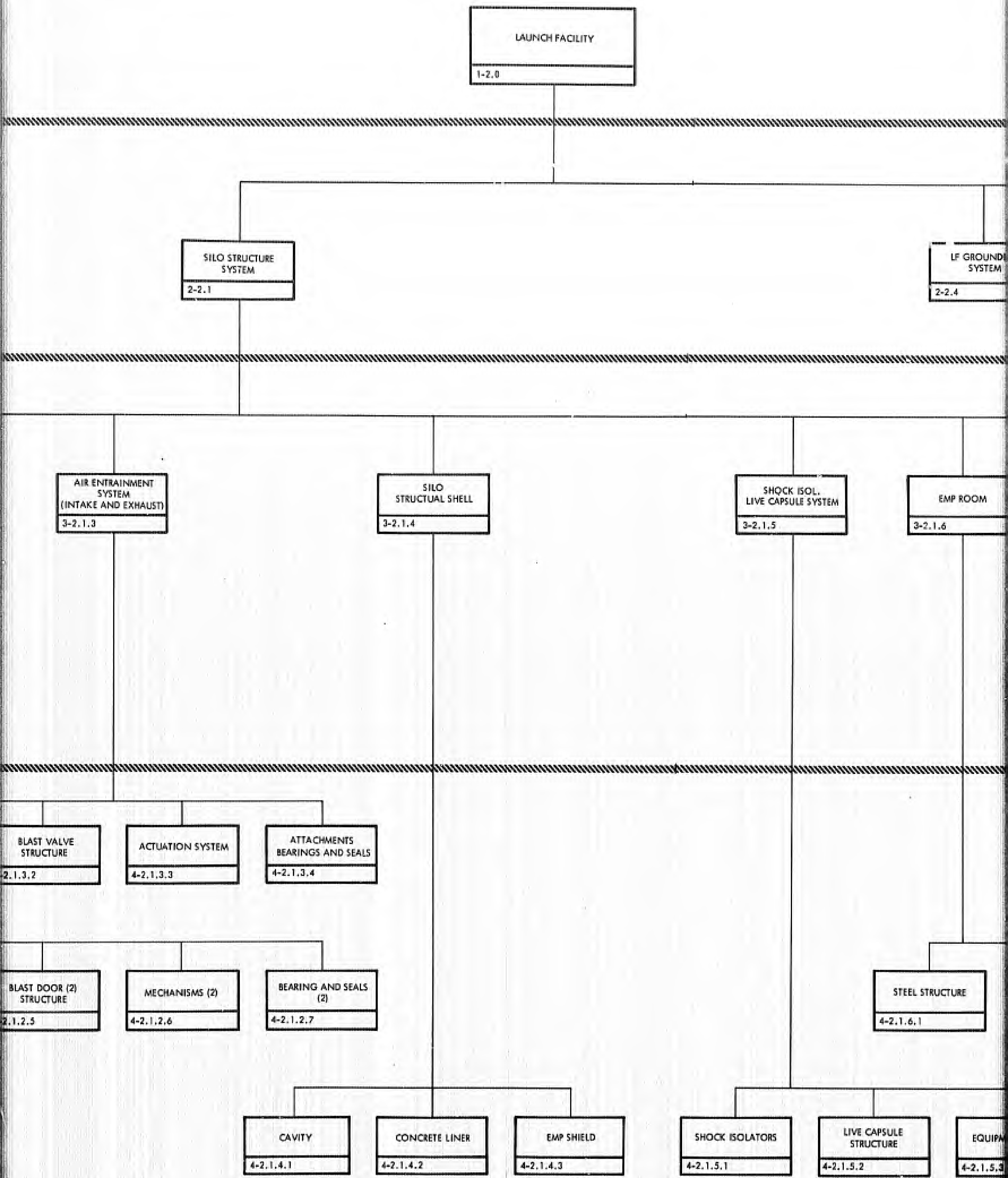
2.2 SYSTEM LEVEL ORIENTATION

In order to permit a complete examination of all elements of the weapon system, a breakdown of the system must be made. The approach taken in this study was to identify the most complex system (a complete facility) as System Level 1 (see Figure 2-1); system elements of lesser complexity that comprise the complete system are System Level 2; subsystems relating to these system elements are System Level 3; and, for purposes of this study, the least complex system elements or components are identified as System Level 4. The system elements are identified in blocks (in Figure 2-1) by name and number. Consistency in numbering the blocks is important since they become the basic referencing tool throughout the study.

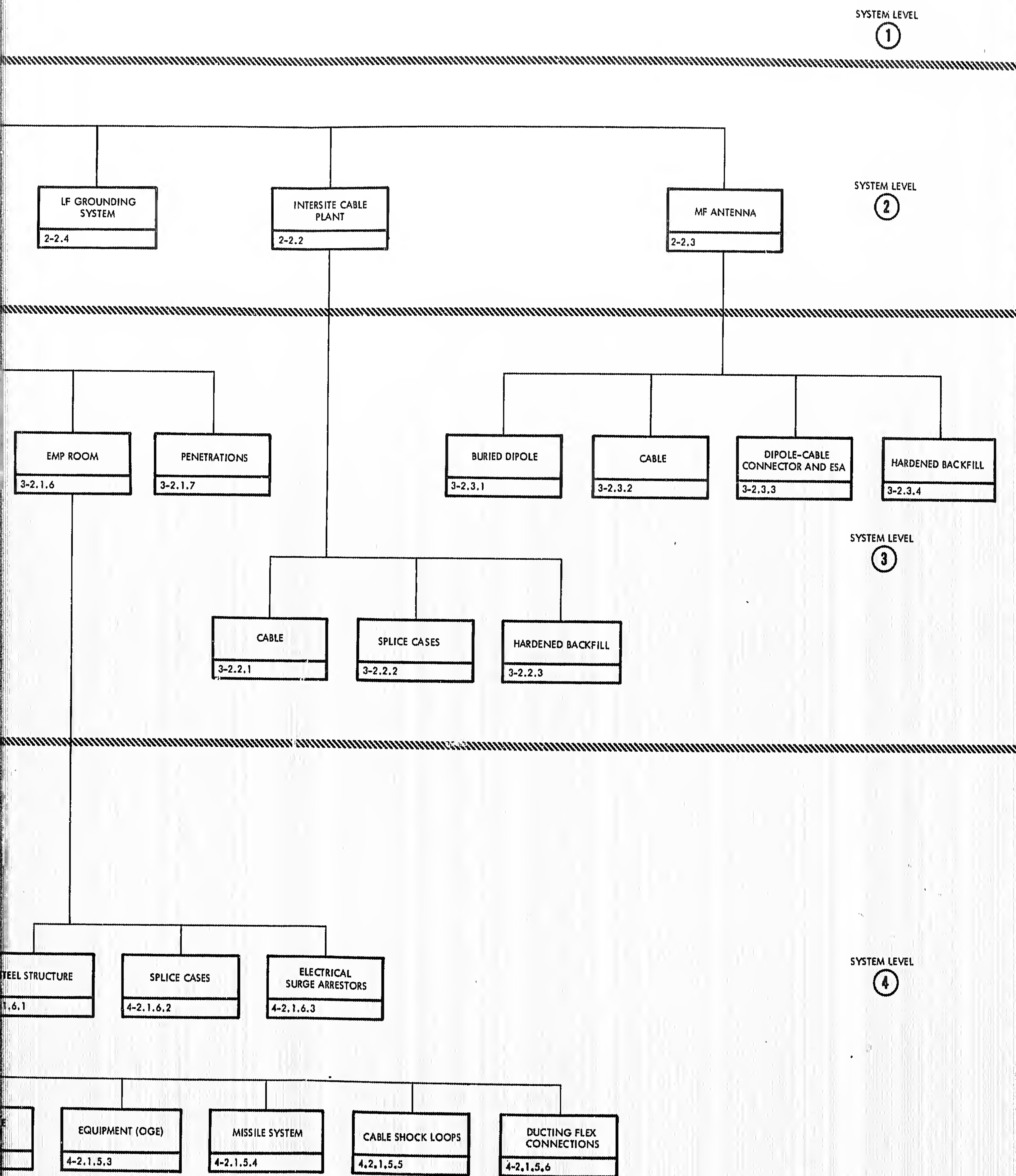
Figure 2-1 represents a typical breakdown and identification of a system configuration. The numbering consistency is evident in that the first number in each block represents the system level number, while numbers following the hyphen represent the system, subsystem, or component.


SYSTEM LEVEL 1
SYSTEM LEVEL 2
SYSTEM LEVEL 3
SYSTEM LEVEL 4
MAIN CLOSURE SYSTEM 3-2.1.1
PERSONNEL ACCESS SYSTEM 3-2.1.2
AIR ENTRAIN SYSTEM (INTAKE AND E 3-2.1.3
EXPANSION CHAMBERS AND ATTENUATION DUCTS 4-2.1.3.1
BLAST VALVE STRUCTURE 4-2.1.3.2
BLAST DOOR (1) STRUCTURE 4-2.1.2.1
MECHANISMS (1) 4-2.1.2.2
BEARING AND SEALS (1) 4-2.1.2.3
ENTRANCE SHAFT 4-2.1.2.4
BLAST DOOR (2) STRUCTURE 4-2.1.2.5
CONCRETE SLAB 4-2.1.1.1
EMP SHIELD 4-2.1.1.2
BEARING AND SEALS 4-2.1.1.3
ACTUATION SYSTEM 4-2.1.1.4
DEBRIS DEFLECTION SYSTEM 4-2.1.1.5

A.


LAUNCH FACILITY
1-2.0
SILO STRUCTURE SYSTEM
2-2.1
LF GROUND
SYSTEM
2-2.4
AIR ENTRAINMENT SYSTEM (INTAKE AND EXHAUST)
3-2.1.3
SILO STRUCTUAL SHELL
3-2.1.4
SHOCK ISOL. LIVE CAPSULE SYSTEM
3-2.1.5
EMP ROOM
3-2.1.6
BLAST VALVE STRUCTURE
2.1.3.2
ACTUATION SYSTEM
4-2.1.3.3
ATTACHMENTS BEARINGS AND SEALS
4-2.1.3.4
BLAST DOOR (2) STRUCTURE
2.1.2.5
MECHANISMS (2)
4-2.1.2.6
BEARING AND SEALS (2)
4-2.1.2.7
STEEL STRUCTURE
4-2.1.6.1
CAVITY
4-2.1.4.1
CONCRETE LINER
4-2.1.4.2
EMP SHIELD
4-2.1.4.3
SHOCK ISOLATORS
4-2.1.5.1
LIVE CAPSULE STRUCTURE
4-2.1.5.2
EQUIP
4-2.1.5.3

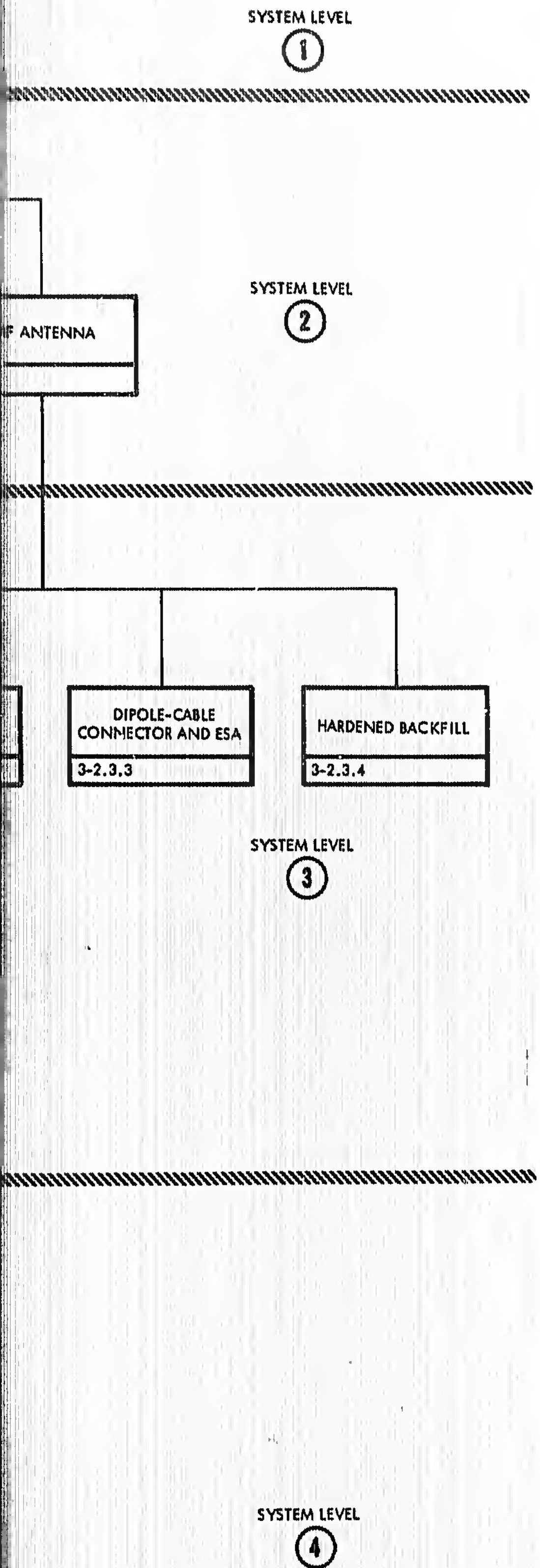
B.



SYSTEM LEVEL 1
SYSTEM LEVEL 2
LF GROUNDING SYSTEM
2-2.4
INTERSITE CABLE PLANT
2-2.2
MF ANTENNA
2-2.3
EMP ROOM
3-2.1.6
PENETRATIONS
3-2.1.7
BURIED DIPOLE
3-2.3.1
CABLE
3-2.3.2
DIPOLE-CABLE CONNECTOR AND ESA
3-2.3.3
HARDENED BACKFILL
3-2.3.4
SYSTEM LEVEL 3
CABLE
3-2.2.1
SPLICE CASES
3-2.2.2
HARDENED BACKFILL
3-2.2.3
TEEL STRUCTURE
1.6.1
SPLICE CASES
4-2.1.6.2
ELECTRICAL SURGE ARRESTORS
4-2.1.6.3
SYSTEM LEVEL 4
EQUIPMENT (OGE)
4-2.1.5.3
MISSILE SYSTEM
4-2.1.5.4
CABLE SHOCK LOOPS
4.2.1.5.5
DUCTING FLEX CONNECTIONS
4-2.1.5.6

C.

LAUNCH FACILITY SYSTEM CONFIGURATION



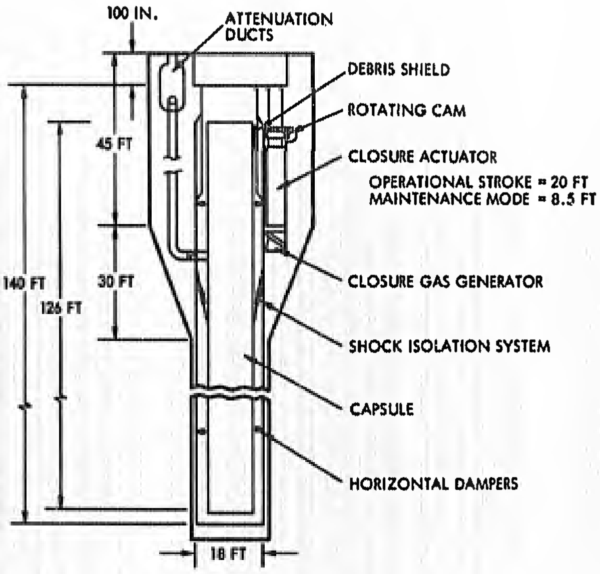


Figure 2-1.

D.

3. WEAPONS EFFECTS ENVIRONMENT CRITICAL PATH

Once the system has been defined in terms of critical system elements, the weapons effects environments to which each of the system elements will be exposed must be identified. The method used here is simply to depict graphically the route or critical path that each weapons effect (air blast, nuclear radiation, EMP, etc.) will follow as it impinges and/or penetrates the protective elements of the system to the sensitive internal systems (see Figure 3-1).

3.1 SYSTEM ELEMENT REORIENTATION

The first task is the orientation of the system element blocks identified in the system configuration (Figure 2-1) in a manner that reflects the facility physical geometry with respect to the order in which the elements experience the weapons effects. The elements exposed to the free field environment appear at the top of the chart, with the other elements arranged under them in order of depth and protection. The most sensitive systems (the missile and launch essential OGE) are shown at the bottom of the chart.

3.2 WEAPONS EFFECTS ENVIRONMENT APPLICATION

Each weapons effects environment is applied individually to the chart, with the weapons effect criteria level environment (free field environment) represented by a solid line. The solid line begins at the System Level 1 block, continuing through the applicable System Level 2 and 3 blocks, to the System Level 4 block. The path that the weapons effects take through the blocks is called the critical path. As the environment encounters a system element that is functional in protecting against that environment, attenuation of the effect occurs. This is represented by a dashed line coming from the functional system element. Should the system element attenuate the environment to the allowable internal level, it is represented by a dotted line. Interaction of subsystem elements can also be represented by a cross-hatched line. The process of drawing the critical path through the system requires a knowledge of the system and the protective or functional capabilities of each of the system elements, as well as a familiarity with each of the weapons effects environments and their characteristics.

3.3 WEAPONS EFFECTS INPUT MAGNITUDE

The weapons effects input level can be represented graphically with solid or dotted lines in most cases. However, at some points in the critical path it is desirable to note the attenuated input magnitude for use in the later stages of the test requirements analysis to determine applicability of a simulation technique. These values need not be computed to a great degree of accuracy but must only give a good indication of the type and magnitude of the weapons effects at the point desired.

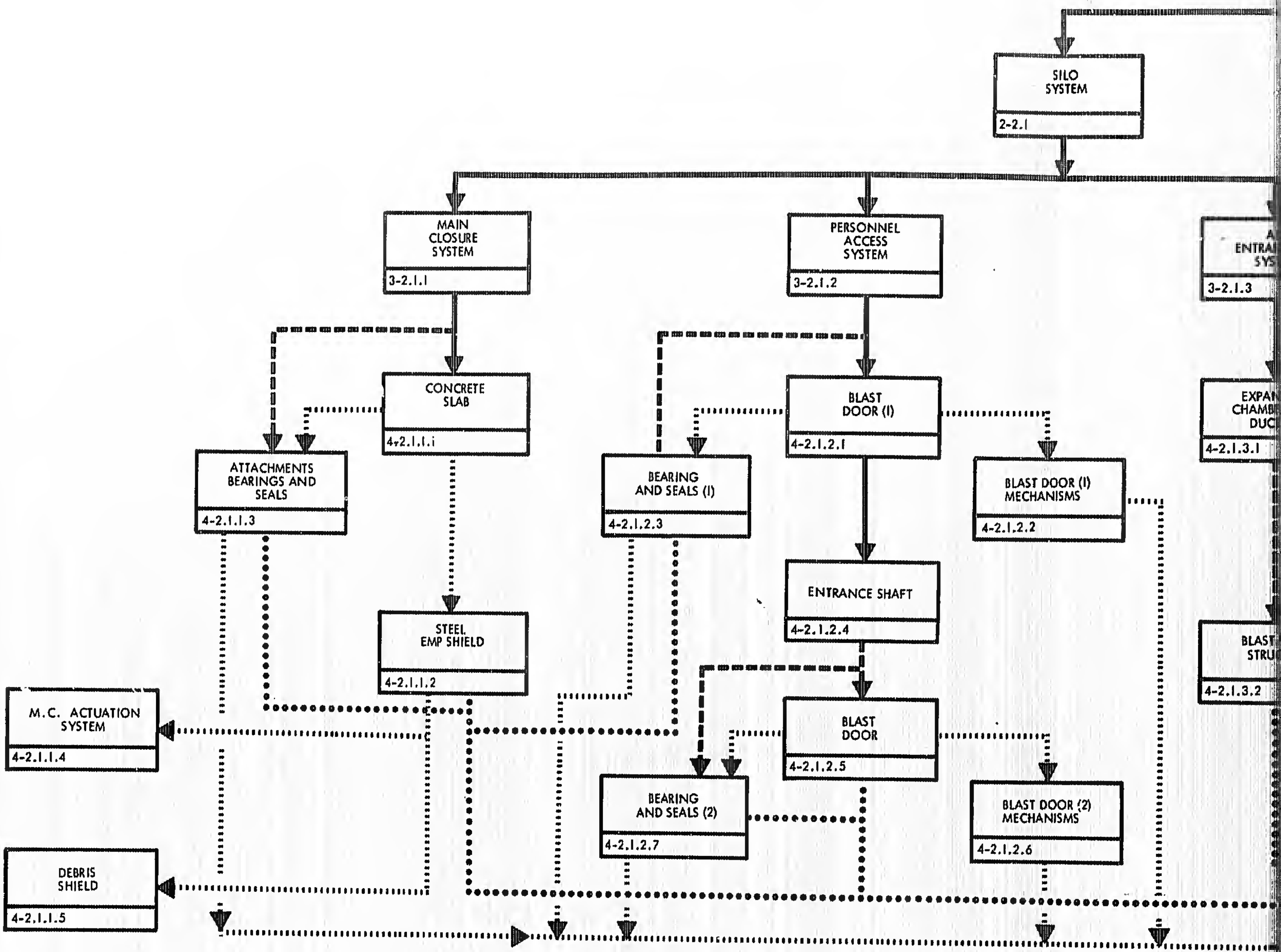
The input levels may also be represented as

Level 1: Weapons effects criteria level (the free field magnitudes defined by criteria)

Level 2: Attenuated (the free field magnitudes attenuated due to the reaction of an intermediate facility system)

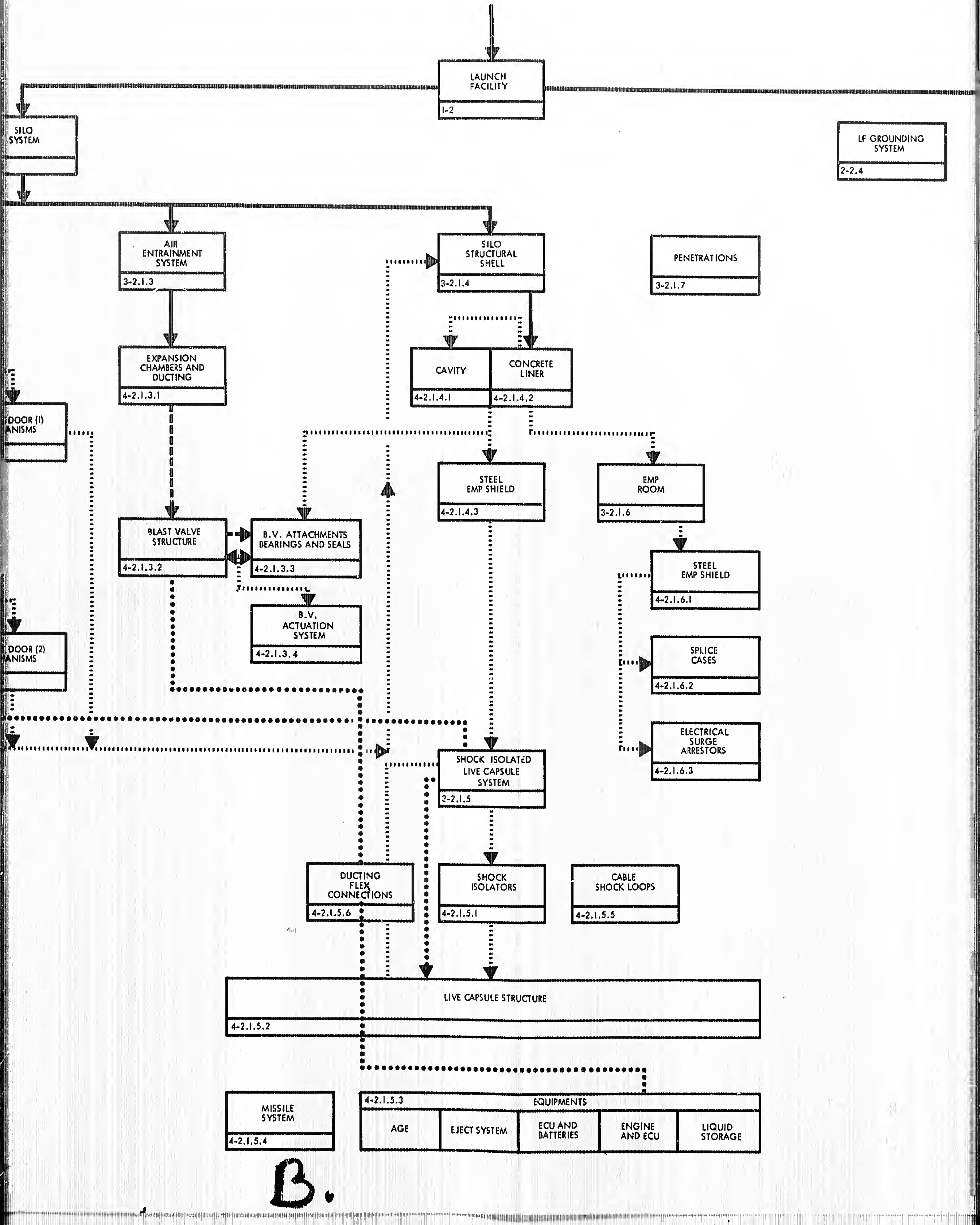
Level 3: Internal allowable (allowable magnitudes for launch equipments or components).

The input level and type will be summarized for each system element at the point in the test requirements analysis when each element is examined with respect to the environment it encounters. This occurs during the recommendation to test evaluation process (see Section 4).

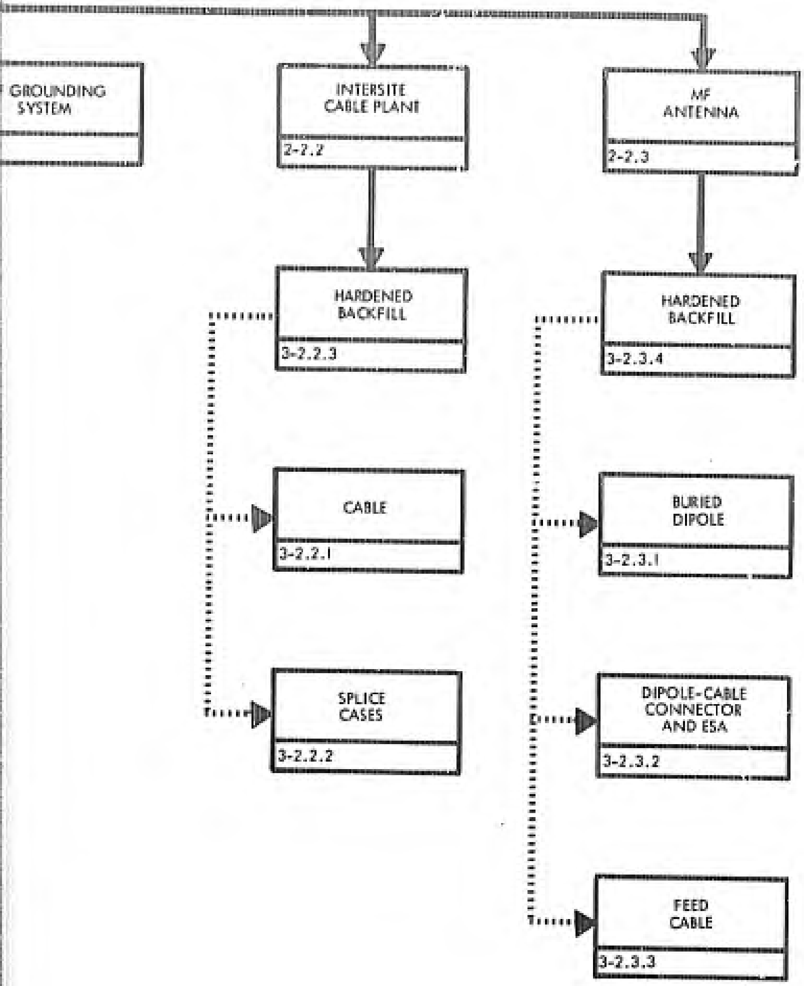


SILO SYSTEM
2-2.1
MAIN CLOSURE SYSTEM
3-2.1.1
PERSONNEL ACCESS SYSTEM
3-2.1.2
3-2.1.3
CONCRETE SLAB
4-2.1.1.1
BLAST DOOR (1)
4-2.1.2.1
EXPAN
4-2.1.3.1
ATTACHMENTS BEARINGS AND SEALS
4-2.1.1.3
BEARING AND SEALS (1)
4-2.1.2.3
BLAST DOOR (1) MECHANISMS
4-2.1.2.2
ENTRANCE SHAFT
4-2.1.2.4
STEEL EMP SHIELD
4-2.1.1.2
4-2.1.3.2
M.C. ACTUATION SYSTEM
4-2.1.1.4
BLAST DOOR
4-2.1.2.5
BEARING AND SEALS (2)
4-2.1.2.7
BLAST DOOR (2) MECHANISMS
4-2.1.2.6
DEBRIS SHIELD
4-2.1.1.5

A.


LAUNCH FACILITY
1-2
SILO SYSTEM
LF GROUNDING SYSTEM
2-2.4
AIR ENTRAINMENT SYSTEM
3-2.1.3
SILO STRUCTURAL SHELL
3-2.1.4
PENETRATIONS
3-2.1.7
EXPANSION CHAMBERS AND DUCTING
4-2.1.3.1
CAVITY
4-2.1.4.1
CONCRETE LINER
4-2.1.4.2
DOOR (1) ANISMS
STEEL EMP SHIELD
4-2.1.4.3
EMP ROOM
3-2.1.6
BLAST VALVE STRUCTURE
4-2.1.3.2
B.V. ATTACHMENTS BEARINGS AND SEALS
4-2.1.3.3
STEEL EMP SHIELD
4-2.1.6.1
B.V. ACTUATION SYSTEM
4-2.1.3.4
DOOR (2) ANISMS
SPLICE CASES
4-2.1.6.2
ELECTRICAL SURGE ARRESTORS
4-2.1.6.3
SHOCK ISOLATED LIVE CAPSULE SYSTEM
3-2.1.5
DUCTING FLEX CONNECTIONS
4-2.1.5.6
SHOCK ISOLATORS
4-2.1.5.1
CABLE SHOCK LOOPS
4-2.1.5.5
LIVE CAPSULE STRUCTURE
4-2.1.5.2
MISSILE SYSTEM
4-2.1.5.4
4-2.1.5.3
EQUIPMENTS
AGE
EJECT SYSTEM
ECU AND BATTERIES
ENGINE AND ECU
LIQUID STORAGE
B.

LAUNCH FACILITY WEAPON
ENVIRONMENT CRITICAL



AIR OVERPRESSURE

W.E. ENVIRONMENTAL CRITERIA L

ATTENUATED

ALLOWABLE LEVEL

BLAST INDUCED REACTION

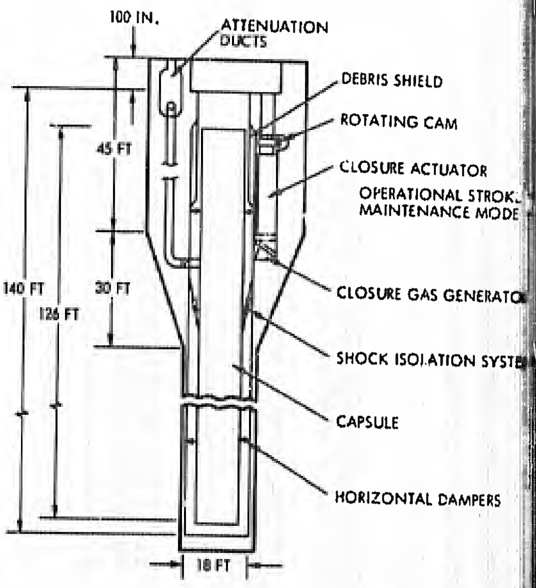
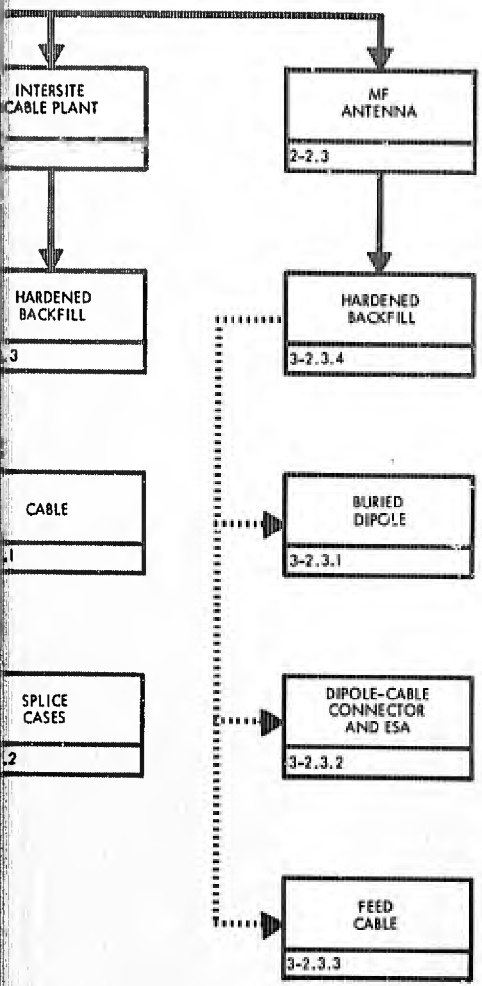


Figure 3-1



LAUNCH FACILITY WEAPONS EFFECTS ENVIRONMENT CRITICAL PATH

AIR OVERPRESSURE

W.E. ENVIRONMENTAL CRITERIA LEVEL

ATTENUATED

ALLOWABLE LEVEL

BLAST INDUCED REACTION

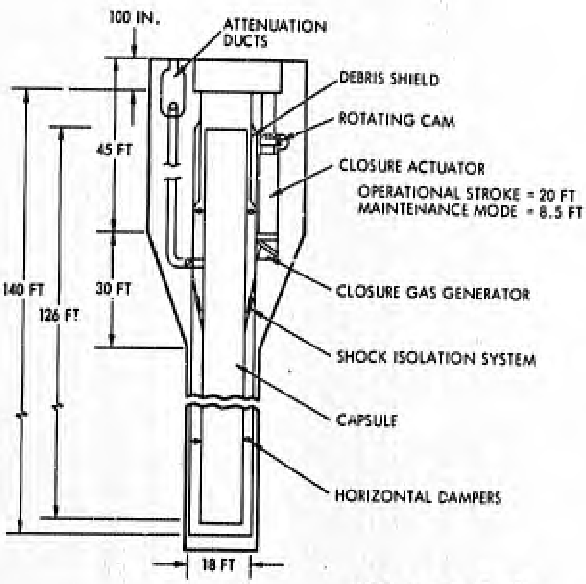


Figure 3-1.

4. RECOMMENDATION TO TEST

The recommendation to test evaluation is performed for each major component in the system which is exposed to one or more of the weapons effects environments. Test requirements, methods, and simulation techniques are not considered in this initial evaluation. The basic question to be answered at this point is the following:

> Is a test necessary and beneficial to demonstrate hardness of the component in its final installed condition?

Some general knowledge about the systems and subsystems and input loading is needed to answer this question. The more we know about the characteristics of the system for the specified inputs enables us to make a good judgment for the need to test. The following subsections describe the systematic method used for this evaluation.

4.1 SUBSYSTEM AND SYSTEM COMBINATION OF THE VARIOUS LEVELS

In Section 2 the facility is described as a group of systems and subsystems which are the major parts of the hardened operational facility. In general, each system or subsystem has an important function for the load path of one or more of the weapons effects critical environments. The particular launch facility (LF) and launch control facility (LCF) used for the preparation of the hardness demonstration test evaluation in this study were defined to four subsystem levels as described in Section 2.

The consideration for testing is started at the smallest subsystem level and combinations thereof which are parts of a major system. This is illustrated in Figure 4-1.

A closure system (Level 3) has five major parts (Level 4 subsystems), as noted by the blocks in the column on the left margin of the figure. Each of these blocks (components) is considered for testing. Subsystems which have strong physical interaction or reaction are combined as shown in Figure 4-1 and are also considered for testing. It is obvious at this point that a system configuration concept is conceived, and components must be assumed to mate in a specific manner.

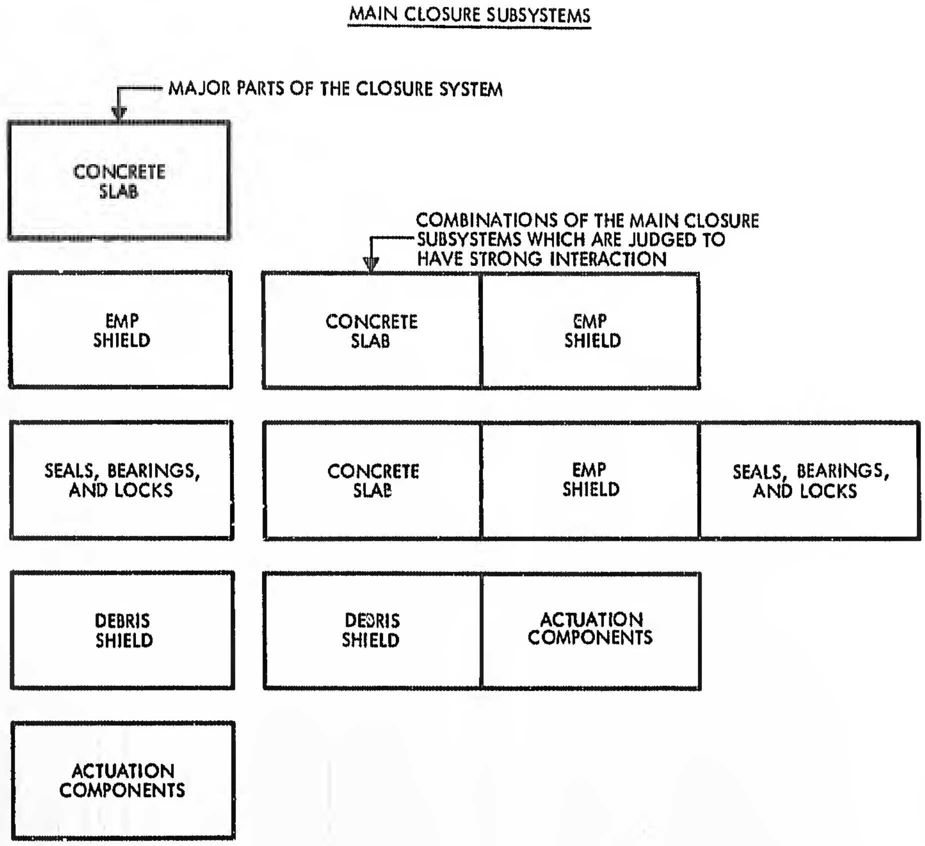


Figure 4-1. Subsystem Combinations

There may be cases where a Level 4 component from one system may have strong interaction with a component from another system. These conditions are also considered for testing as demonstrated in the recommendation for test evaluation in Volume III.

The procedure continues at the higher levels after all the lower subsystems have been considered. Each higher level system is evaluated separately and in combination with other systems with strong interaction. This is illustrated in Figure 4-2.

After all systems are evaluated at the above intermediate levels, the main systems and total system are considered for testing. For the systems shown in Figure 4-3, there is only weak interaction between main systems so that combinations are not considered other than the complete facility. However, the LCF facility does have major systems with varying degrees of interaction at this level, and combinations are considered for testing. Major systems with weak interaction (such as the LF structure) demonstrate a more compact design concept which may have an inherent advantage in demonstrating hardness.

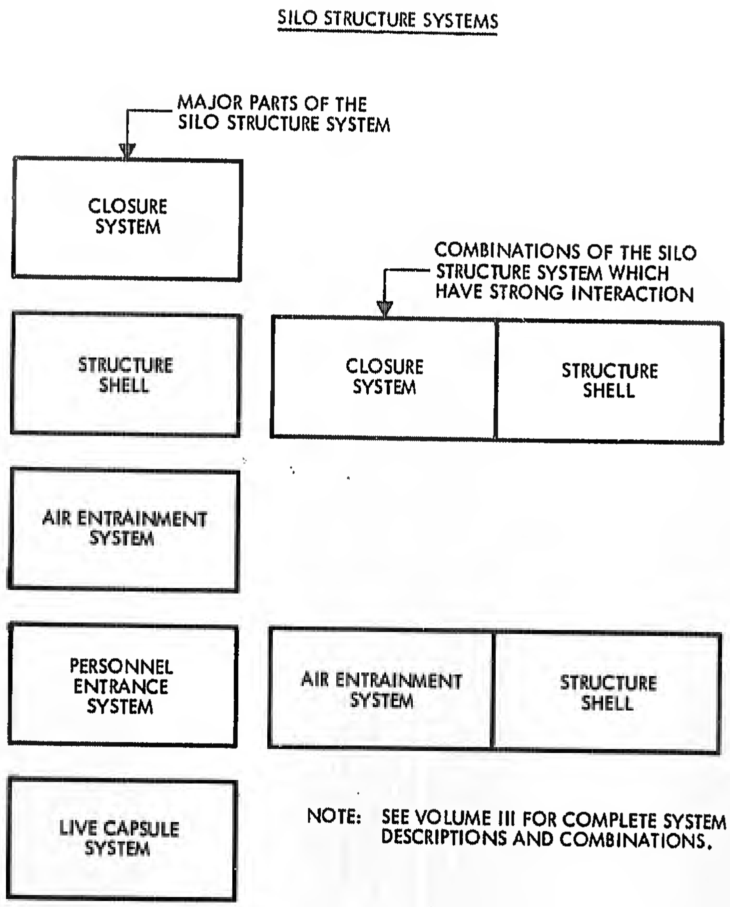


Figure 4-2. S[illegible]em Combinations

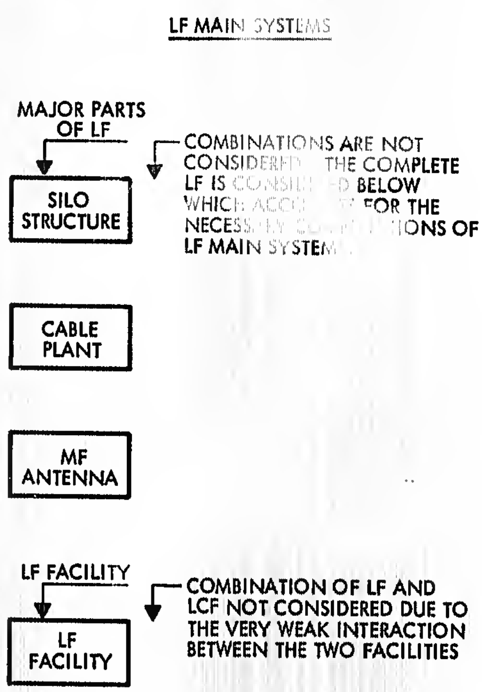


Figure 4-3. Major System Combinations

4.2 INPUT CONDITIONS

The input loads due to weapons effects are distinguished as seven separate effects which are defined in the so-called free field as critical for design. The free field refers to the free air environment above the structure location or in the ground medium adjacent to the structure. Section 3 describes the load path and approximate peak magnitudes through each of the critical systems. The range of the input load magnitudes is considered at this stage of the evaluation only in an approximate manner to support the judgment for consideration of testing.

Three input levels are defined:

- Level 1: Free field magnitudes defined by criteria
- Level 2: Free field magnitude attenuated due to the reaction of an intermediate facility system
- Level 3: Allowable magnitudes for launch equipments or components.

When a test is required only to support analysis or to verify reaction loads, this is so indicated in the evaluation. Simultaneity of effects is not considered at this phase of the evaluation.

4.3 CONSIDERATIONS LEADING TO RECOMMENDATION TO TEST

For each system and subsystem a recommendation to test is made if there is a positive (yes) answer to a group of considerations. If a negative (no) answer is made for any one consideration, then a test at that system or subsystem level is not recommended. The four considerations are explained in the following paragraphs.

4.3.1 Negligible Interaction Effects

A subsystem or system may have a strong or weak interaction with other subsystems for a particular load environment which normally dictates the significance of interaction effects. If a system response is dependent upon the composite connection with other systems, then significant interaction exists, and a test at this system level is not beneficial for hardness demonstration. There will be cases where subsystems have strong interaction links, but the load across the link can be estimated by analysis or test. In this case, a meaningful test can be performed where the load input point is the attachment point to other subsystems.

Consequently, negligible interaction generally exists when the system can be modeled to a noncomposite system with other systems.

4.3.2 Low Confidence in Analysis

There are three basic factors in analyses which may lead to a low confidence in analysis.

1) The mathematical model is very complex, and there is very little experience with the model. When a complex inelastic continuous system is modeled by a mathematical discrete elastic, viscoelastic, or elastic plastic system, the adequacy of the model must be verified by test.

2) Theoretical characteristics of materials in the installed configuration are indeterminate. Material behavior characteristics are very indeterminate for the postulated load magnitudes (e.g., high pressure, high thermal and nuclear radiation). Also, laboratory test reported data will in general be nonapplicable for the installed conditions.

3) Large probable errors in response analysis due to approximations or numerical techniques to obtain the solution. Most complex analyses require numerical techniques for solution. Solution errors exist, and, depending on the complexity of the problem, the solution error may or may not be significant.

A low confidence in analysis may be due to one or more of the above considerations and is so indicated in the evaluation. A high confidence in analysis exists for systems where conventional analytical techniques have been shown to correlate with test results either in basic laboratory experiments or during analyses and tests of prior weapons system components (i.e., Minuteman, Titan, and Atlas).

4.3.3 Test Cannot be Performed at Lower Subsystem Level

The test program as described herein is initiated at the lowest subsystem level. In some cases a test of a subsystem for the specified environment will qualify the complete system hardness. In other words, part of the system is nonresponsive or noneffective for the specified loading. Therefore, testing would not be recommended if the system could be qualified by testing a subsystem (i.e., a lower level subsystem). Testing is recommended when the system consisting of a combination of subsystems gives a new or additional responsive phenomenon which can only be determined by testing at the particular level in question.

4.3.4 Test Will Increase Confidence in Hardness

A final factor which is considered in the recommendation to test is the degree to which a test will increase confidence in hardness. The response of the system must be meaningful and capable of interpretation for hardness assessment. If not, a system test would not increase confidence in hardness, and consequently a test would not be recommended.

4.4 PROCEDURES

The foregoing considerations (Subsections 4.1 through 4.3) are summarized in matrix form for a simplified evaluation. Figure 4-4 shows the format and notes the judgment required under each column. An example is given at the bottom.

RECOMMENDATION TO TEST

SYSTEM	INPUT SUMMARY: AIR BLAST	GROUND STRESS	GR. MOTION/ A.B. REACTION	NUCLEAR RADIATION	THERMAL RADIATION	EMP	DEBRIS	CONSIDERATIONS: NEGLIGIBLE INTERACTION EFFECTS	LOW CONFIDENCE IN ANALYSIS	TEST CANNOT BE PERFORMED AT LOWER SUBSYSTEM LEVEL	TEST WILL INCREASE CONFIDENCE IN HARDNESS	TEST IS RECOMMENDED	REMARKS
Number and name from figure ________.													
EXAMPLE:													
4-2.1.5.1			2					Yes	Yes (2)	Yes	Yes	Yes	
Shock Isolator				3				Yes	No	Yes	No	No	
Elements					3			Yes	No	Yes	No	No	

*CRITERIA FOR LOW CONFIDENCE IN ANALYSIS

1. The mathematical model is very complex; very little experience with the required model.
2. Theoretical characteristics of materials in the installed configuration are indeterminate.
3. Large probable errors in response analysis due to approximations or numerical techniques to obtain solution.

Weapon Effects which affect component response. Three levels are indicated:

Level 1: Criteria Level Unattenuated
Level 2: Criteria Level Attenuated
Level 3: Allowable

A yes judgment denotes that system can be tested independent of other systems and produce a meaningful test for hardness demonstration.

A yes judgment denotes that there are many uncertainties in the analysis. A number in parenthesis following a yes indicates the criteria for low confidence in analysis.*

A yes judgment denotes that a test (or tests) at a lower level cannot demonstrate in-place hardness.

A yes judgment denotes that a test at this level will increase confidence in hardness.

A yes decision is made when all four judgments to the left are yes. If a no judgment exists in any one column, a no decision is made.

Figure 4-4. Recommendation to Test Form

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5. TEST CONCEPT TRADEOFF MATRIX

In Sections 2 through 4 the facility is described as systems and subsystems exposed to the various weapons effects environment. Each subsystem and system up to the complete facility is examined for the need to test to demonstrate hardness. For each system that must be tested we now wish to establish test requirements, select combinations of test methods which will to some degree satisfy all the requirements, rate the relative validity and cost of simulation test techniques that satisfy the selected test methods, and finally arrive at a recommended test concept. The procedure for this tradeoff analysis is described in the following paragraphs.

5.1 TEST REQUIREMENTS

Test requirements are prepared for the complete group of systems starting at the lowest level (System Level 4) subsystem. At the lowest level the requirements will usually be basic, such as: determine response characteristics to verify the design analyses, determine failure mode and load which produces failure, or determine material or component characteristics so that complete hardness verification can be performed by analysis. As subsystems are combined, the system test requirements are now concerned with performance characteristics after the simulated weapons effects environment input relative to the preload performance characteristics. Finally, test requirements for groups of systems and the complete facility are written to determine operating integrity of launch-essential components and equipments during and after the critical load conditions.

Only preliminary general requirements can be established prior to the design phase. Prior experience on the Atlas, Titan, and Minuteman weapons systems provides valuable design, analytical, and test data which can be the basis for test requirements for the new system. In the preparation of test requirements for the LF and LCF facilities for this study, the TRW prior experience on the above-noted weapons systems was a major contributing influence.

5.2 TEST METHODS

Test methods are selected which satisfy one or more of the test requirements specified for a particular system. The number of test methods must be sufficient to satisfy all the requirements. In general, a number of test methods will be considered in various combinations so that a test concept can be selected on a quantitative basis. This can be described best by an example.

Consider the test methods for the shock isolator subsystem. The six requirements are

a) Determine isolator characteristics (static)

b) Determine isolator characteristics (dynamic)

c) Determine strains in isolator elements

d) Determine response of simulated mass

e) Determine acceleration response of simulated mass

f) Determine shock spectra of simulated mass (i.e., response of spring-mass elements attached to simulated mass).

Test methods are selected which satisfy one or more of the above requirements as follows:

1) Static pull and compression test

2) Dynamic pull and compression test

3) Total displacement, quick release, twang test

4) Impact shock test

5) Total displacement shock test.

Test method 1 will determine static load displacement behavior, requirement A. Test method 2 will determine dynamic load displacement characteristics, requirement B. Test methods 3 and 5 will satisfy requirements C through F to varying degrees, and test method 4 will satisfy requirements E and F. The simplest combination and least sophisticated are test methods 1, 2, and 3, which satisfy all requirements; therefore, this would be option 1. The twang test does not provide an input ground motion simulation of the initial rise of the velocity pulse; the low-frequency residual motion only is simulated.

Consequently, an additional impact shock test will improve the test combination, especially for requirements E and F; test methods 1, 2, 3, and 4 become option 2. Test method 5 is an alternate, more sophisticated method for producing a simulated ground shock input to the isolator; this, in combination with methods 1 and 2, will satisfy all six requirements, giving a third option for consideration as a test concept.

5.3 SIMULATION TECHNIQUES

Simulation techniques which satisfy the selected test methods are now chosen and evaluated against the test requirements. The simulation technique may be an in-plant, laboratory, or field test and is so noted in the evaluation. Each chosen technique is subjectively assessed for factors which are used to rate the techniques in the combination options. The factors are

a) Degree to which simulation technique reproduces critical nuclear weapons effect

b) Test article size which can be tested

c) Is complex analysis required in conjunction with the test technique?

d) Past performance record

e) Cost.

Figure 5-1 is the standard form used to subjectively evaluate the simulation techniques. Section 4 of Volume III has a catalog of simulation techniques that includes a general listing of test techniques that are state-of-the-art techniques considered applicable for the proposed Hardness Demonstration Test Plan. In-plant tests also are considered from experience on Minuteman systems (specifically The Boeing Company in-plant capability) which are not reflected in the catalog. These in-plant tests are believed to be within the capability of almost any qualified integration contractor.

5.4 RATING SYSTEM

A simple quantitative rating system is used to assign a validity to a simulation technique against the selected requirements. The validity consists of three parts:

SUBSYSTEM ______________________________

INPUT ______________________________

TEST METHOD ______________________________

SIMULATION TECHNIQUE ______________________________

1. To what degree does this technique simulate the required input magnitude?

2. Can all of the input characteristics be simulated?

3. Can a specimen ____________ in size be tested in this facility?

4. Is validity of the test a function of specimen size or input magnitude?

5. Can the input and response be measured accurately?

6. Are complex analytical techniques required in conjunction with this test technique?

7. Past performance record:

8. What is the approximate cost?

9. Availability:

Figure 5-1. Evaluation of Simulation Techniques

a) Degree input simulates weapons effect

b) Degree test article simulates operational configuration

c) Past performance record.

The input simulation (a) is in reference to one of the specific critical loads from the postulated nuclear event, i.e., air blast, nuclear radiation, thermal radiation, EMP, and ground motion. The ability of the test to simulate both the peak magnitudes as well as the time-history characteristics is investigated. The sensitivity of the test article to a particular characteristic of the load also is considered. For example, if the test article is a high-frequency system, the peak pressure or rise to peak velocity will be the important characteristic of the true input function which should be simulated in the test.

The validity factor (b) is concerned with the capability of the simulation technique to test a full-scale test article. This is a principal factor in rating existing laboratory test simulation techniques wherein the geometry and weight of test articles are the limiting factors. Article size will also depend on load magnitude, especially in shock and dynamic pressure tests. For example, high pressure and high shock levels can only be obtained on small-scale articles in most of the laboratory test facilities.

Past performance record, validity factor (c), is concerned with the actual test performance relative to the required performance and the repeatability experience with the simulation technique. Obviously, a simulation technique which has been used with repeated success would be a preferred technique for testing of development or prototype hardware. The probability of satisfying the test objectives within a specified schedule would be greater for a simulation technique with a past performance record.

The summation of the above factors (a) through (c) provides a resultant validity for relative comparison of simulation techniques. A number from zero to three is given to each validity factor with the following meanings:

3 - Good

2 - Average

1 - Poor

Therefore, a simulation technique or group of simulation techniques with a large resultant validity number will indicate a preferred test concept. This resultant validity can only be interpreted as a relative rating and does not provide a basis for evaluating the absolute validity of the test method in comparison with the actual critical nuclear effect. A subjective comment will be necessary at the conclusion of each recommended test concept to indicate the estimated absolute validity.

The cost of the simulation technique is also considered in conjunction with the resultant validity number. The cost is also a reflection of the complexity of the test, pretest, and post test analyses and time period to perform the test. The rating number used is, again, a relative number since a very thorough investigation would be necessary to arrive at absolute costs. The following orders of magnitudes were used in this study:

$1 \leq \$100,000$

$2 \leq \$200,000$

and the reliability of these costs only has some credibility in a relative manner.

The two resulting numbers for validity and cost are then used to support the judgment for selecting a test concept. The step-by-step procedure is demonstrated in Subsection 5.6.

5.5 RECOMMENDED TEST CONCEPT

The recommended test concept is a test or a group of tests which provides a number of loading conditions to satisfy the test requirements with a preferred validity and low relative cost rating. A test concept for a particular subsystem or system is not independent of the test concepts at levels below or above the system considered. The test concept is recommended at each level with the knowledge that this test concept may be one of a series of tests as the system is built up from the smallest subsystem to the complete facility.

5.6 PROCEDURE, TEST CONCEPT TRADEOFF ANALYSIS

The steps described in Subsections 5.1 through 5.5 are performed for each subsystem and combinations (see Sections 2 and 4), starting at the lowest level and working up to the complete facility. A test concept tradeoff matrix is used to perform this analysis, and the step-by-step procedure is demonstrated in Figures 5-2 through 5-6. Explanatory notes are given on the figures which summarize the methodology at each step, and supporting discussions are in Subsections 5.1 through 5.5.

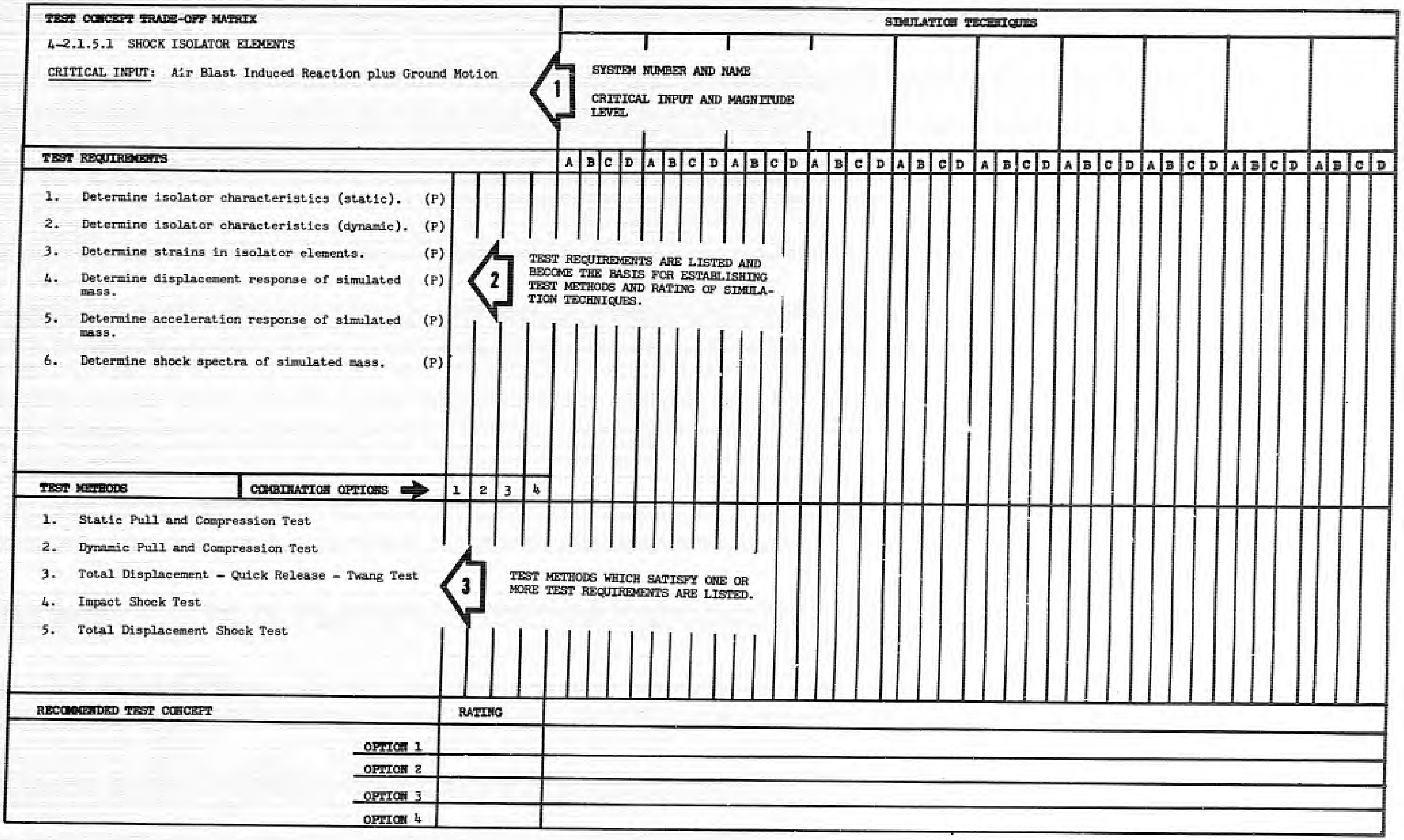


Figure 5-2. Test Concept Tradeoff Matrix Sample

TEST CONCEPT TRADE-OFF MATRIX

4-2.1.5.1 SHOCK ISOLATOR ELEMENTS

CRITICAL INPUT: Air Blast Induced Reaction plus Ground Motion

(1)

TEST REQUIREMENTS		1	2	3	4
1. Determine isolator characteristics (static).	(P)	✓	✓	✓	
2. Determine isolator characteristics (dynamic).	(P)	✓	✓	✓	
3. Determine strains in isolator elements.	(P)	✓	✓	✓	
4. Determine displacement response of simulated mass.	(P)	✓	✓	✓	
(2) 5. Determine acceleration response of simulated mass.	(P)	✓	✓	✓	
6. Determine shock spectra of simulated mass.	(P)	✓	✓	✓	

TEST METHODS	COMBINATION OPTIONS ➡	1	2	3	4
1. Static Pull and Compression Test		X	X	X	
2. Dynamic Pull and Compression Test		X	X	X	
(3) 3. Total Displacement - Quick Release - Twang Test		X	X		
4. Impact Shock Test			X		
5. Total Displacement Shock Test				X	

SIMULATION TECHNIQUES										
Static Load Tester (In-plant)	Hydraulic Cyclic Actuator Tester (In-plant)	Impact Tester (In-plant)	Hyge Shock Machine (Lab)	Large Displacement Actuator Test Machine (.FSWC Special)	Twang Test Fixture (In-plant)					
A B C D	A B C D	A B C D	A B C D	A B C D	A B C D	A B C D	A B C D	A B C D	A B C D	A B C D

(4) LIST ALL KNOWN SIMULATION TECHNIQUES WHICH CAN BE USED IN THE TEST OPTIONS LISTED IN STEP 3.

(5a) (5b) COMBINATIONS OF TEST METHODS ARE DERIVED (a) AND EACH COMBINATION IS CHECKED (b) TO VERIFY THAT ALL REQUIREMENTS ARE SATISFIED FOR EACH OPTION.

RECOMMENDED TEST CONCEPT	RATING	
OPTION 1		
OPTION 2		
OPTION 3		
OPTION 4		

Figure 5-3. Test Concept Tradeoff Matrix Sample

TEST CONCEPT TRADE-OFF MATRIX

4-2.1.5.1 SHOCK ISOLATOR ELEMENTS

CRITICAL INPUT: Air Blast Induced Reaction plus Ground Motion

(1)

TEST REQUIREMENTS (2)

TEST REQUIREMENTS		1	2	3	4
1. Determine isolator characteristics (static).	(P)	✓	✓	✓	
2. Determine isolator characteristics (dynamic)	(P)	✓	✓	✓	
3. Determine strains in isolator elements.	(P)	✓	✓	✓	
4. Determine displacement response of simulated mass.	(P)	✓	✓	✓	
5. Determine acceleration response of simulated mass.	(P)	✓	✓	✓	
6. Determine shock spectra of simulated mass.	(P)	✓	✓	✓	

(5)

TEST METHODS (3)	COMBINATION OPTIONS ➡ 1	2	3	4
1. Static Pull and Compression Test	X	X	X	
2. Dynamic Pull and Compression Test	X	X	X	
3. Total Displacement - Quick Release - Twang Test	X	X		
4. Impact Shock Test		X		
5. Total Displacement Shock Test			X	

SIMULATION TECHNIQUES (4)

	Static Load Tester (In-plant) A	B	C	D	Hydraulic Cyclic Actuator Tester (In-plant) A	B	C	D	Impact Tester (In-plant) A	B	C	D	Hyge Shock Machine (Lab) A	B	C	D	Large Displacement Actuator Test Machine (AFSWC Special) A	B	C	D	Twang Test Fixture (In-plant) A	B	C	D
Req. 1	0	3	3																					
Req. 2					3	3	3																	
Req. 3									2	3	3		2	3	2		3	3	3		0	3	0	
Req. 4																	3	3	3		1	3	3	
Req. 5									2	3	3		2	3	2		3	3	3		0	3	0	
Req. 6									2	3	3		1.5	3	2		3	3	3		1	3	3	
Method 1	0	3	3	.1																				
Method 2					3	3	3	.1																
Method 3																					2	12	6	.1
Method 4									6	9	9	.1	5.5	9	6	.1								
Method 5																	12	12	12	.2				

(6) COLUMNS A,B, AND C RATE THE VALIDITY OF EACH SIMULATION TECHNIQUE AGAINST THE TEST REQUIREMENTS AS FOLLOWS:

A. DEGREE INPUT SIMULATES WEAPON EFFECT — 3-Good

B. DEGREE TEST ARTICLE SIMULATES OPERATIONAL CONFIGURATION — 2-Avg

C. PAST PERFORMANCE RECORD — 1-Poor

(7) THE COST INDEX IS LISTED IN COLUMN D AT EACH ROW WHEREIN THE PARTICULAR TEST TECHNIQUE IS USED:

1 $100,000
2 $200,000
3 $300,000

RECOMMENDED TEST CONCEPT	RATING	
OPTION 1		
OPTION 2		
OPTION 3		
OPTION 4		

Figure 5-4. Test Concept Tradeoff Matrix Sample

TEST CONCEPT TRADE-OFF MATRIX

4-2.1.5.1 SHOCK ISOLATOR ELEMENTS

CRITICAL INPUT: Air Blast Induced Reaction plus Ground Motion

(1)

(2) TEST REQUIREMENTS		1	2	3	4	Static Load Tester (In-plant) A	B	C	D	Hydraulic Cyclic Actuator Tester (In-plant) A	B	C	D	(4) Impact Tester (In-plant) A	B	C	D	Hyge Shock Machine (Lab) A	B	C	D	Large Displacement Actuator Test Machine (AFSWC Special) A	B	C	D	Twang Test Fixture (In-plant) A	B	C	D
1. Determine isolator characteristics (static).	(P)	✓	✓	✓		0	3	3																					
2. Determine isolator characteristics (dynamic).	(P)	✓	✓	✓						3	3	3																	
3. Determine strains in isolator elements.	(P)	✓	✓	✓										2	3	3		2	3	2		3	3	3		0	3	0	
4. Determine displacement response of simulated mass.	(P)	✓	✓	✓																		3	3	3		1	3	3	
5. Determine acceleration response of simulated mass.	(P)	✓	✓	✓										2	3	3		2	3	2		3	3	3		0	3	0	
6. Determine shock spectra of simulated mass.	(P)	✓	✓	✓										2	3	3		1.5	3	2		3	3	3		1	3	3	
(5)																													(6)
(3) TEST METHODS	**COMBINATION OPTIONS ➡**	**1**	**2**	**3**	**4**																								
1. Static Pull and Compression Test		X	X	X		0	3	3	.1																				
2. Dynamic Pull and Compression Test		X	X	X						3	3	3	.1																
3. Total Displacement - Quick Release - Twang Test		X	X																							2	12	6	.1 (7)
4. Impact Shock Test			X											6	9	9	.1	5.5	9	6	.1								
5. Total Displacement Shock Test				X																		12	12	12	.2				

(8)

RECOMMENDED TEST CONCEPT	RATING
OPTION 1	
OPTION 2	
OPTION 3	
OPTION 4	

SUM THE VALIDITY NUMBERS IN COLUMNS A, B, AND C AND LIST THEM IN THE APPROPRIATE ROW UNDER TEST METHODS. WHERE TWO OR MORE SIMULATION TECHNIQUES EXIST IN A SINGLE OPTION TEST METHOD, SELECT THE BEST SIMULATION TECHNIQUE (i.e., HIGHEST SUM OF VALIDITY NUMBERS AND LOWEST COST NUMBER.

Figure 5-5. Test Concept Tradeoff Matrix Sample

TEST CONCEPT TRADE-OFF MATRIX

4-2.1.5.1 SHOCK ISOLATOR ELEMENTS

CRITICAL INPUT: Air Blast Induced Reaction plus Ground Motion

(1)

SIMULATION TECHNIQUES

TEST REQUIREMENTS		✓	✓	✓		Static Load Tester (In-plant) A	B	C	D	Hydraulic Cyclic Actuator Tester (In-plant) A	B	C	D	Impact Tester (In-plant) A	B	C	D	Hyge Shock Machine (Lab) A	B	C	D	Large Displacement Actuator Test Machine (AFSWC Special) A	B	C	D	Twang Test Fixture (In-plant) A	B	C	D
1. Determine isolator characteristics (static).	(P)	✓	✓	✓		0	3	3																					
2. Determine isolator characteristics (dynamic).	(P)	✓	✓	✓						3	3	3																	
3. Determine strains in isolator elements.	(P)	✓	✓	✓										2	3	3		2	3	2		3	3	3		0	3	0	
4. Determine displacement response of simulated mass.	(P)	✓	✓	✓																		3	3	3		1	3	3	
5. Determine acceleration response of simulated mass.	(P)	✓	✓	✓										2	3	3		2	3	2		3	3	3		0	3	0	
6. Determine shock spectra of simulated mass.	(P)	✓	✓	✓										2	3	3		1.5	3	2		3	3	3		1	3	3	
TEST METHODS	**COMBINATION OPTIONS** ➡	1	2	3	4																								
1. Static Pull and Compression Test		X	X	X		0	3	3	.1																				
2. Dynamic Pull and Compression Test		X	X	X						3	3	3	.1																
3. Total Displacement - Quick Release - Twang Test		X	X																							2	12	6	.1
4. Impact Shock Test			X											6	9	9	.1	5.5	9	6	.1								
5. Total Displacement Shock Test				X																		12	12	12	.2				

(2) (3) (4) (5) (6) (7) (8)

SUM UP VALIDITY NUMBERS (NUMERATOR) AND COST NUMBERS (DENOMINATOR). LARGEST VALIDITY AND LOWEST COST IS BASIS FOR RECOMMENDED CONCEPT.

THE RECOMMENDED TEST CONCEPT IS REPRESENTED IN A BLOCK DIAGRAM, INDICATING THE TEST METHOD AND SIMULATION TECHNIQUE UTILIZED. (11)

RECOMMENDED TEST CONCEPT

STATIC PULL TEST (IN-PLANT) — DYNAMIC PULL TEST (IN-PLANT) — TOTAL DISPLAC SHOCK TEST (AFSWC - LAB)

	RATING (10)	Static Load Tester	Hydraulic Cyclic Actuator Tester	Impact Tester	Hyge Shock Machine	Large Displacement Actuator Test Machine	Twang Test Fixture
OPTION 1	35/.3	3 3 .1	3 3 3 .1				2 12 6 .1
OPTION 2	44.5/.4	3 3 .1	3 3 3 .1	6 9 9 .1			1 3 3 .1
OPTION 3	51/.4	3 3 .1	3 3 3 .1			12 12 12 .2	
OPTION 4							

(9) BRING DOWN THE VALIDITY NUMBERS AND COST NUMBERS FOR EACH SIMULATION TECHNIQUE AND LIST THEM IN THE ROWS FOR EACH TEST OPTION WHERE USED. WHEN TWO OR MORE SIMULATION TECHNIQUES SATISFY THE VALIDITY FOR A SPECIFIC REQUIREMENT, USE THE LARGEST VALIDITY NUMBER.

Figure 5-6. Test Concept Tradeoff Matrix Sample

6. TEST CONCEPT FLOW DIAGRAM

The recommended test concepts developed in the test requirements analysis as described in Section 5 are summarized on a test concept flow diagram. Here again the concepts are presented in a systematic manner to account for each system element at each system level.

6.1 TEST CONCEPT FLOW DEVELOPMENT

Construction of the flow diagram begins by listing all of the Level 4 system elements in their numerical order vertically at the left of the chart. Each of the elements will then be followed (to the right of the chart) by either a block or a series of blocks, each representing a recommended test or a notation that testing is not recommended. Each test block contains the title of the test, where the test should be performed (laboratory, in-plant, etc.), the simulation technique to be employed, and a reference number relating to the system element.

As the flow is constructed from left to right, the recommended test concepts developed in the test requirements analysis are added at each system level. System Level 4 elements are shown first, then the combinations of System Level 4 elements, then System Level 3 elements, then combinations of System Level 3 elements, and so on up through System Level 1. The completed flow (see Figure 6-1) presents the complete spectrum of test concepts that are recommended to assure hardness of the system. Total system hardness can only be demonstrated through the implementation of the complete spectrum of recommended testing. Under the basic philosophy adopted for this study, the In-Place Hardness Demonstration Test Program can then be defined as the sum of all Level 4 subsystem tests plus Level 3 system tests plus Level 2 major systems tests plus Level 1 facility tests. <u>No single block may be deleted without disturbing the validity and/or completeness of the test program.</u> The test concepts must be re-evaluated and redeveloped where necessary to assure accomplishment of all test requirements.

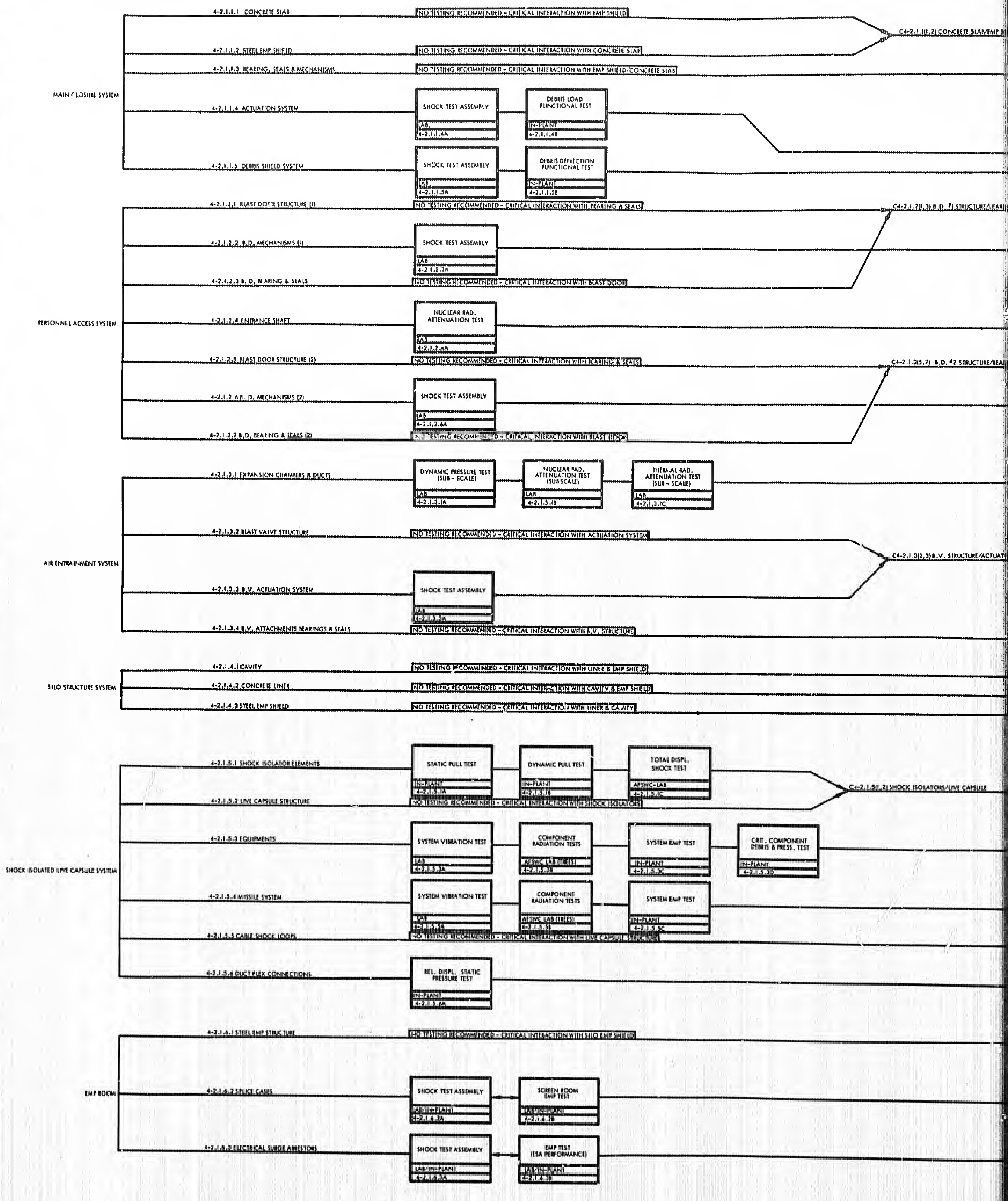
6.2 COMBINATION OF RECOMMENDED TEST CONCEPTS

As can be expected, many of the test blocks on the flow diagram may utilize the same type of simulation technique or test facility and are compatible with regard to scheduling. These tests may logically be combined and planned for implementation at a single test site. Other test blocks may have similar test requirements, but the simulation techniques for each are quite different. These will also be candidates for logical combinations in a single test.

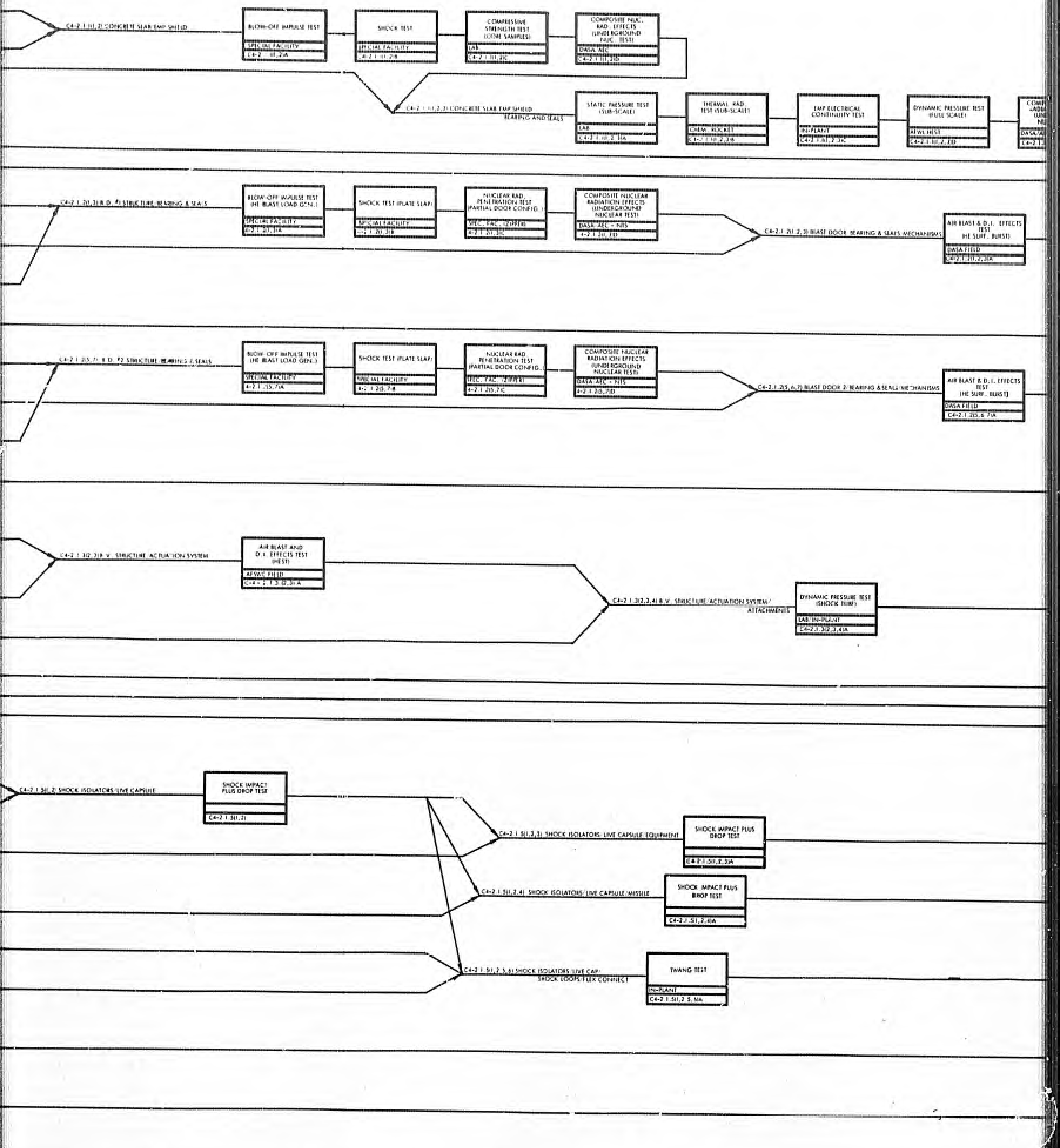
The reorientation and combination of the test concept blocks from the test concept flow diagram into a more efficient, cost-effective test program is a test planning task and is not included in the test requirements analysis (see 6. 3 below). An example would be test concept blocks 4-2. 1. 1. 4B, Main Closure Actuation System Debris Load Functional Test, and 4-2. 1. 1. 5B, Main Closure Debris Shield Functional Test, from Figure 6-1 which can readily be combined and conducted at a common test facility. (In fact, the facility utilized by these tests probably will have been constructed for other system development tests as well.) The object is to retain all of the test requirements developed in the test requirements analysis while limiting the number of test facilities by optimizing the utilization of the test facilities or simulation techniques.

6. 3 TEST PROGRAM PLAN

The test planning activity converts the recommended test concepts into a definitized series of tests phased to a system development schedule to provide the most efficient and timely evaluation of the system for in-place hardness. The result is a test program plan of the type submitted as Volume IV of this technical report.

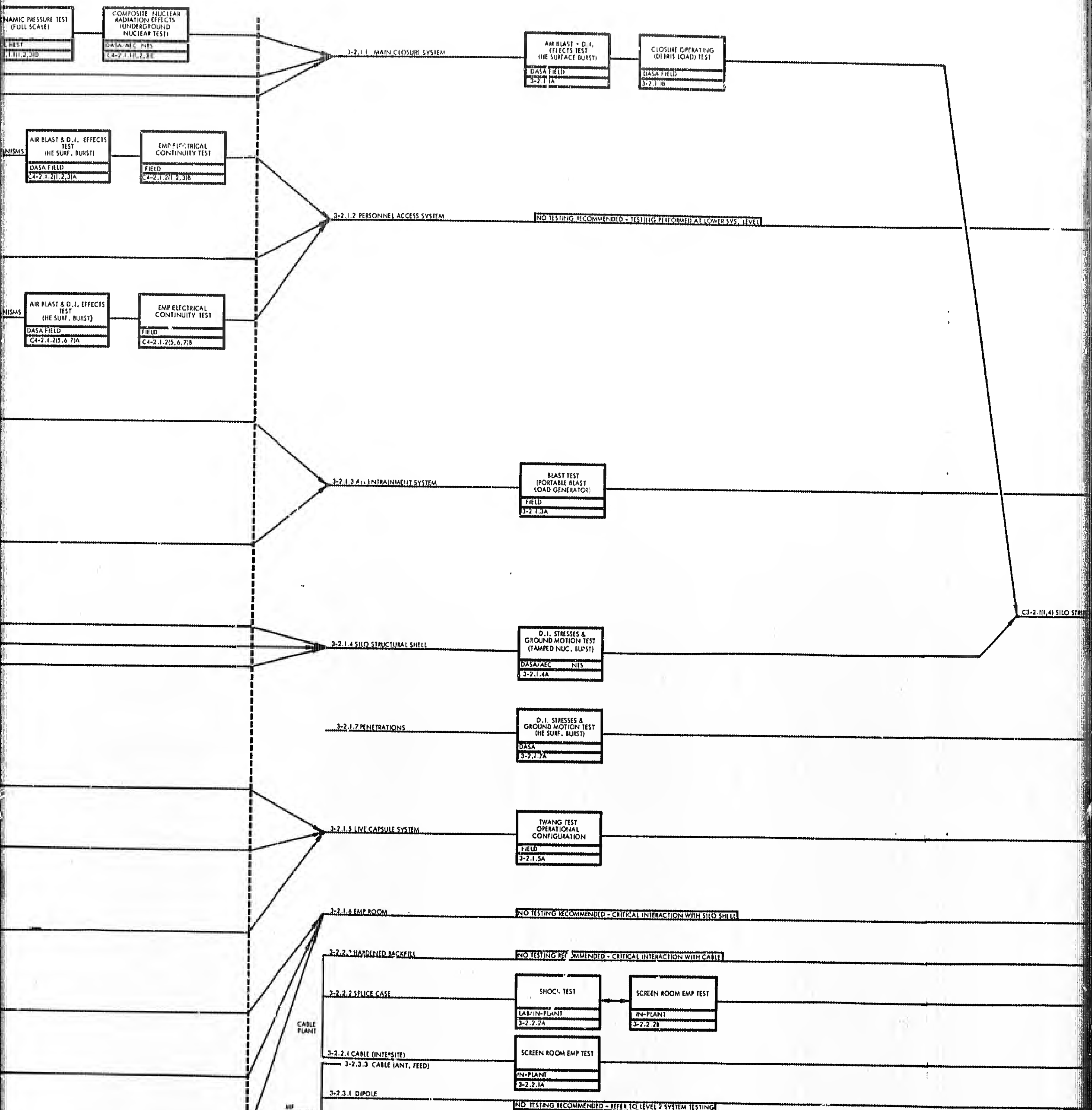

MAIN CLOSURE SYSTEM
4-2.1.1.1 CONCRETE SLAB
NO TESTING RECOMMENDED - CRITICAL INTERACTION WITH EMP SHIELD
C4-2.1.1(1,2) CONCRETE SLAB/EMP
4-2.1.1.2 STEEL EMP SHIELD
NO TESTING RECOMMENDED - CRITICAL INTERACTION WITH CONCRETE SLAB
4-2.1.1.3 BEARING, SEALS & MECHANISMS
NO TESTING RECOMMENDED - CRITICAL INTERACTION WITH EMP SHIELD/CONCRETE SLAB
4-2.1.1.4 ACTUATION SYSTEM
SHOCK TEST ASSEMBLY
LAB
4-2.1.1.4A
DEBRIS LOAD FUNCTIONAL TEST
IN-PLANT
4-2.1.1.4B
4-2.1.1.5 DEBRIS SHIELD SYSTEM
SHOCK TEST ASSEMBLY
LAB
4-2.1.1.5A
DEBRIS DEFLECTION FUNCTIONAL TEST
IN-PLANT
4-2.1.1.5B
PERSONNEL ACCESS SYSTEM
4-2.1.2.1 BLAST DOOR STRUCTURE (1)
NO TESTING RECOMMENDED - CRITICAL INTERACTION WITH BEARING & SEALS
C4-2.1.2(1,3) B.D. #1 STRUCTURE/BEARI
4-2.1.2.2 B.D. MECHANISMS (1)
SHOCK TEST ASSEMBLY
LAB
4-2.1.2.2A
4-2.1.2.3 B.D. BEARING & SEALS
NO TESTING RECOMMENDED - CRITICAL INTERACTION WITH BLAST DOOR
4-2.1.2.4 ENTRANCE SHAFT
NUCLEAR RAD. ATTENUATION TEST
LAB
4-2.1.2.4A
4-2.1.2.5 BLAST DOOR STRUCTURE (2)
NO TESTING RECOMMENDED - CRITICAL INTERACTION WITH BEARING & SEALS
C4-2.1.2(5,7) B.D. #2 STRUCTURE/BEAR
4-2.1.2.6 B.D. MECHANISMS (2)
SHOCK TEST ASSEMBLY
LAB
4-2.1.2.6A
4-2.1.2.7 B.D. BEARING & SEALS (2)
NO TESTING RECOMMENDED - CRITICAL INTERACTION WITH BLAST DOOR
AIR ENTRAINMENT SYSTEM
4-2.1.3.1 EXPANSION CHAMBERS & DUCTS
DYNAMIC PRESSURE TEST (SUB - SCALE)
LAB
4-2.1.3.1A
NUCLEAR RAD. ATTENUATION TEST (SUB SCALE)
LAB
4-2.1.3.1B
THERMAL RAD. ATTENUATION TEST (SUB - SCALE)
LAB
4-2.1.3.1C
4-2.1.3.2 BLAST VALVE STRUCTURE
NO TESTING RECOMMENDED - CRITICAL INTERACTION WITH ACTUATION SYSTEM
C4-2.1.3(2,3) B.V. STRUCTURE/ACTUAT
4-2.1.3.3 B.V. ACTUATION SYSTEM
SHOCK TEST ASSEMBLY
LAB
4-2.1.3.4 B.V. ATTACHMENTS BEARINGS & SEALS
NO TESTING RECOMMENDED - CRITICAL INTERACTION WITH B.V. STRUCTURE
SILO STRUCTURE SYSTEM
4-2.1.4.1 CAVITY
NO TESTING RECOMMENDED - CRITICAL INTERACTION WITH LINER & EMP SHIELD
4-2.1.4.2 CONCRETE LINER
NO TESTING RECOMMENDED - CRITICAL INTERACTION WITH CAVITY & EMP SHIELD
4-2.1.4.3 STEEL EMP SHIELD
NO TESTING RECOMMENDED - CRITICAL INTERACTION WITH LINER & CAVITY
SHOCK ISOLATED LIVE CAPSULE SYSTEM
4-2.1.5.1 SHOCK ISOLATOR ELEMENTS
STATIC PULL TEST
IN-PLANT
DYNAMIC PULL TEST
IN-PLANT
TOTAL DISPL. SHOCK TEST
AFSWC-LAB
4-2.1.5.2 LIVE CAPSULE STRUCTURE
NO TESTING RECOMMENDED - CRITICAL INTERACTION WITH SHOCK ISOLATORS
4-2.1.5.3 EQUIPMENTS
SYSTEM VIBRATION TEST
LAB
COMPONENT RADIATION TESTS
SYSTEM EMP TEST
IN-PLANT
CRIT. COMPONENT DEBRIS & PRESS. TEST
IN-PLANT
4-2.1.5.4 MISSILE SYSTEM
SYSTEM VIBRATION TEST
COMPONENT RADIATION TESTS
SYSTEM EMP TEST
IN-PLANT
4-2.1.5.5 CABLE SHOCK LOOPS
REL. DISPL. STATIC PRESSURE TEST
IN-PLANT
EMP ROOM
4-2.1.6.1 STEEL EMP STRUCTURE
NO TESTING RECOMMENDED - CRITICAL INTERACTION WITH SILO EMP SHIELD
4-2.1.6.2 SPLICE CASES
SHOCK TEST ASSEMBLY
LAB/IN-PLANT
SCREEN ROOM EMP TEST
LAB/IN-PLANT
SHOCK TEST ASSEMBLY
LAB/IN-PLANT
EMP TEST (TSA PERFORMANCE)
LAB/IN-PLANT

A.



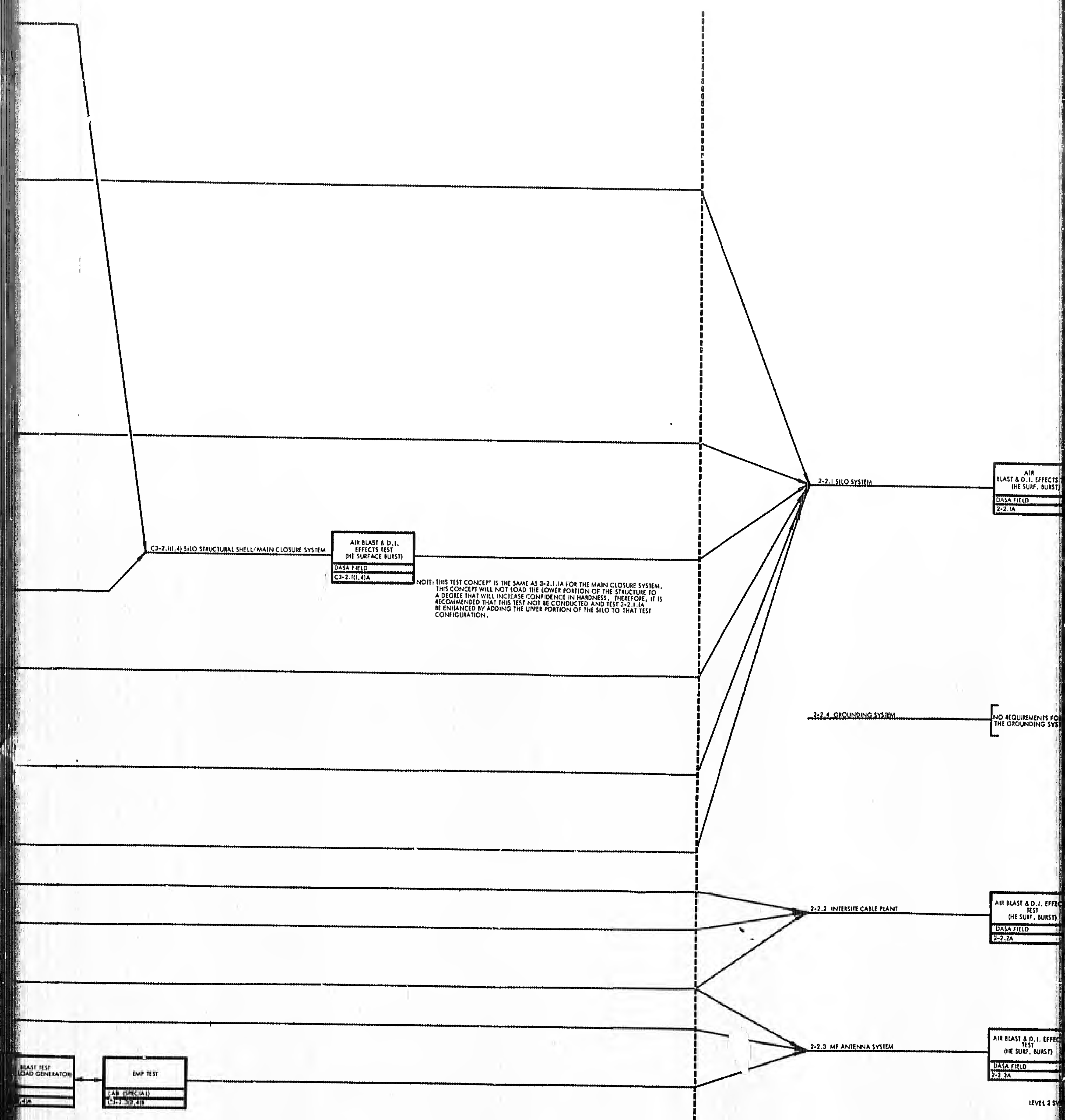
CONCRETE SLAB EMP SHIELD
BLOW-OFF IMPULSE TEST
SPECIAL FACILITY
SHOCK TEST
SPECIAL FACILITY
COMPRESSIVE STRENGTH TEST (CORE SAMPLES)
LAB
COMPOSITE NUC. RAD. EFFECTS (UNDERGROUND NUC. TEST)
DASA AEC
CONCRETE SLAB EMP SHIELD BEARING AND SEALS
STATIC PRESSURE TEST (SUB-SCALE)
LAB
THERMAL RAD. TEST (SUB-SCALE)
CHEM. ROCKET
EMP ELECTRICAL CONTINUITY TEST
IN-PLANT
DYNAMIC PRESSURE TEST (FULL SCALE)
STRUCTURE, BEARING & SEALS
BLOW-OFF IMPULSE TEST (HE BLAST LOAD GEN.)
SPECIAL FACILITY
SHOCK TEST (PLATE SLAP)
SPECIAL FACILITY
NUCLEAR RAD. PENETRATION TEST (PARTIAL DOOR CONFIG.)
COMPOSITE NUCLEAR RADIATION EFFECTS (UNDERGROUND NUCLEAR TEST)
DASA-AEC + NTS
BLAST DOOR BEARING & SEALS MECHANISMS
AIR BLAST & D.I. EFFECTS TEST (HE SURF. BURST)
DASA FIELD
STRUCTURE, BEARINGS & SEALS
BLOW-OFF IMPULSE TEST (HE BLAST LOAD GEN.)
SPECIAL FACILITY
SHOCK TEST (PLATE SLAP)
SPECIAL FACILITY
NUCLEAR RAD. PENETRATION TEST (PARTIAL DOOR CONFIG.)
COMPOSITE NUCLEAR RADIATION EFFECTS (UNDERGROUND NUCLEAR TEST)
DASA-AEC + NTS
BLAST DOOR 2/BEARING & SEALS/MECHANISMS
AIR BLAST & D.I. EFFECTS TEST (HE SURF. BURST)
DASA FIELD
STRUCTURE ACTUATION SYSTEM
AIR BLAST AND D.I. EFFECTS TEST (HEST)
AFWC FIELD
STRUCTURE/ACTUATION SYSTEM/ ATTACHMENTS
DYNAMIC PRESSURE TEST (SHOCK TUBE)
LAB/IN-PLANT
SHOCK ISOLATORS/LIVE CAPSULE
SHOCK IMPACT PLUS DROP TEST
SHOCK ISOLATORS/LIVE CAPSULE/EQUIPMENT
SHOCK IMPACT PLUS DROP TEST
SHOCK ISOLATORS/LIVE CAPSULE/MISSILE
SHOCK IMPACT PLUS DROP TEST
SHOCK ISOLATORS/LIVE CAP/ SHOCK LOOPS/FLEX CONNECT
TWANG TEST
IN-PLANT

B.



NAMIC PRESSURE TEST (FULL SCALE)
COMPOSITE NUCLEAR RADIATION EFFECTS (UNDERGROUND NUCLEAR TEST)
DASA/AEC NTS
C4-2.1.1(1,2,3)E
3-2.1.1 MAIN CLOSURE SYSTEM
AIR BLAST + D.I. EFFECTS TEST (HE SURFACE BURST)
DASA FIELD
3-2.1.1A
CLOSURE OPERATING (DEBRIS LOAD) TEST
DASA FIELD
3-2.1.1B
NISMS
AIR BLAST & D.I. EFFECTS TEST (HE SURF. BURST)
DASA FIELD
C4-2.1.2(1,2,3)A
EMP ELECTRICAL CONTINUITY TEST
FIELD
C4-2.1.2(1,2,3)B
3-2.1.2 PERSONNEL ACCESS SYSTEM
NO TESTING RECOMMENDED - TESTING PERFORMED AT LOWER SYS. LEVEL
NISMS
AIR BLAST & D.I. EFFECTS TEST (HE SURF. BURST)
DASA FIELD
C4-2.1.2(5,6,7)A
EMP ELECTRICAL CONTINUITY TEST
FIELD
C4-2.1.2(5,6,7)B
3-2.1.3 AIR ENTRAINMENT SYSTEM
BLAST TEST (PORTABLE BLAST LOAD GENERATOR)
FIELD
3-2.1.3A
C3-2.1(1,4) SILO STR
3-2.1.4 SILO STRUCTURAL SHELL
D.I. STRESSES & GROUND MOTION TEST (TAMPED NUC. BURST)
DASA/AEC NTS
3-2.1.4A
3-2.1.7 PENETRATIONS
D.I. STRESSES & GROUND MOTION TEST (HE SURF. BURST)
DASA
3-2.1.7A
3-2.1.5 LIVE CAPSULE SYSTEM
TWANG TEST OPERATIONAL CONFIGURATION
FIELD
3-2.1.5A
3-2.1.6 EMP ROOM
NO TESTING RECOMMENDED - CRITICAL INTERACTION WITH SILO SHELL
3-2.2.3 HARDENED BACKFILL
NO TESTING RECOMMENDED - CRITICAL INTERACTION WITH CABLE
3-2.2.2 SPLICE CASE
SHOCK TEST
LAB/IN-PLANT
3-2.2.2A
SCREEN ROOM EMP TEST
IN-PLANT
3-2.2.2B
CABLE PLANT
3-2.2.1 CABLE (INTERSITE)
SCREEN ROOM EMP TEST
IN-PLANT
3-2.2.1A
3-2.3.3 CABLE (ANT. FEED)
3-2.3.1 DIPOLE
NO TESTING RECOMMENDED - REFER TO LEVEL 2 SYSTEM TESTING
MF ANTENNA SYSTEM
3-2.3.2 DIPOLE-CABLE CONN. & ESA
EMP TEST (ESA PERFORMANCE)
LAB/IN-PLANT
3-2.3.2A
C3-2.3(2,4) DIPOLE/CABLE CONNECTOR & HARDENED BACKFILL
BLAST TEST (BLAST LOAD GENERATOR)
LAB
C3-2.3(2,4)A
EMP TEST
LAB (SPECIAL)
C3-2.3(2,4)B
3-2.3.4 HARDENED BACKFILL (MF ANT.)
CONDUCTIVITY TEST (WITH DEBRIS)
IN-PLANT
3-2.3.4A
LEVEL 3 SYSTEM TESTING

C.


C3-2.1(1,4) SILO STRUCTURAL SHELL/MAIN CLOSURE SYSTEM
AIR BLAST & D.I. EFFECTS TEST (HE SURFACE BURST)
DASA FIELD
C3-2.1(1,4)A
NOTE: THIS TEST CONCEPT IS THE SAME AS 3-2.1.1A FOR THE MAIN CLOSURE SYSTEM. THIS CONCEPT WILL NOT LOAD THE LOWER PORTION OF THE STRUCTURE TO A DEGREE THAT WILL INCREASE CONFIDENCE IN HARDNESS. THEREFORE, IT IS RECOMMENDED THAT THIS TEST NOT BE CONDUCTED AND TEST 3-2.1.1A BE ENHANCED BY ADDING THE UPPER PORTION OF THE SILO TO THAT TEST CONFIGURATION.
2-2.1 SILO SYSTEM
AIR BLAST & D.I. EFFECTS (HE SURF. BURST)
DASA FIELD
2-2.1A
2-2.4 GROUNDING SYSTEM
NO REQUIREMENTS FO THE GROUNDING SYS
2-2.2 INTERSITE CABLE PLANT
AIR BLAST & D.I. EFFEC TEST (HE SURF. BURST)
DASA FIELD
2-2.2A
2-2.3 MF ANTENNA SYSTEM
AIR BLAST & D.I. EFFEC TEST (HE SURF. BURST)
DASA FIELD
2-2 3A
EMP TEST
LEVEL 2 SY
M TESTING

D.

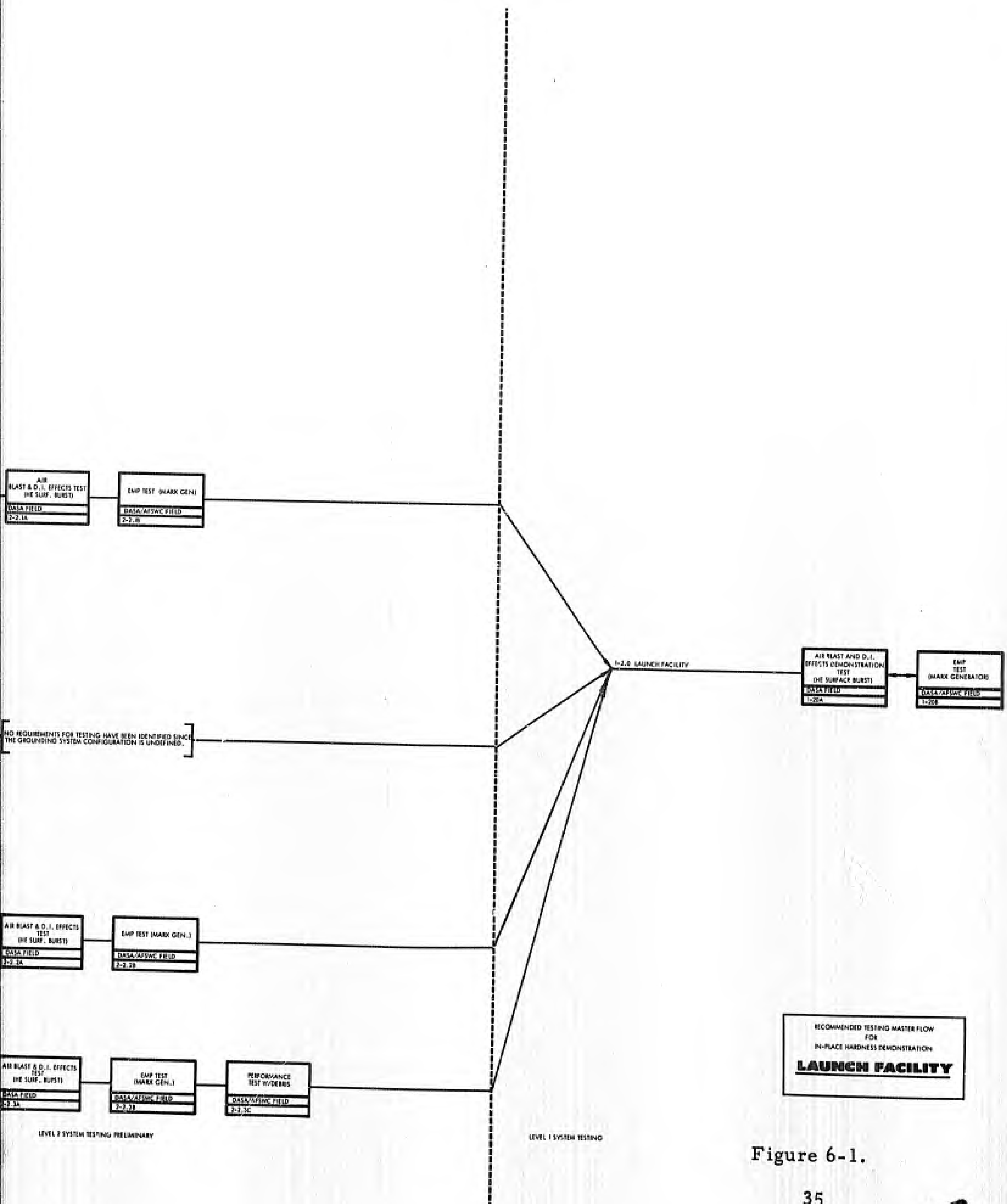

AIR BLAST & D.I. EFFECTS TEST (HE SURF. BURST)
DASA FIELD
2-2.1A
EMP TEST (MARK GEN)
DASA/AFSWC FIELD
2-2.1B
NO REQUIREMENTS FOR TESTING HAVE BEEN IDENTIFIED SINCE THE GROUNDING SYSTEM CONFIGURATION IS UNDEFINED.
AIR BLAST & D.I. EFFECTS TEST (HE SURF. BURST)
DASA FIELD
2-2.2A
EMP TEST (MARK GEN.)
DASA/AFSWC FIELD
2-2.2B
AIR BLAST & D.I. EFFECTS TEST (HE SURF. BURST)
DASA FIELD
2-2.3A
EMP TEST (MARK GEN.)
DASA/AFSWC FIELD
2-2.3B
PERFORMANCE TEST W/DEBRIS
DASA/AFSWC FIELD
2-2.3C
LEVEL 2 SYSTEM TESTING PRELIMINARY
1-2.0 LAUNCH FACILITY
AIR BLAST AND D.I. EFFECTS DEMONSTRATION TEST (HE SURFACE BURST)
DASA FIELD
1-20A
EMP TEST (MARX GENERATOR)
DASA/AFSWC FIELD
1-20B
LEVEL 1 SYSTEM TESTING
RECOMMENDED TESTING MASTER FLOW
FOR
IN-PLACE HARDNESS DEMONSTRATION
LAUNCH FACILITY

Figure 6-1.

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ABBREVIATIONS

AEC	Atomic Energy Commission
AES	Air Entrainment System
AFSWC	Air Force Special Weapons Center
AFWL	Air Force Weapons Laboratory
AGE	Aerospace Ground Equipment
AVE	Aerospace Vehicle Equipment
BV	Blast Valve
CBR	Chemical, Biological, and Radiological
CDR	Critical Design Review
CG	Center of Gravity
DASA	Defense Atomic Support Agency
DI	Direct Induced
DIHEST	Direct Induced High Explosive Simulation Technique
DOD	Department of Defense
EC	Equipment Capsule
ECU	Environmental Control Unit
E-M	Electric and Magnetic
EMP	Electromagnetic Pulse
ERDL	Engineering Research and Development Laboratories
ESA	Electrical Surge Arrestor
FAC	Facility
GTM	Ground Test Missile
HE	High Explosive
HEST	High Explosive Simulation Technique
HET	High Explosive Test
HF	High Frequency
HPT	Hardness Proof Test
IITRI	IIT Research Institute
LASL	Los Alamos Scientific Laboratory
LCF	Launch Control Facility
LF	Launch Facility
MC	Main Closure
MF	Medium Frequency

ABBREVIATIONS (Continued)

NEST	Nuclear Explosive Shock Tube
NTS	Nevada Test Site
NWSSG	Nuclear Weapon System Safety Group
OGE	Operating Ground Equipment
OP	Operational
PC	Personnel Capsule
PDR	Preliminary Design Review
PSI	Pounds per Square Inch
PTPD	Preliminary Test Development Plan
RF	Radio Frequency
SAC	Strategic Air Command
SAMSO	Space and Missile Systems Operation
SI	Shock Isolator
SOR	System Operational Requirement
SOW	Statement of Work
SPUD	Synthetic Pulse Diagnosis
TRA	Test Requirements Analysis
TREES	Transient Radiation Effects, Electronics System
TSE	Test Support Equipment
UHF	Ultra High Frequency
WES	Waterways Experiment Station

Unclassified

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13. ABSTRACT

This study has developed a test program plan for demonstrating the in-place hardness of an advanced ballistic missile weapon system. A test requirements analysis methodology was devised, utilizing a systems approach, to examine a WS-120A system baseline design with respect to a given weapons effect environment criteria, define the testing required to assure hardness of each system element, trade off applicable simulation techniques, and recommend a series of test concepts. These concepts were then logically combined into efficient and cost-effective in-place hardness demonstration test programs for the launch facility and launch control facility. ( )

This report has been divided into five volumes and classified as follows:

Volume I	Study Report Summary (Unclassified)
Volume II	Methodology (Unclassified)
Volume III	Test Requirements Analysis (Secret, RD)
Volume IV	Test Program Plan (Unclassified)
Volume V	Selected LF Subsystems Test Plan (Unclassified)

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14 KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
In-Place Hardness Demonstration Test Requirements Analysis LF and LCF Hardness Test Plan Test Concept						

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