AD-A278 230

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Form Approved
OMB No 0704-0188

(2)

average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering the collection of information. Send comments regarding this burden estimate or any other aspect of this to Washington Headquarters Services, Directorate for information Operations and Reports, 1215 Jefferson Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	15 April 1994	Final

4. TITLE AND SUBTITLE
Test Operations Procedure (TOP)
1-2-612 Nuclear Environment Survivability

5. FUNDING NUMBERS
WU A268445

DTIC
ELECTE
APR 19 1994
S C

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER
Test Operations Procedure (TOP) 1-2-612

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
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Aberdeen Proving Ground, MD 21105-5055

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
Same as item 8

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release:
Distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This TOP provides a general outline of the test and analysis procedures required to determine the effects of specified nuclear environment on Army materiel. The purpose of these test and analysis procedures is to ascertain the degree to which the Operational Requirements Document (ORD), Independent Evaluation Plan (IEP)/ Independent Assessment Plan (IAP) criteria, and Army Nuclear Hardening Criteria (NHC) are met.

94-11678

DTIC QUALITY INSPECTED 3

94 4 18 091

14. SUBJECT TERMS		15. NUMBER OF PAGES
Nuclear thermal radiation Gamma dose rate Nuclear environments	Neutron fluence	116 16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED			SAR

20030110000

DEPARTMENT OF THE ARMY
HEADQUARTERS, U.S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MARYLAND 21005-5055

REPLY TO ATTENTION OF

AMSTE-CT-T (70-10p)

1 APR 1994

MEMORANDUM FOR Administrator, Defense Technical Information Center, ATTN: DDAC, Cameron Station, Alexandria, VA 22304-6145

SUBJECT: Test Operations Procedure (TOP) 1-2-612, Nuclear Environment Survivability, 15 Apr 94

1. Enclosed are DTIC Form 50 (Encl 1) and two copies of subject test operations procedure (Encl 2) for assignment of accession number.

2. This TOP supersedes TOP 1-2-612, AD No: A069845, 12 Apr 79, which should be removed from your library and discarded.

3. Point of contact at this headquarters is Mr. Wolfgang HR. Schmidt, AMSTE-CT-T, amstectt@apg-9.apg.army.mil, DSN 298-1486.

FOR THE COMMANDER:

2 Encls

RICHARD A. HAYES
Acting Chief, Tech Dev Div
Directorate for Corporate Information
and Technology

US ARMY TEST AND EVALUATION COMMAND
TEST OPERATION PROCEDURES

*Test Operations Procedure (TOP) 1-2-612 15 April 1994
AD No.

NUCLEAR ENVIRONMENT SURVIVABILITY

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*This TOP supersedes TOP 1-2-612, 12 April 1979.
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1. SCOPE. This Test Operation Procedure (TOP) is a general outline on test and analysis procedures required to determine the effects of a specified nuclear environment on Army materiel. The purpose of these test and analysis procedures is to ascertain the degree to which the Operational Requirements Document (ORD), Independent Evaluation Plan (IEP)/Independent Assessment Plan (IAP) criteria, and Army Nuclear Hardening Criteria (NHC) are met. Army materiel can consist of complete end items, subsystems, Line Replaceable Units (LRUs), components or piece-parts of major systems. All materiel must be tested and analyzed to its NHC with respect to the performance of all its mission essential functions. Realistic hardware, and practical test configurations and scenarios must be tested and analyzed in order to achieve an accurate and complete Nuclear Survivability Analysis (NSA). This TOP adheres to an integrated set of test principles and procedures that will result in timely, reliable, and consistent data for nuclear survivability analysis. This document is encouraged for use by all nuclear survivability testers (government and contractor) for test planning, for test conduct, and for acquiring and analyzing data in technical and customer tests.

2. FACILITIES AND INSTRUMENTATION.

2.1 Nuclear Airblast Facilities and Instrumentation.

2.1.1 Nuclear Airblast Criteria Parameters. These criteria parameters must be thoroughly analyzed to ensure that acceptable facilities and appropriate instrumentation are utilized.

Airblast Parameter		Unit
Peak Overpressure	(ΔP)	[kPa]
Overpressure Duration	(t_p)	[sec]
Overpressure Impulse	(I_p)	[kPa-sec]
Peak Dynamic Pressure	(q)	[kPa]
Positive Duration	(t_q)	[sec]
Dynamic Pressure Impulse	(I_q)	[kPa-sec]
Peak Underpressure	(ΔP_{neg})	[kPa]
Arrival Time	(t_a)	[sec]

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Performance criteria requirements of the test system include allowable downtime and recovery procedures, operate through, acceptable damage and degradation, and the availability of and time required to implement repair and replacement parts.

2.1.2 Nuclear Airblast Facilities.

Acceptable test facilities can be categorized as either large-scale High-Explosive (HE) field tests, or threat relatable shock tubes. Major military systems should utilize a large-scale HE field test because of the system's size, mass, and response; while existing shock tubes should be utilized for small systems or subsystems that are attached to a rigid structure. In general, items that can translate or be damaged by ground shock should be tested at an HE event. Examples of acceptable facilities are:

Facility	Type	Location	Comments
1. DNA PHETS	HE Field Test	WSMR, NM	Large test area Bi-Annual Up To 16 kT simulations Distributed system level
2. USA ARL 2.4 m	Shock Tube	APG, MD	Tube Width - 2.4 m Max Overpressure - 138 kPa Max Duration - 750 ms Component, LRU, and Small System level
3. USA WSMR LBTS	Shock Tube/ Thermochemical Reaction	WSMR, NM	Construction Completed FY94 On Completion, Preferred US Facility Tube Width - 20.0 m Max Overpressure - 241 kPa Max Duration - 3300 ms 0.1 kT - 3MT System level

Other airblast facilities available for nuclear airblast testing are listed in Defense Nuclear Agency (DNA) publication, DASIAC SR-90-252, "Guide to Nuclear Weapons Effects Simulation Facilities and Techniques[1]" (1990 Edition) on pages 2-4 through 2-48. The Project Engineer (PE) must ensure that the airblast test facility utilized is the foremost facility available for the desired criteria, test system configuration, and the anticipated responses. It is important that a pretest analysis be performed so that the best test facility will be selected to provide the best available stimulus for producing the primary responses in the test system. It is emphasized that available facilities will provide only a simulated nuclear blast environment.

**Superscript numbers/letters correspond to those in Appendix J, References.

Therefore, in addition to test data adequate analysis must be performed to account for the facility deficiencies which must be known, quantified, and documented.

2.1.3 Nuclear Airblast Instrumentation.

Devices for Measuring	Preferred Device	Desired Measurement Accuracy
1. Pressure	Pressure Transducers	± 10 %
2. Strain	Strain Gages	± 10 %
3. Acceleration	Accelerometers	± 10 %
4. Translation	High Speed Camera	250 - 400 fps

These measuring devices should be positioned at locations on the test item based upon the pretest response analysis. Data transmissions are normally through twisted pair cable. Transmitted data are normally input to adjustable gain instrumentation amplifiers and transient data recorders with an operating bandwidth of 200 kHz.

2.2 Nuclear Thermal Radiation Facilities and Instrumentation.

2.2.1 Nuclear Thermal Radiation Criteria Parameters. These criteria parameters must be thoroughly analyzed to ensure that acceptable facilities and appropriate instrumentation are utilized.

Thermal Radiation Parameter	Unit
Pulse Width	[sec]
Thermal Flux (Q_{dot})	[cal/cm^2-sec]
Thermal Fluence (Q)	[cal/cm^2]
Time to Maximum Irradiance (t_{max})	[sec]

Performance criteria requirements of the test system include allowable downtime and recovery procedures, operate through, acceptable damage and degradation, and the availability of and time required to implement repair and replacement parts.

2.2.2 Nuclear Thermal Radiation Facilities.

Acceptable test facilities can be categorized as solar collectors, electrical resistance heaters, or thermochemical reactions. For system level response, usually thermochemical reactions are used because they are the only

facilities that can irradiate these large systems, while solar collectors and electrical resistance heaters are preferred and should be utilized on small systems, material samples, and when spectrum fidelity is a concern. Examples of acceptable facilities are:

Facility	Type	Location	Comments
1. USA WSMR Solar Furnace	Solar Collector	WSMR, NM	Excellent Spectrum Subsonic Wind Tunnel Shaped Nuclear Thermal Pulse / No limit on Fluence Peak Flux - 100 cal/cm^2-sec Area - 15 cm diameter Component level
2. DNA Xenon Lamps	Electrical Resistance Heater	Wright Patterson Air Force Base (WPAFB), OH	Wind and Load Peak Flux -1748 cal/cm^2 sec Max Fluence - 474 cal/cm^2 Area - 10 x 11 cm Component and LRU level
3. DNA TRS	Thermochemical Reaction	WSMR, NM	Large Test Items System level
4. LBTS	Thermochemical Reaction/ Shock Tube	WSMR, NM	Construction Completed FY94 On Completion, Preferred US Facility Tube Width - 20.0 m Max Flux - 75 cal/cm^2-sec Max Fluence - 300 cal/cm^2 System level

Other thermal radiation facilities available for nuclear thermal radiation testing are listed in DASIAC SR-90-252 on pages 3-4 through 3-18. The PE must ensure that the thermal radiation test facility utilized is the best one to accurately simulate desired test environment criteria and test item response in order to adequately test the system configuration. It is emphasized that available facilities will provide only a simulated nuclear thermal radiation environment. Therefore, in addition to good test data, adequate analysis must be performed to account for the facility deficiencies which must be known, quantified, and documented.

2.2.3 Nuclear Thermal Radiation Instrumentation.

Devices for Measuring	Preferred Device	Desired Error of Measuring Device
Temperature	Calorimeters	±5°C
	Thermocouples	±5°C

The nuclear thermal radiation pulse will be monitored and recorded generally through the use of a calorimeter. The waveform generated by the calorimeter will be utilized to determine the simulated thermal radiation environment against the thermal NHC specified for the system. Thermocouples should be attached to the test item to monitor thermal response and recorded utilizing analog and digital recording instruments.

2.3 High Altitude Electromagnetic Pulse (HEMP)/Source Region Electromagnetic Pulse (SREMP) Facilities and Instrumentation.

2.3.1 HEMP/SREMP Criteria Parameters. These criteria parameters must be thoroughly analyzed to ensure that acceptable facilities and appropriate instrumentation are utilized.

HEMP Parameter	SREMP Parameter	Unit
Electric Field - E-field	E-field	[volts/meter]
Magnetic Field - H-field	H-field	[amp-turns/meter]
Risetime	Risetime	[nanoseconds]
	Gamma Dose Rate	[Rads(Si)/sec]
Pulse Width	Pulse Width	[nanoseconds]

Performance criteria requirements of the test system include allowable downtime and recovery procedures, operate through, acceptable damage and degradation, re-boot, and the availability of and time required to implement repair and replacement parts.

2.3.2 HEMP/SREMP Facilities.

Acceptable HEMP test facilities can be categorized as radiating HEMP, hybrid HEMP, or bounded wave HEMP. Simulators in these categories can be vertically or horizontally polarized. Vertically polarized simulators should be utilized on systems which response vertically such as missiles or those possessing large vertical antennas. Horizontally polarized simulators should be utilized on all military land systems, distributed systems, and aircraft. No facility as of this date has been defined as a SREMP facility. However, a

gamma dose rate facility, the HERMES III facility located at Sandia National Laboratories (SNL), Albuquerque, NM, is currently being utilized for this type of testing. Examples of acceptable facilities are the following:

Facility	Type / Polarization	Location	Comments
1. USA WESTA	Bounded Wave Array/ Horizontal	WSMR, NM	Max E-Field - 65 kV/m Area - 13.4 x 13.4 x 15.5h meters QSTAG 244, Ed. 3 System level
2. DNA ARES	Bounded Wave/Vertical	KAFB, NM	Max E-Field - 97 kV/m Area - 40 x 33 x 40h m QSTAG 244, Ed. 3 or MIL-STD 2169A(Approx.) System level
3. USA WSMR HPD	Radiating/Horizontal	KAFB, NM	E-Field at 30 m - 35 kV/m Area - 76 m Diameter QSTAG 244, Ed. 3 Distributed system level
4. USA WSMR VPD	Radiating/Vertical	KAFB, NM	E-Field at 50 m - 70 kV/m Area - 100 m Diameter QSTAG 244, Ed. 3 System level
5. USA WSMR ALECS	Bounded Wave/Vertical	KAFB, NM	Max E-Field - 75 kV/m Area - 25 x 13 7 x 12.5h m QSTAG 244, Ed. 3 System level
6. USA HPD-II	Radiating/Horizontal	KAFB, NM	Max E-Field - 65 kV/m Area - 76 m diameter QSTAG 244, Ed.4 or MIL-STD 2169A System level
7. HERMES-III	SREMP	SNL, NM	System Level

Other HEMP facilities are listed in the DASIAC SR-90-252 on pages 4-5 through 4-54. The PE must ensure that the HEMP test facility utilized is the foremost facility to accurately simulate desired criteria and test system response in order to adequately test the system configuration. More than one facility may be required to adequately test a system to account for horizontal and vertical responses as well as SREMP effects. It is emphasized that available facilities will provide only a simulated HEMP/SREMP environment. Therefore, in addition to good test data, adequate analysis must be performed

to account for the facility deficiencies which must be known, quantified, and documented.

2.3.3 HEMP/SREMP Instrumentation/Dosimetry.

Devices for Measuring	Preferred Device	Desired Error of Measuring Device
1. Current	Current Probes	± 5 %
2. E-Field	D-Dot Probe	± 5 %
3. H-Field	B-Dot Probe	± 5 %
4. Gamma Dose	CaF_2 (Mn)	± 10 %
5. Gamma Dose Rate	Compton Diode	± 10 %

The data acquisition system for the free-field tests should consist of transient digitizers with an operating bandwidth of 250 MHz and 500 MHz (small test items), with a 1 Gigasample per second sampling rate. Fiber optic data transmission system must be equal to the operating bandwidth. All utilized probes must be responsive to at least 1 GHz.

Measurements of each illumination must be monitored by a B-dot probe (measures the time rate of change in the H-Field) or D-dot probe (measures the time rate of change in the E-Field) so that the magnitude of the E-field and pulse shape information is obtained. This information should be digitized, analyzed, and stored for a later detailed analysis.

In the case of SREMP testing, the gamma dose and dose rate at selected locations on the test system will be measured using Calcium Fluoride Manganese CaF_2 (Mn) Thermoluminescent Dosimeter (TLDs) and Compton diodes, respectively. The measured gamma dose values will be expressed in cGy(Si) and cGy(tissue) by these general ratios, however the "Annual Book of ASTM Standards[2]", E666 and E668 must be referenced for each test:

$cGy(Si)/cGy(CaF_2) = 1.02$ and $cGy(tissue)/cGy(CaF_2) = 1.13$, respectively.

2.4 Gamma Dose Rate Facilities and Instrumentation.

2.4.1 Gamma Dose Rate Criteria Parameters. These criteria parameters must be thoroughly analyzed to ensure that acceptable facilities and appropriate instrumentation are utilized.

Prompt gamma radiation pulses generate the production of charge carriers and subsequent photocurrents. These damaging photocurrents which flow across device junctions induce transient upset, latch-up and/or burnout in the semiconductor devices.

Gamma Dose Rate Parameter	Units
Peak gamma dose rate	[cGy(Si)/sec]
Pulse Width	[nanoseconds]
Energy	[Mev]

Performance criteria requirements of the test system include allowable downtime and recovery procedures, operate through, acceptable damage and degradation, and the availability of and time required to implement repair and replacement parts.

2.4.2 Gamma Dose Rate Facilities.

Acceptable test facilities can be categorized as electron linear accelerators (LINAC), or flash X-Ray simulators. Major military systems and subsystems should utilize flash X-ray simulators because they can irradiate large test systems; while LINACs should be utilized on electronic piece-parts, components, and circuit card assemblies because of cost effectiveness, pulsewidth variability, and quick turn-around times. Examples of acceptable facilities are:

Facility	Type	Location	Comments
1. USA WSMR LINAC	LINAC	WSMR, NM	Max Dose Rate - 2E11 cGy(Si)/sec Pulse Width - 10 ns to 10 μs Piece-part and component level
2. USA WSMR REBA	Flash X-ray	WSMR, NM	Max Dose Rate -2.6E11 cGy(Si)/sec Pulse Width - 50 to 85 ns Up to system level
3. DOE SNL HERMES III	Flash X-ray	KAFB	Max Dose Rate - > 5E12 cGy(Si)/sec Pulse Width - 20 ns Large system level

Other gamma dose rate facilities are listed in DASIAC SR-90-252 on pages 5-63 through 5-128. The PE must ensure that the gamma dose rate test facility utilized is the foremost facility to accurately simulate desired criteria over an adequate exposure area and test item responses in order to adequately test the system configuration. It is emphasized that available facilities will provide only a simulated gamma dose rate environment. Therefore, in addition to good test data, adequate analysis must be performed to account for the facility deficiencies which must be known, quantified, and documented.

2.4.3 Gamma Dose Rate Instrumentation/Dosimetry.

Devices for Measuring	Preferred Device	Desired Error of Measuring Device
1. Photocurrent	Photocurrent Probes	± 5 %
2. Gamma Dose	**CaF_2 (Mn) TLDs	± 10 %
3. Gamma Radiation Pulse	PIN Diode	± 10 %
	Compton Diode	± 10 %
4. Current	Multimeter/Digitizer /Oscilloscope	± 5 %
5. Voltage	Multimeter/Digitizer /Oscilloscope	± 5 %

** Other materials may be utilized instead of CaF_2 (Mn) to determine gamma dose. However, the material's calibration and detection must conform with the procedures outlined in "Annual Book of ASTM Standards, Section 12".

The gamma dose is generally measured using CaF_2 (Mn) TLDs. The measured gamma dose values will be expressed in cGy(Si) and cGy(tissue) by these general ratios, but the "Annual Book of ASTM Standards", E666 and E668 must be referenced for each test:

$cGy(Si)/cGy(CaF_2) = 1.02$ and $cGy(tissue)/cGy(CaF_2) = 1.13$, respectively.

Each radiation pulse will be measured using a PIN or Compton diode and digitized on a transient digitizing system. The pulsewidth (FWHM) of each radiation pulse will be obtained from this digitized signal. The gamma dose rate for each pulse will then be determined from the dose recorded on the TLDs and divided by the pulsewidth obtained from the digitizers.

2.5 Neutron Fluence Facilities and Instrumentation.

2.5.1 Neutron Fluence Criteria Parameter. This criteria parameter must be thoroughly analyzed to ensure that acceptable facilities and appropriate instrumentation are utilized.

Fast neutrons interact with semiconductor material in electronic piece-parts by elastic collisions with lattice atoms which decrease minority carrier lifetimes and increase device resistivity. This resulting damage alters electrical parameters of the device which can cause failure in the semiconductor devices or circuit applications.

Neutron Fluence Parameter	Units
Neutron Fluence	[1 Mev(Si) n/cm^2]

Performance criteria requirements of the test system include allowable

downtime and recovery procedures, operate through, acceptable damage and degradation, and the availability of and time required to implement repair and replacement parts.

2.5.2 Neutron Fluence Facilities.

Acceptable test facilities can be categorized as either a Fast Burst Reactor (FBR) or a TRIGA reactor. (Sometimes, Californium-252 is utilized for piece-part testing.) These reactors generally can be utilized in the pulse or steady-state mode of operation. In the pulse mode of operation, the FBR can generate neutron fluence up to 5E14 n/cm^2 with energies > 10 keV and gamma dose rate up to 1E9 cGy(Si)/sec with a pulsewidth of approximately 50 μs. However, when total neutron fluence is the primary concern, the steady-state mode of operation is typically used. Examples of acceptable facilities are:

Facility	Type	Location	Comments
1. USA WSMR FBR	FBR	WSMR, NM	Peak Pulse Power - 6.5E4 MW Neutron Fluence - 7E13 n/cm^2 FWHM Pulse Width - 40 to 3000μs Up to system level
2. USA APG APRF	FBR	APG, MD	Peak Pulse Power - 1E5 MW Neutron Fluence - 5E14 n/cm^2 FWHM Pulse Width -50 μs to 10ms Up to system level

Other neutron fluence facilities are listed in DASIAC SR-90-252 on pages 5-42 through 5-62. The PE must ensure that the neutron fluence test facility utilized is the foremost facility to accurately simulate desired criteria and test item responses in order to adequately test the system configuration. It is emphasized that available facilities will provide only a simulated neutron fluence environment. Therefore, in addition to good test data, adequate analysis must be performed to account for the facility deficiencies which must be known, quantified, and documented.

2.5.3 Neutron Fluence Instrumentation/Dosimetry.

Devices for Measuring	Preferred Device	Desired Measurement Accuracy
1. Neutron Fluence	**Sulfur Activation Foil	± 10 %
2. Gamma Dose	**CaF_2 (Mn) TLDs	± 10 %

** Other materials or techniques may be utilized instead of sulfur and CaF_2 (Mn) to determine neutron fluence and gamma dose, respectively. However, the material's calibration and detection must conform with the procedures outlined in "Annual Book of ASTM Standards, Section 12".

Devices for Measuring	Preferred Device	Desired Measurement Accuracy
3. Current	Multimeter/Digitizer /Oscillioscope	± 5 %
4. Voltage	Multimeter/Digitizer /Oscilloscope	± 5 %

The neutron fluence at each test location will be measured using sulfur activation foils which measure neutrons with energies greater that 3 MeV; but, the "Annual Book of ASTM Standards", E720, E721, and E722 must be referenced. The measured fluence will be converted to 1 MeV(Si) equivalent damage fluence by the following relationship:

1 MeV(Si) eq. neutron fluence = K * (3 MeV neutron fluence)

where K is experimentally determined with respect to many factors, such as energy, spectrum, and source-to-target distance.

The gamma dose will be measured using CaF_2 (Mn) TLDs. The measured gamma dose values will be expressed in cGy(Si) and cGy(tissue) by these typical ratios, but the "Annual Book of ASTM Standards", E666 and E668 must be referenced for each test:

$cGy(Si)/cGy(CaF_2)$ = 1.02 and $cGy(tissue)/cGy(CaF_2)$ = 1.13, respectively.

2.6 Total Gamma Dose Facilities and Instrumentation.

2.6.1 Total Gamma Dose Criteria Parameter. This criteria parameter must be thoroughly analyzed to ensure that acceptable facilities and appropriate instrumentation are utilized.

Total gamma dose generates hole-electron pairs through the process of ionization in the semiconductor material resulting in trapped charges. These total dose effects are exhibited either as a change in electrical parameters or as a catastrophic failure in semiconductor devices.

Total Gamma Dose Parameter	Units
Total Gamma Dose	[cGy(Si)]

Obtaining the proper total gamma dose test criterion can be difficult. The PE must first obtain NHC and the identify the subheading: "Silicon Absorption/Displacement Damage". Under this subheading, is the title " Max Combined Neutron and Gamma Ionizing Dose, (cGy(Si))" referred to as D_1. With this value of D_1, the PE must subtract the neutron dose contribution. This acquired value is the actual Center-Of-Mass (COM) total gamma dose to be received by the test item.

Performance criteria requirements of the test system include allowable downtime and recovery procedures, operate through, recovery time, degradation and/or acceptable damage, and the availability of and time required to implement repair and replacement parts.

2.6.2 Total Gamma Dose Facilities.

Acceptable test facilities typically utilize a Cobalt-60 source or multiple Cobalt-60 sources. Large systems are extremely difficult to test adequately because no large scale DOD /DOE gamma dose facility is available. Therefore, most testing should be accomplished at the piece-part, component, LRU, and subsystem level. Whole body irradiations are typically limited to surfaces < 1.5 m on a side for gradient and disposition rate reasons. Examples of acceptable facilities are:

Facility	Location	Comments
1. USA WSMR GRF	WSMR, NM	Max Dose Rate - 1700 cGy(Si)/sec Exposure Area - 13 x 6 x 4 height m 8 Sources Piece-part, Component, LRU, subsystem and system level
2. USA APG APRF	APG, MD	Max Dose Rate - 600 cGy(Si)/sec Exposure Area - 15.2 cm Dia. x 20.3 height cm Piece-part, Component, small LRU/subsystem level
3. USA ARL Cobalt-60 Facility	Adelphi, MD	Max Dose Rate - 215 cGy(Si)/sec Exposure Area - 9.5 cm Dia. x 25 height cm Piece-part, Component, very small LRU/ subsystem level

Other total gamma dose facilities are listed in DASIAC SR-90-252 on pages 5-9 through 5-41. The PE must ensure that the total gamma dose test facility utilized is the foremost facility to accurately simulate desired criteria over an adequate exposure area and test item responses in order to adequately test the system configuration. It is emphasized that available facilities will provide only a simulated total gamma dose environment. Therefore, in addition to good test data, adequate analysis must be performed to account for the facility deficiencies which must be known, quantified, and documented.

2.6.3 Total Gamma Dose Instrumentation/Dosimetry.

Devices for Measuring	Preferred Device	Desired Error of Measuring Device
1. Gamma Dose	**CaF_2 (Mn) TLDs	± 10 %
2. Current	Multimeter/Digitizer /Oscilloscope	± 5 %
3. Voltage	Multimeter/Digitizer /Oscilloscope	± 5 %

**Other materials may be utilized instead of CaF_2 (Mn) to determine gamma dose. However, the material's calibration and detection must conform with the procedures outlined in "Annual Book of ASTM Standards, Section 12".

The gamma dose will be measured using CaF_2 (Mn) TLDs. The measured gamma dose values will be expressed in cGy(Si) and cGy(tissue) by these typical ratios for Cobalt 60, but the "Annual Book of ASTM Standards", E666 and E668 must be referenced for each test:

$cGy(Si)/cGy(CaF_2) = 1.02$ and $cGy(tissue)/cGy(CaF_2) = 1.13$, respectively.

3. REQUIRED TEST CONDITIONS.

3.1 Test Preparation.

3.1.1 Scope of Testing. Once a test program is initiated, the first concern of the PE is the establishment of the objectives and the scope of the program. In essence, these questions must be addressed: What equipment and support items are required, how must the equipment be tested in order to maximize determination of its performance, what test environments and at what assumably levels must testing occur, what data are required and how it will be collected, how must the information be processed and analyzed in order to obtain an accurate and complete survivability analysis of the test system and ultimately the system configuration to the criteria environment. The PE must thoroughly understand the operation of all mission essential functions, test criteria, test facility limitations, test objectives, operational and maintenance procedures, performance and operational checkouts, material composition, instrumentation, dosimetry, system integration, environmental considerations, nuclear effects, transient radiation effects on electronics, statistical processes, and safety considerations to adequately devise a realistic test scenario, test schedule, and performance analysis program.

3.1.2 Cost Estimates. Upon devising an appropriate test scenario, a TECOM cost estimate (STE Form 1195) must be prepared IAW TECOM Regulation (REG.) 37-1, TECOM Test Cost Estimates[a] and draft TECOM REG. 70-8, Test Resource Management System[b]. The PE must ensure that the cost estimate adequately covers all reasonable expenditures of the proposed nuclear test and analysis program. These direct expenditures are for manhours, material and supplies, travel, contractual service, equipment, minor construction, facilities, repair

and replacement of test related consumables. Additionally, a small percentage of the total funding should be allotted for contingencies because of facility and test system related problems that almost always occur.

3.1.3 Test Coordination. From the initiation to the completion of the test program, test coordination is a constant and essential task. The PE must coordinate effectively with a multitude of various personnel in order to properly prepare, execute, and determine the nuclear survivability of a test system. Without proper and effective test coordination, a NSA program will experience cost overruns, unnecessary test delays, inadequate test data, improper determinations, and improper usage of manpower. In conclusion, test coordination is one of the most important aspects to project engineering and is essential to the conduct of a successful NSA program.

3.1.4 Environmental Impact. An important pretest requirement IAW Army Regulations (AR) AR 200-1, Environmental Protection and Enhancement[c], and AR 200-2, Environmental Effects of Army Actions[d], is an environmental analysis. This analysis will help alleviate environmental problems that could interfere with the test schedule and completion of the NSA program. The proper documents must be completed and submitted to the environmental office and/or personnel who regulate and control environmental practices at the test execution site prior to start-of-test. The actual time requirement for document submission before test execution, is dependent on the level of preparation required, type of system, and required documentation as well as the workload of the environmental office. Most of the required information can be obtained from the PM's office.

3.1.5 Safety Analysis. Another important pretest coordination task is the safety analysis which must be prepared IAW AMC-R 385-100, Safety Manual[e]. Like the environmental analysis, it should be prepared, submitted, and approved As Soon As Possible (ASAP) to alleviate safety problems which could affect the completion of the NSA program. The safety analysis can usually be obtained from the PM's office or system's contractor. If a complete initial safety analysis is needed, extra time and funds must be allotted to identify the necessary safety procedures and prepare the documentation.

3.1.6 Preferred Nuclear Environment Test Methodology. The PE must ensure that sufficient analysis is performed to account for deficiencies in the simulated nuclear test environment versus the United States Army Nuclear and Chemical Agency (USANCA) environments, variations between the test and production configuration, and the corresponding variations in hardware response. One must initially assume that neither the test environment or hardware are accurate representations of the NHC and system configuration, respectively. There will be differences which must be identified and quantified in order that a survivability analysis can be successfully performed. To accurately achieve compliance with the test objective, one must accomplish the following:

First, perform the pretest analysis to identify:

a. Instrumentation and dosimetry for required response and environment data.

b. Test hardware for each environment.

c. Location of instrumentation and dosimetry.

d. Test facilities and limitations.

e. Test levels per environment.

f. Test system's performance and operational checkouts to adequately analyze all mission essential functions.

g. Required test data per environment.

h. Safety margins of Hardened Critical Items (HCIs).

i. Electromagnetic (EM) energy paths and port-of-entries.

j. Potential test system's responses.

k. Potential susceptibilities and hardness levels in all nuclear environments with respect to the USANCA criteria.

l. Test system's configuration with respect to each environment.

m. Test system's configuration baseline.

n. Differences between test and production configuration.

Second, the PE must thoroughly document and analyze the test hardware which is to be utilized during the NSA. This documentation and determination includes the test system's material composition, shape, size, mass, fastening schemes, shielding and attenuation characteristics, nuclear hardening concepts and devices, mission essential functions, and HCIs and circuits. Then, the PE must analyze the test hardware relative to fielded or proposed fielded system hardware and identify all of the relevant differences. With all this information, the PE can identify and establish the test system and proposed system baseline configuration. This baseline will be utilized for the survivability analysis as well as a basis for analysis of all product improvements, Engineering Change Proposals (ECPs), and configuration changes to ensure that the test system remains nuclear survivable during production, maintenance, and deployment.

Third, the PE must identify the environmental tests that will best meet the requirements identified in the pretest analysis. The nuclear test

environments are Nuclear Airblast, Nuclear Thermal Irradiation, EMP (Endoatmospheric (SREMP) and Exoatmospheric (HEMP)) and Initial Nuclear Radiation (INR) (gamma dose rate, total gamma dose, and neutron fluence). All INR testing should be conducted in the following sequence: gamma dose rate, neutron fluence, and total gamma dose. This sequence is based on actual occurrence and the fact that some semiconductor devices may generate inaccurate failure thresholds if this acknowledged sequence is not preserved. If time constraints or test facility scheduling forces the PE to deviate from this INR test sequence, analysis must be performed to insure that any out-of-sequence related effects on the test system are identified and accounted for. Testing conducted in the EMP, nuclear airblast, and nuclear thermal radiation environments can usually be performed independently with disregard to the test sequence because of the nature of their effects. However, HEMP is preferred after airblast and thermal because: HEMP is produced by an exo-atmospheric detonation and can occur after a surface/near-surface event, and the response of the damaged test item is likely to be more adverse. Synergistic effects on the test system, particularly for thermal and airblast, must be determined because it is real and may significantly enhance damage.

Lastly, the PE must analyze and determine the test system's performance with a detailed post-test analysis. This post-test analysis includes test environments and results of the pretest analysis, documentation and detailed determination of the test system's performance, determination of all shortcomings and failures, and determination of obtained environmental data against the USANCA criteria. In order to effectively determine criteria compliance, the PE must thoroughly understand the simulation fidelity of each test facility. All test facilities have one or more parameter deficiencies; therefore, these deficiencies must be well understood and analysis performed to establish the effects of these parameter deficiencies on the results of the test. With this analysis, the PE can adequately determine the environmental test parameters against the desired USANCA criteria. In order to effectively analyze survivability of the system configuration, the PE must thoroughly understand the differences between the test system's and the system's configuration, and corresponding effects on the analyzed system. Combined with the piece-part/circuit analysis, pretest analysis or other analytical data, the PE will then be able to analyze the survivability of the system's configuration to the USANCA requirements.

3.1.7 Test Plan. The PE must incorporate all the factors and ideas presented in paragraphs 3.1.1 through 3.1.6 into a test plan that must be written IAW TECOM Pamphlet (Pam) 73-1[3]. The test plan must be developed by the PE, submitted to TECOM approximately sixty days prior to, and approved by TECOM approximately thirty days prior to test execution. Test plans should contain the following information:

I. Section 1: Introduction.
1.1 Test Objective.
1.2 Test Authority.
1.3 Test Concept.

1.4 System Description.
1.5 Unique Test Personnel Requirements.
II. Section 2: Subtests. (for each test environment).
2.1 Name of Subtest.
2.1.1 Objectives.
2.1.2 Criteria.
2.1.3 Test Procedures.
2.1.4 Data Required.
2.1.5 Data Analysis/Procedure.
III. Section 3: Appendices.
A. Test Criteria.
B. Test Schedule.
C. Informal Coordination.
D. References.
E. Abbreviations.
F. Distribution List.

Events are likely to occur during the test execution that causes the PE to utilize sound engineering judgement to deviate from the original test plan. Major deviations must be approved by HQ TECOM before implemented. All deviations must be documented in the detailed test report.

3.2 Test Execution.

3.2.1 Pretest Analysis/Modeling. Before the execution of any nuclear test program, a pretest analysis must be performed. During the pretest analysis, the PE must thoroughly examine the test system and manipulate engineering principals and nuclear effects responses to estimate where potential nuclear survivability problems exist. The PE must also determine test facilities to ensure that the best facility is scheduled, sufficient data acquisition is available and scheduled, and required test configurations/orientations can be tested. In order to perform an adequate pretest analysis, the PE must have accurate schematics, part lists, details of deliberate hardening methods/ hardware, previous test and/or analytical data, material composition, wiring diagrams, cable shielding details, and piece-part specifications. Based on the pretest analysis, the PE can establish functional models where significant data can be obtained on the expected performance of the test system through all the different nuclear environments.

3.2.2 Piece-Part/Circuit Analysis Program. One of the major limitations in NSA programs is the difficulty of establishing survivability confidences on systems with extremely small sample sizes. To effectively establish confidence levels, and, hence, the survivability of the baseline system, the PE must consider an analysis program. For INR, this program will use piece-part test data, circuit analysis, modelling methods, and statistical procedures to determine design margins and confidence levels. The piece-part/ circuit analysis program will identify all potential nuclear survivability deficiencies by accounting for response variances due to different manufacturing processes. For EMP, this program will identify and analyze

grounding schemes, cabling, cable shielding, transient and terminal protection devices. For airblast and thermal analysis, the material composition, shape, size, mass, and fastening schemes are analyzed. Only by having adequate design margins in all nuclear survivability environments, can an acceptable airblast, thermal, HEMP, and/or INR survivability analysis be performed on the system's baseline configuration.

3.2.3 Test Organization and Documentation. The formulation of a detailed test plan and effective test coordination prior to the test execution is critical to test organization and execution, and cost effectiveness. Test organization consists of a set of preset procedures for accomplishing specific test execution tasks. Proper test organization will result in superior test execution. The PE must assign and explain to each test support personnel their specific tasks and schedules. Examples include test system and dosimetry placement, probe placement, test documentation, data acquisition, performance checkouts, maintenance procedures, etc. The most important of these specific tasks is test documentation. The PE must ensure that all aspects of the nuclear test program are carefully, completely, and correctly documented. To achieve effective documentation, test specific control forms should be generated. Improper documentation can lead to an inaccurate and incomplete NSA. In conclusion, careful organization and adequate documentation of the test is essential.

3.2.4 Sound Engineering Judgement. During the entire execution of the test, the PE must utilize sound engineering judgement to effectively test and analyze the test item and maintain schedules and costs. Sound engineering judgement becomes extremely critical when schedule impacts occur such as facility downtime, inclement weather, failures and/or re-priorization. Under such conditions, the PE must determine the problem, deviate from the original test plan, and devise an alternate plan or set of procedures. The PE must also devise work-arounds that maximize completion of testing and test objectives.

3.3 Test Reporting and Life-Cycle.

3.3.1 Data Reduction and Analysis. After the completion of all survivability testing, the PE must conduct data reduction and analysis on the raw data. The raw test data are manipulated into an understandable format and documented in Appendix B and summarized in the Test Results section of the test report. The actual data reduction procedures selected are dependent on performance parameters, the test environment, and the criteria parameters. All data reduction procedures must be standardized for each individual test and documented. Clear and concise data reduction and analysis will enhance and enrich the final product, the survivability analysis.

3.3.2 Statistical and Error Analysis. Other forms of analysis that should be performed on the test data are statistical and error analysis. The PE should use statistical analysis to obtain the nuclear survivability probability of electronic piece-parts based on test data, circuit analysis, and safety

margins. The preferred probability with confidence is 99/90 tolerance level (0.99 probability of survivable with a 90 percent confidence). Also, statistical analysis should be utilized to obtain the criteria compliance between actual environment parameters and desired criteria. An error analysis should be performed to account for and eliminate sources of error present in the raw test data. Possible sources of error are: instrumentation and data acquisition, human, test setup, probe, dosimetry, and roundoff. The PE utilizes this error analysis to help predict how accurate the simulated test environment was to the specified USANCA environment and to ensure that test system received its nuclear survivability criteria taking the predicted error into account.

3.3.3 Survivability Analysis of the System Configuration versus USANCA Criteria. Based on data processed (system and environmental), the PE analyzes nuclear survivability of the test system to each test environment. The PE then proceeds to analyze the nuclear survivability of the system's configuration to each of the USANCA environments. To accomplish this, the PE must first identify and define the test system's configuration, test environments, and safety margins. The PE then uses this information to establish nuclear survivability of the test system configuration to the test environments. The test results and environments are then corrected to represent the USANCA environments by accounting for differences and deficiencies. Finally, the PE analyzes the baseline system configuration performance against the corrected or USANCA environments. This is the NSA of the baseline configuration and is the information for the Technical Analysis of the test report. Also, the system's baseline configuration and analysis is the basis for analyzing effects of product improvements or other system configuration changes or repairs on the hardness level and survivability of the system during its lifetime. These future analyses will involve additional piece-part/circuit analysis and piece-part testing where data are not available.

3.3.4 Test Reports. After the PE has completed all test execution, data analyses, and survivability analysis, a detailed test report must be written IAW TECOM Pam 73-1. The test report must be completed and submitted to TECOM NLT seventy days after test completion and approved by TECOM NLT thirty days after submission. Test reports should contain the following information:

Foreword.
I. Section 1: Executive Digest.
1.1 Summary.
1.2 Test Objective.
1.3 Testing Authority.
1.4 Test Concept.
1.5 System Description.
1.6 Conclusions.
1.7 Recommendations.
II. Section 2: Subtests. (for each test environment).
2.1 Name of Subtest.

2.1.1 Objectives.
2.1.2 Criteria.
2.1.3 Test Procedure.
2.1.4 Test Findings.
a. Test Results.
b. Analytical Procedure.
2.1.5 Technical Analysis.
a. Significance of Test Results.
b. Criteria Compliance.
III. Section 3: Appendices.
A. Test Criteria.
B. Test Data.
C. Preliminary Determination of Deficiencies, Shortcomings, and Suggested Improvements.

Other necessary appendices may be included at the option of the author or if specified in the test directive.

The following appendices are required and close in order the test report:

References.
Abbreviations.
Distribution List.

The highlighted portions of the previous list (Summary, Test Findings, & Technical Analysis) are the most significant sections of the test report. The PE must give special consideration to ensure these sections are concise, detailed, complete, accurate and comprehensible.

3.3.5 Life-Cycle Nuclear Survivability Program. The production, operation, maturity, storage, maintenance, modification, and ambient environments must not introduce any form of susceptibilities or unacceptable levels of degradation into a nuclear survivable system. To ensure continued nuclear survivability, a Life-Cycle Nuclear Survivability (LCNS) program must be established IAW the NHC, Army Regulation (AR) 70-60[4], and the Department of Defense Instruction (DODI) 5000.2[5]. The basic purpose of the LCNS program is to control all changes to the baseline configuration during production and product improvements, ensure that an acceptable hardness level is preserved during maintenance by using certified spare parts and procedures, and verifying that the hardness level is not degraded to an unacceptable level during fielding, storage, and operating in the ambient environments.

3.4 Nuclear Airblast Pretest Analysis. During the pretest analysis, the PE must analyze and identify the high risk susceptibilities and test conditions of the test system to the airblast environment. To do this, the PE must effectively:

a. Identify potentially susceptible subsystems and/or system components based upon exposure conditions, materiel composition, shape, size, mass, and

fastening schemes.

b. Identify test system's configuration.

c. Define data acquisition requirements

d. Analyze contractor's program documentation.

e. Analyze hardening and analysis performed by contractor.

f. Define baseline performance checks for test hardware.

g. Identify the most realistic and severe test configuration and orientation with respect to GZ or the source.

h. Identify the type, number, and location of gages to measure response of areas of concern.

i. Analyze potential test facilities to determine the one best for test system or test item(s).

j. Analyze selected test facility's response producing parameters and calculate the expected system response utilizing engineering principals.

k. Perform structural analysis of mechanical and structural response of the test system and of mission critical external fixtures/appendages to the transient loads induced by the blast wave utilizing finite element methods or similar analytical techniques.

l. If appropriate, perform an overturn analysis using TRUCK or a similar code.

m. Identify detailed photography scheme.

3.5 Nuclear Thermal Radiation Pretest Analysis. During the pretest analysis, the PE must analyze and identify the high risk susceptibilities and test conditions of the test system to the thermal radiation environment. To do this the PE must effectively:

a. Identify potentially susceptible subsystems and/or system components based upon exposure conditions, materiel composition, shape, size, and mass.

b. Identify test system's configuration.

c. Define data acquisition requirements

d. Analyze contractor's program documentation.

e. Analyze hardening and analysis performed by contractor.

f. Define baseline performance checks for test hardware.

g. Identify the most realistic and severe test configuration and orientation with respect to the thermal radiation source.

h. Identify the type, number, and location of gages to measure response of areas of concern.

i. Analyze potential test facilities to determine the one best for test system or test item(s). More than one may be required.

j. Analyze selected test facility's response producing parameters and calculate the expected system's thermal response utilizing engineering principals.

l. Define and document all pretest visual inspections and quantified performance check baselines.

m. Identify detailed photography scheme on all exposure areas.

3.6 HEMP/SREMP Pretest Analysis. During the pretest analysis, the PE must analyze and identify the high risk susceptibilities and test conditions of the test system to the HEMP/SREMP environments. To do this the PE must effectively:

a. Analyze drawings and circuits to determine potentially harmful energy paths. The analysis should be concentrated on external unshielded cables of significant length and interface of these cables into subsystems of the test system.

b. Identify test system's configuration.

c. Identify and determine all point-of-entries.

d. Analyze grounding scheme and shielded cables to include backshells and connectors for shielding effectiveness.

e. Determine inherent hardness afforded by the system to its mission critical electronics.

f. Define data acquisition requirements.

g. Analyze contractor's program documentation.

h. Analyze hardening and analysis performed by contractor.

i. Define baseline performance checks for test hardware.

j. Utilize peak pulse power data to analyze the piece-part and terminal

protection devices (TPDs) that are inputs to these large energy paths.

k. Fabricate Breakout Boxes (BOBs) for all cables of concern to enable actual pin measurements to be performed during testing and current injection.

l. Analyze potential test facilities to determine the one best for the test system or its test item(s).

m. Identify the type and location of current and differential voltage probes to be utilized to measure predicted cables and pins of concern.

n. Identify all test orientations.

o. Identify test levels based on results of hardening determination.

p. Identify all test configurations and operating modes.

q. Identify the location for all dosimetry (SREMP).

3.7 Gamma Dose Rate Pretest Analysis. During the pretest analysis, the PE must analyze and identify high risk HCI's and test conditions of the test system to the gamma dose rate environment. To accomplish this, the PE must effectively:

a. Identify all HCIs based upon technology. Consider existing circuit hardening in this screening.

b. Identify test system's configuration.

c. Define data acquisition requirements.

d. Analyze contractor's program documentation.

e. Analyze hardening and analysis performed by contractor.

f. Define baseline performance checks for test hardware.

g. Analyze potential test facilities to determine the one best for the test system and/or its test item(s). At least two different facilities will likely be required - one for piece-parts/components and one for LRUs and/or systems.

h. Identify the most realistic and severe test setup/circuit with respect to the radiation exposure.

i. Identify all current limiting, power removal, and/or gamma dose rate hardening applications.

j. Identify the type, number, and location for all dosimetry and data

acquisition required to collect real time response data.

k. Establish the baseline configuration of the test system.

l. Identify test orientations.

m. Identify test levels based on results of hardening determination.

n. Identify test configurations and operating modes.

o. Acquire test data for all high priority HCIs.

p. Analyze all HCI circuit performance characteristics.

q. Determine HCI safety margins based upon test data, circuit analysis, and statistical techniques.

r. Analyze potential for Dose Enhancement Effects.

3.8 Neutron Fluence Pretest Analysis. During the pretest analysis, the PE must analyze and identify high risk HCIs and test conditions of the test system to the neutron fluence environment. To accomplish this, the PE must effectively:

a. Identify HCIs based upon technology.

b. Identify test system's configuration.

c. Define data acquisition requirements.

d. Analyze contractor's program documentation.

e. Analyze hardening and analysis performed by contractor.

f. Define baseline performance checks for test hardware.

g. Analyze potential test facilities to determine the one best for the test system and/or its test item(s).

h. Identify the most realistic and severe test setup with respect to the neutron source.

i. Identify the type, number, and location for all dosimetry and data acquisition required to collect real time response data.

j. Establish the baseline configuration of the test system.

k. Acquire test data for all high priority HCIs.

l. Analyze all HCI circuit performance characteristics.

m. Determine HCI safety margins based upon test data, circuit analysis and statistical techniques.

n. Identify test orientations with respect to the neutron source.

o. Identify test levels based on results of the hardening determination.

p. Identify test configurations and operating modes.

q. Asses potential for Dose Enhancement Effects.

3.9 Total Gamma Dose Pretest Analysis. During the pretest analysis, the PE must analyze and identify high risk HCIs and test conditions of the test system to the total gamma dose environment. To accomplish this, the PE must effectively:

a. Identify HCIs based upon technology.

b. Identify test system's configuration.

c. Define data acquisition requirements.

d. Analyze contractor's program documentation.

e. Analyze hardening and analysis performed by contractor.

f. Define baseline performance checks for test hardware.

g. Analyze potential test facilities to determine the one best for the test system and/or its test item(s).

h. Identify the most realistic and severe test setup with respect to the radiation source.

i. Identify circumvention and/or total gamma dose hardening techniques.

j. Identify the type, number, and location for all dosimetry and data acquisition required to collect real time response data.

k. Establish the baseline configuration of the test system.

l. Identify test orientations for exposure.

m. Identify test configurations and operating modes.

n. Identify test levels based on results of hardening determination.

o. Acquire test data for all high priority HCIs.

p. Analyze all HCI circuit performance characteristics.

q. Determine HCI safety margins based upon test data, circuit analysis and statistical techniques.

r. Analyze potential for Dose Enhancement Effects.

4. TEST PROCEDURES.

4.1 Nuclear Airblast.

4.1.1 General.

4.1.1.1 Test System. Survivability of the test hardware when exposed to the airblast test environment will be analyzed by:

a. Performing a detailed pretest analysis.

b. Ensuring that the test hardware is properly deployed and in a realistic operational state and configuration as established by the pretest analysis.

c. Establishing the performance baseline of the test hardware prior to the event.

d. Determining effects by visual inspections, performance of the baseline checks, and detailed failure diagnosis.

e. Determining performance/operational data of the test hardware.

f. Analyzing both still and high speed motion photography of the test hardware taken before, during, and after the airblast event.

g. Analyzing response measurements from instruments such as acceleration, pressure, and strain gages.

h. Determining damage and/or degradation in regards to impacts on mission accomplishment.

i. Analyzing test environment data.

4.1.1.2 Baseline System. The survivability of the baseline system configuration when exposed to the airblast USANCA environments will be analyzed by:

a. Analyzing the differences between the test and USANCA environments.

b. Analyzing the differences between the test and baseline configurations.

c. Determining the response of the baseline configuration to the USANCA environment.

4.1.2 Test Setup. The test setup is based upon results obtained from the pretest analysis and should consist of:

a. Position the test hardware at the desired test location and in the correct test configuration.

b. Prior to the event, the complete test hardware must be examined to ensure proper operation and establish the performance baseline.

c. Instrument the test hardware IAW the pretest analysis to acquire critical response data of the test hardware. Instrumentation includes pressure transducers, accelerometers, and strain gages. Ensure instrumentation is calibrated.

d. Photograph the pretest setup to include instrumentation locations.

e. Setup, check, and calibrate the complete data acquisition system. Check the cables to ensure adequate attachment to the transducers, data recorders, and amplifiers; and that they are sufficiently protected against the blast wave. Set-up amplifiers and transient digitizers IAW predictions of the pretest analysis. All data acquisition calibration should be accomplished at the test location to ensure accuracy.

f. Setup, checkout, and calibrate backup data channels for critical areas and responses.

g. Setup, checkout, and calibrate the pressure transducers to measure the principal free-field environmental parameters.

h. Setup the high speed motion cameras to record the response of the test hardware during the event. Typical speeds are 250 and 400 Frames Per Second (fps).

i. Ensure the test hardware is in the proper operational mode for the test.

4.1.3 Test. After the airblast environment has been produced and the test area is considered safe, a comprehensive damage analysis must be performed on the test hardware. This damage analysis will consist of post-event photography, a detailed visual inspection, displacement measurements, and complete post-event performance/operational checks. Response data obtain from pressure transducers, accelerometers, and strain gages will be processed and thoroughly analyzed and determined. All pertinent pre-event and post-event

information must be clearly and accurately documented and analyzed. Diagnostics of all failed and mission degraded areas must be performed and the results determined.

The test environment data will be processed, analyzed, and determined. The eight test environment parameters will be analyzed against the USANCA parameters to determine criteria compliance. These criteria compliances must be utilized in correcting induced and projected responses in the test system and baseline configuration, respectively.

4.2 Nuclear Thermal Radiation.

4.2.1 General.

4.2.1.1 Test System. Survivability of the test hardware when exposed to the test thermal radiation environment will be analyzed by:

a. Performing a detailed pretest analysis.

b. Establishing the performance baseline of the test hardware prior to testing to include pretest photography, performance and operational checks, and visual inspections.

c. Determining effects by repeating all performance baseline procedures and visual checks on each test item after exposure to thermal radiation.

d. Exposing mission critical items to at least 1.3X with 1.5X desired to establish safety margins and confidence levels.

e. Analyzing photography of the test hardware.

f. Analyzing all instrumentation data (thermocouples & calorimeters).

g. Analyzing all environmental data.

h. Determining damage and/or degradation in regards to impacts on mission accomplishment.

4.2.1.2 Baseline System. The survivability of the baseline system configuration when exposed to the thermal radiation USANCA environments will be analyzed by:

a. Analyzing the differences between the test and USANCA environments.

b. Analyzing the differences between the test and baseline configurations.

c. Determining the response of the baseline configuration to the USANCA environment.

4.2.2 Test Setup. Before testing, the performance of each test item identified in the pretest analysis will be baselined and documented utilizing photographs, visual inspections, and, performance and operational checks. All problems identified will be documented and corrected if detrimental to the thermal radiation test program. The thermal radiation environment will then be monitored using calorimeters and adjusted until the specified thermal pulse is generated. Upon verifying the content of the generated pulse, the calorimeter will be removed and the instrumented test item will be properly positioned in the test chamber. Test setup photographs will be taken. Likewise, the above setup procedures will be repeated for each remaining set of criteria.

4.2.3 Test. After the thermal exposure, the pretest baseline check procedures will be performed. The test item will be repositioned to expose another thermal sensitive area to 1.0X, if required. If the test item survives, a second test sample will be positioned for testing to 1.3X to confirm the previous results and to provide confidence. If this test item fails, a third sample will be exposed to 1.0X to confirm the result of the first test and to provide additional confidence. If the sample survives 1.3X, then, the third sample will also be exposed to 1.3X. This procedure will be repeated until all thermal sensitive areas and/or samples have been exposed and all sets of criteria have been addressed. It is essential that mission critical test items or test samples should be exposed to 1.3X to establish a safety margin to ensure nuclear thermal radiation survivability. All exposed areas will be photographed. Failures will be diagnosed and analyzed as to the cause and effects on mission performance. Response data will be processed, analyzed, and determined. All pertinent data will be documented and analyzed. Where necessary, diagnostics of all failed areas must be performed and the results determined.

The test environment data will be processed, analyzed, and determined. The four critical test environment parameters will be analyzed against the USANCA parameters to determine criteria compliance. These criteria compliances must be utilized in correcting induced and projected responses in the test system and baseline configuration, respectively.

4.3 HEMP/SREMP.

4.3.1 General.

4.3.1.1 Test System. Survivability of the test system when exposed to the test HEMP and/or SREMP environment will be analyzed by:

a. Performing the detailed pretest analysis.

b. Calibrating required Data Acquisition Systems (DAS).

c. Establishing the performance and operational baseline for the test system prior to testing.

d. Determining effects by repeating the performance and operational baseline checks or abbreviated checks after each illumination.

e. Illuminating the test system in the pre-selected orientations, configurations, and modes at 0.5, 0.75, 1.0, and 1.5 times (if possible) its E-field criterion level as defined in the pretest analysis phase. Determining all upsets, failures, downtimes, mission performance impacts, and corrective actions.

f. Analyzing response and environmental data.

g. Current injecting at 1X, 5X, and 10X based upon simulator signals and/or damped sinusoidal waveforms obtained from CS10 and CS11 in Military Standard (MIL-STD) 461C[6] or 461D[7].

h. Acquiring Shield Cable Test (SCT) measurements for baselining the test system and for the LCNS database.

i. Analyzing system response in both the time and frequency domains.

The PE must ensure that accurate, consistent and documented operational checks are utilized. Many of the problems induced by the illumination will be transient upsets and will be correctable by recycling power.

4.3.1.2 Baseline System. The survivability of the baseline system configuration when exposed to the HEMP/SREMP USANCA environments will be analyzed by:

a. Analyzing the differences between the test and USANCA environments.

b. Analyzing the differences between the test and baseline configurations.

c. Determining the response of the baseline configuration to the USANCA environment.

4.3.2 Test Setup. Prior to testing, the complete test system will be analyzed to ensure proper operation and establish the performance baseline. All problems identified will be documented and corrected if detrimental to the HEMP and/or SREMP test program. The test facility will perform calibration and noise measurements on the DAS to ensure that accurate data acquisition will be achieved. The DAS utilized must account for all introduced error and be adequately protected against EM interference. The test system will be positioned in its first orientation in the facility's test volume based upon facility mapping data. Breakout boxes will be installed, dosimetry positioned (SREMP), and current and/or voltage probes will be positioned based on information obtained from the pretest analysis. The baseline or abbreviated baseline checks will be performed. Test setup photographs will be taken. These procedures will be repeated for each test orientation and configuration

at each test level.

4.3.3.1 Test. The test system will be illuminated by a simulated HEMP and/or SREMP waveforms. After illumination, the test system will be analyzed to identify and quantify effects by using the pretest baseline checks and diagnostic checks, if necessary. Test probes and new dosimetry will be repositioned, if required, and the test system will be illuminated again. This procedure will be implemented until sufficient data are obtained for all functional modes and system configurations on all cables identified in the pretest analysis. At the completion of the first successful test system orientation, the system's orientation will be altered IAW the pretest analysis unless the test results dictates differently. Once adequate data are obtained for the initial test level, the test level will be incremented as specified in paragraph 4.3.1.e. The levels specified in paragraph 4.3.1 can be altered based on engineering judgements of the results/effects of the on-going test. Multiple illuminations or a substantial test sample size (seven test items is preferred) must be utilized to provide statistical confidence in the HEMP and/or SREMP survivability of the test system. Failures and significant upsets will be diagnosed as to cause and impacts on mission accomplishment. Response data will be processed, analyzed, and determined. All pertinent data will be analyzed.

The test environment data will be processed, analyzed, and determined. The four critical test environment parameters will be analyzed against the USANCA [illegible]meters to determine criteria compliance. These criteria compliance[illegible] must be utilized in correcting induced and projected responses in the test system and baseline configuration, respectively.

4.3.3.2 Current Injection and SCT.

Current injection techniques are essential to distributed systems and should be utilized as an integral part of the EMP test. Current injection is greatly beneficial in the context of determining safety margins and, enhancing and verifying HEMP simulator results. But, current injection should not be the primary means of obtaining accurate HEMP data.

Based upon the actual response measurements and cable/pins identified in the pretest analysis, there will be current injected, direct or inductive, at the maximum measured current level up to a level recommended for the sub-assemblies by CS10 and CS11 of MIL-STD 461C or 461D. Also, dominant coupling frequencies obtained from the simulator tests will be current injected. Current and/or voltage probes will be positioned on the injected cables and response measurements will be obtained. The baseline or abbreviated baseline checks will be performed.

Circuit response measurements will be made at each test level IAW CS10, C11, and dominant coupling frequencies. These data will be digitized and stored so that a detailed analysis can be performed and, to update and compare against the LCNS database. Also, these data will be utilized to provide

preferred safety margins such as 5X and 10X to account for variations in hardening features/devices and between systems, and input electronic piece-parts. A thorough baseline performance check will be performed at the completion of current injection testing.

The SCT should be performed on shielded cables of concern identified in the pretest analysis or during simulator testing. These data will be obtained from a spectrum analyzer and stored so that a detailed analysis can be performed. The SCT results will be utilized to baseline the performance of shielded cables for model verification and for comparison during future LCNS tests.

4.4 Gamma Dose Rate.

4.4.1 General.

4.4.1.1 Piece-Part. Survivability of the test system's electronic piece-parts when exposed to the gamma dose rate test environment will be analyzed by:

a. Requiring testing of 10 samples of high risk HCI vendor-parts that are identified in the pretest analysis and for which inadequate test data exists.

b. Detailed characterization of all critical performance parameters of each high risk HCI requiring testing.

c. Calibrating the DAS.

d. Establishing HCI performance characteristics by monitoring transient response of the Device Under Test (DUT) and repeating the pretest performance baseline checks after each exposure.

e. Performing a detailed circuit analysis.

f. Irradiating the vendor-parts while energized.

g. Establishing Design Margins (DMs) (99/90) utilizing the results of the circuit analysis and the characterization/test program conducted at 1X, 5X, and 10X, unless consistent piece-part failures dictates other reasonable DMs.

h. If the probability of an nuclear event occurring on a LRU while powered is small, then the LRU(s) can be eliminated from gamma dose rate testing.

i. Accepting/rejecting high risk HCIs based on DMs which are defined as:

$$DM = \frac{\text{Effects Threshold Level}}{\text{Criteria Dose Rate Level}}$$

4.4.1.2 Test System. Survivability of the test system when exposed to the gamma dose rate test environment will be analyzed by:

a. Performing a detailed pretest analysis.

b. Analyzing deliberate hardening devices and/or techniques for adequacy.

c. Establishing performance and configuration baseline of the test system prior to testing.

d. Irradiating the system while energized and operating.

e. Establishing the system' operational status by identifying and quantifying effects on performance and performance differences after each gamma dose rate exposure by repeating the baseline and diagnostic checks as necessary.

f. Instrumenting the test system, installing Break-out Boxes (BOBs), and calibrating the DAS.

g. Irradiating the test system in different configurations, orientations, and modes.

h. Determining and documenting all upsets and/or damage, downtime, mission performance impacts, and necessary corrective action procedures.

i. Stressing the system by utilizing multiple exposures at the criterion level.

j. Exposing mission critical items to levels that can be utilized to verify a specified DM of at least 2X with 5X desired.

k. Determining survivability of the test item/system to the test environment.

Upsets and/or latchups are expected. The first corrective action attempt will be to recycle power.

4.4.1.3 Baseline System. The survivability of the baseline system configuration when exposed to the gamma dose rate USANCA environment will be analyzed by:

a. Analyzing the differences between the test and USANCA environments.

b. Analyzing the differences between the test and baseline configurations.

c. Determining the response of the baseline configuration to the USANCA environment.

4.4.2 Test Setup.

4.4.2.1 Piece-Part. Prior to testing, a detailed pretest performance characterization of each of the high risk HCIs in its specified test circuit must be performed. Characterization data will be collected on eleven samples of each vendor-part utilizing mainframe digital, analog, and/or mixed signal testers. The characterization program should include all major manufacturer's parameter specifications. Before testing, the desired Source-To-Target (STT) distances and pulsewidths required for each test level and configuration must be mapped and calibrated utilizing CaF_2 (Mn) TLDs and a PIN Diode. Each of the DUTs will then be positioned, in turn, centered upon the facility's beamwidth at the determined STT distance to receive the first required test level. A PIN diode will be positioned next to the DUT in the beam to measure each individual pulsewidth. Calibrated probes to measure the response of the DUT are positioned on individual pins of the DUT to monitor currents, voltage, and induced photocurrents during irradiation. These probes are the input to a DAS. The DAS should utilize double shielded data cables or fiber optics to transmit signals to the transient digitizers and waveform processors. Protection of the DAS against Radio Frequency (RF) fields must be provided for, otherwise, instrumentation may be damaged or data corrupted by spurious signals. Finally, the DUT's test circuit is energized and its performance baseline is accurately established.

4.4.2.2 System. Prior to testing, a performance baseline for the test system will be established. Problems identified will be documented and corrected if detrimental to the gamma dose rate analysis program. The various STT distances and exposure areas will be determined from previous test data, then refined by measurements. An area equal to the area of active electronics will be mapped using CaF_2 (Mn) TLDs. The selection of each STT distance will also include the requirement that the gamma dose rate gradient across the target area is less than 10%. The test system will be powered during each irradiation. The system will be positioned at the first STT distance to receive a specified percent of the criterion gamma dose rate level based upon the pretest analysis. In place and prior to irradiation, the test system's baseline and operational status will be re-verified. The gamma dose rate level should be applied to the Center-of-Mass (COM) of the test volume of the system. The TLDs and pulse shape measuring devices such as Compton Diodes will be positioned at selected locations on the test system to measure the received gamma dose and pulsewidth, respectively. The current, voltage, and/or transient photocurrent probes are positioned IAW the pretest analysis. The DAS should be setup using double shielded data cables or fiber optics, transient digitizers, and waveform processors. Protection of the DAS against RF fields must be provided for, otherwise, instrumentation may be damaged or

data corrupted by spurious signals.

4.4.3 Test.

4.4.3.1 Piece-Part. Ten samples of each vendor-part will be characterized, irradiated at 1X the criterion level while biased, and characterized again. This procedure will be repeated at 2X, 5X, and 10X the criterion level unless a valid failure occurs such as the vendor-part failing to meet manufacturer's specifications, upset, latch-up or burnout. An eleventh sample will be characterized and kept as a control device. If a valid failure occurs at or below the criterion level, the vendor-part fails qualification. If a valid failure occurs above the criterion level, then this information along with the circuit analysis will be utilized to establish the DM which, in turn, will be utilized to determine acceptance/rejection. After the DUTs have been irradiated by a gamma dose rate pulse, all circuit operational checks should be initiated within 3 minutes after the irradiation IAW MIL-STD-883[8], Methods 1020, 1021, and 1023; and MIL-STD-750[9], Method 1015. The facility's access time must be taken into consideration in order to provide an accurate analysis of determining whether special action should be initiated. The test environment will be analyzed against the USANCA environment and a criteria compliance established. This criterion compliance will be utilized in determining the survivability analysis of the vendor-part against the USANCA criteria.

4.4.3.2 System Level. After the energized system has been irradiated at 1X the criterion level by a pulse of bremsstrahlung photons, all operational checks should be initiated within 5 minutes or the allowable downtime of the test item after the irradiation. The time duration after irradiation to initiate the baseline checks is dependent on the safety procedures of the utilized test facility. This facility access time must be taken into consideration in order to provide an accurate analysis of determining whether special action should be initiated. If determined to be operational to an acceptable level, the test system's dosimetry will be replaced and the test system will be repositioned and irradiated again. All necessary operation checks between gamma dose rate pulses should be thorough, but as abbreviated as possible to achieve an efficient test program. This process will be repeated until all configurations, modes, orientations and levels identified by the pretest analysis or on-going test results have been accurately tested, analyzed, and documented. The preferred test levels for system level testing are 1X, 2X, 3X, and 5X the criterion level with a preferred sample size of seven. If an upset or latchup occurs, the problem will be documented and diagnosed. Testing will not be continued until the problem is completely understood and its effects on the system has been analyzed. If the problem is upset or latchup, the affected subsystem(s) will be identified and testing will be repeated to ensure that the problem was environment induced. Test/diagnostic circuits will be employed to collect information required in determining the cause and impacts on missions. Usually, resolution can be made at the vendor-level employing the methods described in paragraph 4.4.3.1 above. Work arounds, as necessary, will be implemented to complete the

testing. A follow-up investigation will be performed to identify the failure to the vendor-part level.

A final operational baseline check will be performed on the test system at the end of the test. If possible, sufficient number of test systems should be tested, analyzed, and documented as specified above to achieve extremely important statistical confidence in the gamma dose rate survivability of the test system.

The test environment data will be processed, analyzed, and determined. The critical test environment parameters will be analyzed against the USANCA parameters to determine criteria compliance. This criterion compliance must be utilized in correcting induced and projected responses in the test system and baseline configuration, respectively.

4.5 Neutron Fluence Test Procedures.

4.5.1 General.

4.5.1.1 Piece-Part. Survivability of the test system's electronic piece-parts when exposed to the neutron fluence test environment will be analyzed by:

a. Requiring testing of 10 samples of high risk HCI vendor-parts that are identified in the pretest analysis and for which inadequate test data exists.

b. Detailed characterization of all critical performance parameters of each high risk HCI requiring testing.

c. Establishing HCI performance characteristics by repeating the pretest performance baseline checks after each exposure.

d. Performing a detailed circuit analysis.

e. Irradiating the vendor-parts while not energized.

f. Establishing DMs (99/90) utilizing the results of the circuit analysis and the characterization/test program conducted at 1X, 5X, and 10X, unless consistent piece-part failures dictates other reasonable DMs.

g. Accepting/rejecting high risk HCIs based on DM which are defined as:

$$\text{DM (1 Mev Equivalent)} = \frac{\text{Fluence at Which Circuit/Device Fails}}{\text{Criteria Neutron Fluence Level}}$$

4.5.1.2 Test System. Survivability of the test unit/system when exposed to

the neutron fluence test environment will be analyzed by:

a. Performing a detailed pretest analysis.

b. Analyzing deliberate hardening devices and/or techniques for adequacy.

c. Establishing performance and configuration baseline of the test unit/system prior to testing.

d. Irradiating the unit/system while not energized.

e. Establishing the unit/system's operational status by identifying and quantifying effects on performance and performance differences after each neutron fluence exposure by repeating the baseline and diagnostic checks as necessary.

f. Irradiating the test system in different orientations.

g. Determining and documenting all damage, downtime, mission performance impacts, and necessary corrective action procedures.

h. Exposing mission critical items to levels that can be utilized to verify a specified DM of at least 2X with 5X highly desired.

i. Determining survivability of the test unit/system to the test environment.

4.5.1.3 Baseline System. The survivability of the baseline system configuration when exposed to the neutron fluence USANCA environment will be analyzed by:

a. Analyzing the differences between the test and USANCA environments.

b. Analyzing the differences between the test and baseline configurations.

c. Determining the response of the baseline configuration to the USANCA environment.

4.5.2 Test Setup.

4.5.2.1 Piece-Part. Prior to testing, a detailed pretest performance characterization of each of the high risk HCIs in its specified test circuit must be performed. Characterization data will be collected on eleven samples of each vendor-part using mainframe digital, analog, and/or mixed signal testers. The characterization program should consist of all major manufacturer's specifications. Before testing, the desired STT distances and reactor modes required for each test level must be obtained. The various STT

distances will be determined from previous test data, then refined by measurements, if necessary, utilizing sulfur fluence detectors. Each of the DUTs will then be positioned at the determined STT distance to receive the first required exposure level. Pairs of TLDs and sulfur detectors will be placed beside each of the vendor-parts to measure the received gamma dose and neutron fluence, respectively.

4.5.2.2 Test Unit/System. Prior to testing, a performance baseline for the test unit/system will be established. Problems identified will be documented and corrected if detrimental to the neutron fluence analysis program. The various STT distances will be determined from previous test data and then refined by measurements. An area equal to the area of neutron sensitive piece-parts will be mapped using CaF_2 (Mn) TLDs and sulfur fluence detectors. The selection of each STT distance will also include the requirement that the neutron fluence gradient across the target area is less than 10%. The test unit/system will be deployed and tested in a realistic configuration at the first STT distance. The specified neutron fluence level should be applied to the COM of the test unit/system's exposure volume of concern. The TLDs and sulfur detectors will be positioned at selected locations on the test unit/system. Sulfur detectors and TLDs should also be positioned at locations at each of these STT distances in a relatively free-field environment to measure the received gamma dose and neutron fluence, respectively. If required to adequately determine the neutron fluence response of an operate through system, the data acquisition should be accomplished utilizing photocurrent probes, double shielded data cables or fiber optics, transient digitizers, and waveform processors. If the gradient requirement of 10% cannot be met and the test item does not possess an operate through requirement, the test item can be disassembled, exposed in the neutron fluence environment, reassembled, and analyzed to determine the effects on the mission essential functions on the test item.

4.5.3 Test.

4.5.3.1 Piece-Part Level. Ten samples of each vendor-part will be characterized, irradiated at 1X the criterion level, and characterized again. This procedure will be repeated at 2X, 5X, and 10X the criterion level unless a valid failure occurs such as the vendor-part failing to meet its circuit's specifications. An eleventh sample will be characterized and kept as a control device. If a failure occurs, at or below the criterion level, the vendor-part fails qualification. If a failure occur above the criterion level, then this information along with the circuit analysis will be utilized to establish the DM which, in turn, will be utilized to determine acceptance/rejection. After the DUTs have been irradiated by neutrons, all post characterization should be initiated within 24 hours after the irradiation IAW MIL-STD-883, Methods 1017, and MIL-STD-750, Method 1017. The test environment will be analyzed against the USANCA environment and a criteria compliance obtained. This criterion compliance will be utilized in determining the survivability analysis of the vendor-part against the USANCA criteria.

4.5.3.2 Unit/System Level. After the unit/system has been irradiated at 1X the criterion level, all operational checks should be initiated ASAP after the irradiation. For non-powered experiments, usually one hour is the typical time interval between exposure and checkout. The actual access time after irradiation to perform operational checks is dependent on the safety procedures of the utilized test facility. If determined to be operational to an acceptable level, the test unit's/system's dosimetry will be replaced and the test hardware will be repositioned and irradiated again. This process will be repeated until all test levels and conditions identified by the pretest analysis or on-going test results, have been accurately tested, analyzed, and documented. The preferred test levels for system level testing are 1X, 2X, 3X, and 5X the criterion level and the preferred sample size is seven. If a failure occurs, the problem will documented and diagnosed. Testing will not be continued until the problem is completely understood and its effects on the system has been analyzed. The affected subsystem(s) will be identified and testing may be repeated on a second sample to determine whether the problem was environment induced. Test/diagnostic circuitry may be employed to collect information required in determining the cause and impacts on missions. Usually, resolution can be made at the vendor-part level employing the methods described in paragraph 4.5.3.1 above. Work around, as necessary. will be implemented to complete the testing. A follow-on investigation will be performed to identify the failure to the vendor-part level. A final operational baseline check will be performed on the test system at the end of the test. If possible, sufficient number of test units/systems should be tested, analyzed, and documented as specified above to achieve extremely important statistical confidence in the neutron fluence survivability of the test unit/system.

The test environment data will be processed, analyzed, and determined. The critical test environment parameters will be analyzed against the USANCA parameters to determine criterion compliance. This criterion compliance must be utilized in correcting induced and projected responses in the test system and baseline configuration, respectively.

4.6 Total Gamma Dose Test Procedures.

4.6.1 General.

4.6.1.1 Piece-Part. Survivability of the test system's electronic piece-parts when exposed to the total gamma dose test environment will be analyzed by:

a. Requiring testing of 10 samples of high risk HCI vendor-parts that are identified in the pretest analysis and for which inadequate test data exists.

b. Detailed characterization of all critical performance parameters of each high risk HCI requiring testing.

c. Establishing HCI performance characteristics by repeating the pretest performance baseline checks after each exposure.

d. Performing a detailed circuit analysis including any potential Dose Enhancement Effects, reference E1249 of the ASTM Standards.

e. Irradiating the vendor-parts in one continuous pulse of less than one minute duration while energized and operating.

f. Establishing DMs (99/90) utilizing the results of the circuit analysis and the characterization/test program conducted at 1X, 5X, and 10X, unless consistent piece-part failures dictates other reasonable DMs.

g. If the probability of an nuclear event occurring on a the LRU while powered is small, then the LRU(s) can possibly be eliminated from total gamma dose testing.

h. Accepting/rejecting high risk HCIs based on DM which are defined as:

$$DM = \frac{\text{Failure Absorbed Dose}}{\text{Criteria Total Dose Level}}$$

4.6.1.2 Test System. Survivability of the test system to the total gamma dose test environment will be analyzed by:

a. Performing a detailed pretest analysis.

b. Analyzing deliberate hardening devices and/or techniques for adequacy.

c. Establishing performance and configuration baseline of the test system prior to testing.

d. Irradiating the system while energized and operating.

e. Establishing the system's operational status by identifying and quantifying effects on performance and performance differences after each total gamma dose exposure by repeating the baseline and diagnostic checks as necessary.

f. Instrumenting the test system, installing Break-out Boxes (BOBs), and calibrating the DAS.

g. Irradiating the test system in different configurations, orientations, and modes, as required.

h. Determining and documenting all upsets and/or damage, downtime,

mission performance impacts, and necessary corrective action procedures.

i. Exposing mission critical items to levels that can be utilized to verify a specified DM of at least 2X with 4X highly desired.

j. Determining survivability of the test system to the test environment.

4.6.1.3 Baseline System. The survivability of the baseline system configuration when exposed to the total gamma dose USANCA environment will be analyzed by:

a. Analyzing the differences between the test and USANCA environments.

b. Analyzing the differences between the test and baseline configurations.

c. Determining the response of the baseline configuration to the USANCA environment.

4.6.2 Test Setup.

4.6.2.1 Piece-Part. Prior to testing, a detailed pretest performance characterization of each of the high risk HCIs in its specified test circuit must be performed. Characterization data will be collected on eleven samples of each vendor-part using mainframe digital, analog, and mixed signal testers. The characterization program should consist of all major manufacturer's specifications. Before testing, the desired STT distances and runtimes required for each test level and configuration must be mapped and calibrated utilizing CaF_2 (Mn) TLDs. TLDs will be placed next to each of the DUTs to measure the received gamma dose. Each of the DUTs or set of DUTs will then be positioned at the STT distance to receive the first required test level. Next, the DUT's test circuit will be energized and its baseline performance accurately established. Calibrated probes to measure the response of the DUT are positioned on individual pins of the DUT to monitor currents and voltages during irradiation. These probes are the input to a DAS. The DAS should utilize double shielded data cables to transmit signals to the transient digitizers and waveform processors.

4.6.2.2 System. Prior to testing, a performance baseline for the test system will be established. Problems identified will be documented and corrected if detrimental to the total gamma dose analysis program. The various STT distances and exposure areas will be determined from previous test data, then refined by measurements. The area equal to the area of gamma dose sensitive electronics will be mapped using CaF_2 (Mn) TLDs. The selection of each STT distance will also include the requirement that the total gamma dose gradient across the target area is less than 10%. The test system will be deployed at the first STT distance and tested in realistic configurations based on the pretest analysis. The test system will be powered during each irradiation. In place and prior to irradiation, the test system's baseline and operational

status will be re-verified. The total gamma dose level should be applied to the COM of the test system exposure volume of concern. The TLDs will be positioned at selected locations on the test system to measure the received gamma dose. If required to adequately determine the total gamma dose response of the test system, a DAS will be setup and using voltage and/or current probes along with double shielded data cables, transient digitizers, and waveform processors. If at all possible, the total gamma dose exposure should be deposited on the test item within one minute.

4.6.3 Test.

4.6.3.1 Piece-Part Level. Ten samples of each vendor-part will be characterized, irradiated at 1X the criterion level while biased and operating, and characterized again. The total gamma dose must be delivered to the vendor-part in one continuous pulse within one minute. This procedure will be repeated at 2X, 5X, and 10X the criterion level unless a valid failure occurs such as the vendor-part failing to meet manufacturer's specifications or the circuit requirements. An eleventh sample will be characterized and kept as a control device. If a valid failure occurs, at or below the criterion level, the vendor-part fails qualification. If a failure occur above the criterion level, then this information along with the circuit analysis will be utilized to establish the DM which, in turn, will be utilized to determine acceptance/rejection. After the DUT has been irradiated by gammas, all circuit operational checks should be initiated within 5 minutes after the irradiation IAW MIL-STD-883, Method 1019, and MIL-STD-750, Method 1019. The test environment will be analyzed against the USANCA environment and a criteria compliance will be determined. This criterion compliance will be utilized in determining the survivability of the vendor-part against the USANCA criteria.

4.6.3.2 System Level. After the energized and operating system has been irradiated at 1X the criterion level by gamma photons, all operational checks should be initiated within 5 minute after the irradiation. The time duration after irradiation to initiate the baseline and operational checks is dependent on the safety procedures of the utilized test facility. If determined to be operational to an acceptable level, the test system's dosimetry will be replaced and the test system will be repositioned and irradiated again. All necessary operation checks between total gamma dose exposures should be thorough, but as abbreviated as possible to achieve an efficient test program. This process will be repeated until all configurations, modes, orientations and levels identified by the pretest analysis or on-going test results have been accurately tested, analyzed, and documented. The preferred test levels for system level testing are 1X, 2X, and 4X the criterion level and the preferred sample size is seven. If a failure occurs, the problem will documented and diagnosed. Testing will not be continued until the problem is completely understood and its effects on the system has been analyzed. The affected subsystem(s) will be identified and testing may be repeated on a replacement subsystem to ensure that the problem was environment induced. Test/diagnostic circuits will be employed to collect

information required in determining the cause and impacts on missions. Usually, resolution can be made at the vendor-part level employing the methods described in paragraph 4.6.3.1 above. Work arounds, as necessary, will be implemented to complete the testing. A follow-up investigation will be performed to identify the failure to the vendor-part level. A final operational baseline check will be performed on the test system at the end of the test. If possible, sufficient number of test systems should be tested, analyzed, and documented as specified above to achieve extremely important statistical confidence in the total gamma dose survivability of the test system.

The test environment data will be processed, analyzed, and determined. The critical test environment parameters will be analyzed against the USANCA parameter to determine criterion compliance. This criterion compliance must be utilized in correcting induced and projected responses in the test system and baseline configuration, respectively.

5. DATA REQUIRED.

5.1 Nuclear Airblast.

a. Detailed description of the method of producing the airblast environment to include photographs displaying test system configuration with respect to the origin of the airblast environment.

b. Detailed description of all operational and performance baseline checks for all test items comprising the test system.

c. Results from the pretest analysis to include data from the contractor's test/analysis and other airblast test/analysis programs performed on similar military systems.

d. Detailed description (to include composition of the exposed material and hardening hardware) serial numbers, and dimensions of all test items in the test system.

e. Results of the airblast environment measurements with the peak static overpressure expressed in kilopascals(kPa)(±4%), the overpressure duration expressed in ms.(±4%), the overpressure impulse expressed in kPa-ms(±4%), the peak dynamic pressure expressed in kPa(±4%), the dynamic pressure positive duration expressed in ms(±4%), the dynamic pressure impulse expressed in kPa-ms(±4%), the peak static underpressure expressed in kPa(±4%), and the arrival time expressed in seconds (±4%).

f. Detailed description, serial numbers, and location to include photographs of placement of all response measuring gages such as pressure transducers, strain gages, load cells, and accelerometers.

g. Detailed description of the DAS hardware/software.

h. Calibration and percent error data for all data acquisition equipment.

i. Detailed photographs of the test system before and after exposure of airblast environment.

j. Results of pre- and post-exposure visual inspections and pre- and post-exposure performance/operational checks.

k. Results of all failure diagnostics.

l. Expected system acceleration, pressure, or strain responses for gage selection and setting up data recording equipment.

m. Baseline configuration of the test system and proposed production system.

n. List and description of all expected test system support equipment.

o. Detailed description of mission essential functions.

p. Manikins' response measurements, including acceleration (g ±4%), pressure (kPa ±4%), pressure duration (ms ±4%), and peak force (newtons ±4%).

q. Complete set of pretest calculated peak static overpressure levels versus radial distance of test system position from source.

r. High-speed (250 and/or 400 frames per second) motion-picture camera photographs of the test system during the event.

s. Test Incident Reports (TIRs).

5.2 Nuclear Thermal Radiation.

a. Detailed description of the test facility and method of producing the thermal radiation environment to include photographs displaying test item or system configuration with respect to the thermal radiation environment source.

b. Results of pretest thermal radiation analysis on the test item and/or system, identifying potentially high risk test items and/or areas.

c. Results from the pretest analysis to include data from the contractor's test/analysis and other thermal radiation test/analysis programs performed on similar military systems.

d. Detailed description of all performance and operational baseline checks for all items in the test system to be tested.

e. Detailed description (to include composition of the material), serial

numbers, and dimensions of all test items in the test system.

f. Materiel Safety Data Sheets (MSDS) for all irradiated test items.

g. Results of the thermal radiation environment measurements with the total energy expressed in [cal/cm²] (±7%), maximum irradiance expressed in [cal/cm²-sec] (±7%), time to maximum irradiance expressed in seconds (±7%), and pulsewidth (FWHM) (±7%) expressed in seconds.

h. Detailed description of the DAS hardware/software.

i. Calibration and percent error data for all data acquisition equipment.

j. Photographs of the test item, before and after exposure to the thermal radiation environment.

k. Results of pre- and post-exposure visual inspections and pre- and post-exposure performance and operational checks.

l. Results of failure diagnostics.

m. Detailed description of mission essential functions.

n. Detailed description of test item configurations.

o. Baseline configuration of the test system and proposed production system.

p. Detailed description of all expected test item support equipment.

q. TIRs.

5.3 HEMP/SREMP.

a. Detailed description of the method and facility of producing the HEMP and SREMP environment to include photographs of the test facility setup showing test system location relative to the HEMP and SREMP source.

b. Complete set of pretest mapping data of the facility with the E-field expressed in volts/meter (±5%), risetime and pulsewidth expressed in nanoseconds (±5%), frequency expressed in Hertz (±5%), and H-field amplitude expressed in amp-turns/meter (±5%), gamma dose rate expressed in cGy(Si)/sec (±5%), duration of each gamma radiation pulse expressed in seconds (±5%).

c. Results from the pretest analysis to include data from the contractor's HEMP and SREMP test/analysis programs as well as other such programs performed on similar military systems.

d. Detailed description of system performance and operational checks utilized to baseline the system and determine its post-illumination operational status.

e. Complete list of all active electronic piece-parts utilized in the test system.

f. Complete set of electrical schematics and interconnect diagrams.

g. Detailed description, serial numbers, and dimensions of each subsystem of the test system.

h. Detailed description of all system cables to include type, composition, and dimensions.

i. Detailed description of all backshells and connectors to include attachment methodology. type, and composition.

j. Detailed description of the grounding scheme utilized on the test system.

k. Complete list of safety and environmental concerns.

l. Detailed description of all mission essential functions.

m. Detailed description of all deliberate EM hardening techniques/ hardware to include manufacturer's specifications.

n. Detailed description of pretest selected system configurations, orientations, and modes utilized during the test.

o. Detailed description and documentation of all inspections, downtime (sec) (±10%), performance and operational checks, and maintenance procedures.

p. Detailed description of the facility's data acquisition system to include probe calibration data, noise measurements, hardware and software.

q. Detailed description of utilized current and voltage probes, BOBs and probe locations employed on the test system.

r. Results of all HEMP and SREMP environment and test points measurements to include real time response and Fast Fourier Transforms (FFTs).

s. Results obtained from the pretest analysis, Shielded Cable Tests (SCTs), and Current Injection tests (CI).

t. Detailed description of the method and facility producing the SCTs and CIs.

u. Detailed description of recovery procedures and time.

v. Detailed description of the method and facility of producing the gamma dose rate test environment including photographs of the test facility setup showing test system location relative to the gamma radiation source.

w. Results and locations of dosimetry utilized (SREMP).

x. Complete set of pretest mapping data in radiation absorbed dose (cGy) in silicon (cGy(Si))(±10%) and cGy(tissue) (±10%) for each expected test location.

y. Results of all energy coupling and protection hardware analysis to include DMs.

5.4 Gamma Dose Rate.

a. Detailed description of the method and facility of producing the gamma dose rate test environment including photographs of the test facility setup showing test system location relative to the gamma radiation source.

b. Complete set of pretest mapping data in radiation absorbed dose (cGy) in silicon (cGy(Si))(±10%) and cGy(tissue) (±10%) for each expected test location.

c. Risetime and pulsewidth (FWHM) of each gamma pulse.

d. Results from the pretest analysis to include data from other gamma dose rate test/analysis programs performed on similar military systems.

e. Test data and/or analytical data and analysis on the HCIs and the test system from contractor such as Design Parameter Reports (DPRs).

f. List of all active electronic piece-parts utilized in the test system.

g. Piece-part characterization and test data on HCIs from available databases.

h. Detailed description, serial numbers, and dimensions of each subsystem of the test system.

i. Results of applicable piece-part tests and circuit analysis to include DMs.

j. Description of statistical method(s) used to determine DMs.

k. Detailed description and electrical schematics of test circuits utilized.

l. Detailed description of all mission essential functions.

m. Duration of each gamma radiation pulse (sec) (±10%).

n. Total gamma dose expressed in cGy(Si) and cGy(tissue) (±10%).

o. Detailed description of all utilized data acquisition procedures and hardware/software.

p. Detailed description of expected system configurations, orientations, and modes.

q. Detailed description and documentation of all inspections, downtime (sec) (±10%), operational checks, and maintenance procedures.

r. Type and location of dosimeters on the test system for each test exposure.

s. Conversion factors (±10%) used to convert cGy(CaF_2) to cGy(Si) and cGy(tissue).

t. Complete list of safety and environmental concerns.

u. TIRs.

v. Diagnostic data on all failure(s) or unacceptable degradation(s).

5.5 Neutron Fluence.

a. Detailed description of the method and facility of producing the neutron fluence test environment including photographs of the test facility setup showing test system location relative to the neutron fluence source.

b. Time duration (sec) (±1 sec.) and nominal power level (watts) (±5%) for each steady-state operation.

c. Documentation of each radiation pulse signature to include the shape, width at FWHM (μsec) (±10), and burst size (Delta T °C) (±10%).

d. Results of the pretest analysis and data from other neutron fluence test/analysis programs performed on similar military systems.

e. Test data and/or analytical data and analysis on HCIs and the test system from contractor such as DPRs.

f. List of all active electronic piece-parts utilized in the test system.

g. Piece-part characterization and test data on HCIs from available databases.

h. Detailed description (to include material composition, serial numbers, and dimensions of each test item of the test system.

i. Complete set of electrical schematics.

j. Results of applicable piece-part test and circuit analysis to include DMs.

k. Description of statistical method(s) used to determine DMs.

l. Detailed description of all mission essential functions.

m. Total gamma dose expressed in cGy(Si)(±10%), and cGy(tissue) (±10%).

n. Detailed description of utilized data acquisition procedures, hardware/software.

o. Detailed description of test item or system configurations, orientations, and modes.

p. Detailed description and documentation of all inspections, downtime (sec) (±10%), operational checks, and maintenance procedures.

q. Type and location of dosimeters on the test system for each test exposure.

r. Conversion factors (±10%) used to convert cGy(CaF_2) to cGy(Si) and cGy(tissue).

s. Complete list of safety and environmental concerns.

t. TIRs.

u. Diagnostic data on all failure(s) or unacceptable degradation(s).

v. Results of all neutron environment measurements with neutron fluence expressed in terms of 1 Mev (Si) equivalent damage fluence (n/cm^2), (±10%) neutron dose expressed in cGy(Si) (±10%), and gamma dose expressed cGy(Si) and cGy(tissue) (±10%).

x. Complete list of possible expected radioactive isotopes and corresponding half-lifes.

5.6 Total Gamma Dose.

a. Detailed description of the method and facility of producing the

total gamma dose test environment including photographs of the test facility setup showing test system location relative to the gamma radiation source.

b. Complete set of pretest mapping data in radiation absorbed dose (cGy) in silicon (cGy(Si))(±10%) and cGy(tissue) (±10%) for each expected test location.

c. Results of the pretest analysis and data from other total gamma dose test/analysis programs performed on similar military systems.

d. List of all active electronic piece-parts utilized in the test system.

e. Test data and/or analytical data and analysis on HCIs and the test system from contractor such as DPRs.

f. Piece-part characterization and test data on HCIs from available databases.

g. Detailed description, serial numbers, and dimensions of each subsystem of the test system.

h. Detailed description and electrical schematics of test circuits utilized.

j. Results of piece-part tests and circuit analysis to include DMs.

k. Description of statistical method(s) used to determine DMs.

l. Detailed description of all mission essential functions.

m. Duration of each gamma radiation pulse (sec) (±5%).

n. Total gamma dose expressed in cGy(Si) and cGy(tissue) (±10%).

o. Detailed description of all utilized data acquisition procedures.

p. Detailed description and documentation of all inspections, downtime (sec) (±10%), operational checks, and maintenance procedures.

q. Type and location of dosimeters on the test system for each test exposure.

r. Conversion factors (±10%) used to convert cGy(CaF_2) to cGy(Si) and cGy(tissue).

s. Complete list of safety and environmental concerns.

t. TIRs.

u. Diagnostic data on all failure(s) or unacceptable degradation(s).

See Appendix G , Page G-2 for an example of system test data documentation.

6. PRESENTATION OF DATA.

6.1 Data Appropriation and Compliance.

Results from the pretest analysis, and all other applicable nuclear survivability programs will be analyzed and, whenever possible, incorporated into all facets of the NSA on the test system. The incorporation of all available analytical and test data will be used to enhance and reduce the overall scope of the test program.

Data from free-field environment measurements will be utilized to define the test environment and quantify the differences between the test and criterion environments. Differences greater than fifteen percent between the primary parameter values will be analyzed to determine the effect on the test results. Procedures and analysis utilized will be clearly documented.

Results from the pretest analysis, system test and post-test determination/analysis, and environment compliance will be integrated into an analysis of the survivability of the test system's configuration to the test and then the USANCA environments. The final analysis of the test system may show different damage and mission impacts than the test system's results due to extrapolation and correction of environmental and test results to account for variances and differences.

The USANCA NSA requirements are usually derived from the following documents:

a. QSTAG 244, Edition 3: Nuclear Survivability Criteria for Military Equipment[10].

b. QSTAG 244, Edition 4: Nuclear Survivability Criteria for Military Equipment[11].

c. QSTAG 620: Nuclear Survivability Criteria for Communications-Electronics Equipment[12].

d. QSTAG 620, Edition 2: Nuclear Survivability Criteria for Communications-Electronics Equipment[13].

e. MIL-STD-2169A: Fast Electromagnetic Pulse[14].

The final survivability analysis of the baseline system configuration to the USANCA requirements will utilize, incorporate, and integrate data and

results of the test system survivability determination and analysis of the configuration differences. This final survivability analysis of the baseline configuration may show results different than the test system analysis due to extrapolations and/or corrections for configuration differences.

6.2 Data Reduction.

All raw data collected during nuclear survivability testing must be processed to remove data acquisition and dosimetry error and to refine simulation deficiencies. All analytical procedures and methods utilized to process these raw data must be documented along with example calculations in " Appendix B: Test Data" of a detailed test report. The entire collection of raw data should not be presented in the test report because of its excessive bulk. Reduced data that are pertinent to the analysis and support the determinations should be included in tabular form in the main body.

Quantitative and analytical techniques along with adequate response measurements must be utilized during all nuclear survivability testing. A simple GO/NO-GO test is not acceptable and will not enable the survivability of the system to be determined.

The data must demonstrate that the test hardware was adequately tested to its specified criteria in each nuclear test environment. The test environments will then be processed and combined with the pretest results, along with the body of data analyzed, so that the survivability of the test configuration can be determined. Analytical techniques such as PSPICE, TRUCK, NASTRAN, TSA, TSAR, Messenger-Spratt, and curvefitting must be discussed with constraints and inputs to enable the reader to determine adequacy. All analytical data reduction methods must be identified and presented in Appendix B of the test report.

Testing in the HEMP/SREMP and nuclear airblast environment must include data in both the frequency and time domains as well as pertinent processed data in Appendix B of the test report.

Statistical analysis such as computing the mean, standard deviation, 99/90 tolerance limit, minimum data, DMs, and criteria compliance percentages should be performed on all nuclear survivability system test data. Type and quality of data will determine the statistical methods to be employed.

Whenever an electronic piece-part possesses sample size of eleven or more and the data can be assumed to come from a normally distributed population, a 99/90 tolerance limit will be calculated. This statistical figure, calculated from the mean, standard deviation and sample size, is the limit below (or above, depending on the specific parameters of interest) which we expect (with 90% confidence) 99% of the population to survive. In cases where the underlying distribution of the data is not known and cannot be assumed to be normal, nonparametric statistics should be used. In these cases, larger sample sizes will be required to provide the same confidence of attaining the

DM. It should be noted that some adjustment to the desired confidence level and/or population proportion may be necessary for nonparametric techniques (e.g., the 90/90 nonparametric tolerance limit requires a sample size of 22, the 95/90 nonparameteric tolerance limit requires a sample size of 45, and the 99/90 nonparametric tolerance limit requires a sample size of 230). Any changes in population proportions or confidence levels should be coordinated with the AMSAA independent evaluator or TECOM independent assessor.

In electronic piece-part testing, the minimum preferred sample size is eleven because one device is utilized as a control device, four unexposed devices are required for the gamma dose rate phase, four unexposed devices are required for the total gamma dose phase, and two unexposed devices are required for the neutron fluence phase. If possible, two of the electronic devices should be tested to all required test environments.

In system level testing, the preferred sample size of seven is desired to provide an acceptable level of statistical confidence. However, this sample size is extremely difficult to obtain in system level testing. Therefore, stress testing is used to provide additional confidence in the results. Typical stress levels are 1X, 2X, and 4X for INR, 1.3X for airblast and thermal radiation, and 25 illuminations at HEMP/SREMP criteria or 10 illuminations at 1.5X HEMP/SREMP criteria.

Additional data reduction and analytical techniques can be found in the following documents:

a. TOP 1-2-615[15].

b. TOP 1-2-618[16].

c. TOP 1-2-620[17].

6.3 Data Presentation.

Data must be presented in a clear and concise manner, so they are easy to understand and support the conclusions regarding the nuclear survivability of test item/system hardware as depicted in Appendix G. To accomplish this, a combination of charts, graphs, drawings, tables, and photographs should be utilized.

a. Tables should be utilized to present the following data:

1. Irradiation/Illumination Test Results Summary.

2. Equipment Test Matrix.

3. Criteria Compliance.

4. Test Point Data.

5. Statistical Analysis.

6. Criteria and Test Standards.

7. Test Comparisons.

b. Photographs should be utilized to present the following data:

1. Dosimetry Locations.

2. Test Configurations, Orientations, and Set-ups.

3. Test Facility's Data Acquisition Set-up.

4. Locations of Other Utilized Measuring Devices.

5. Real Time Response (airblast).

6. Test Facility Layout.

7. Visible Damage.

c. Drawings should be utilized when photography is not available or inadequate to display critical data supporting the results and/or conclusions. Drawings may also be utilized to illustrate airblast and/or thermal damage and/or effects and test orientations/configurations.

d. Charts and Graphs should be utilized to present the following data:

1. Test Schedules.

2. Criteria Compliance.

3. Previous Test Comparisons.

4. Comparisons of Test Point Data with the Test Item in Different Configurations, Orientations, or Modes.

5. Test Program Status.

e. Circuit analysis and DM determination for each high risk HCI must be provided in Appendix B. As a minimum, the data must include:

1. Test Circuit Layout.

2. Utilized Analytical Techniques.

3. Application of Utilized Data.

4. Design Margins.

APPENDIX A. GENERAL NUCLEAR WEAPON EFFECTS

The detonation of a nuclear weapon generates the following four primary effects or energy distributions: blast, thermal radiation, Initial Nuclear Radiation (INR), and residual nuclear radiation. A fifth effect is generated by the interaction of the INR with the atmosphere and is designated electromagnetic effects. These distributions illustrated in Figure# A-1 are for a generic tactical event at or near the surface. Height-Of-Burst (HOB), weapon type, and weapon configuration do have an affect on the shown energy distributions.

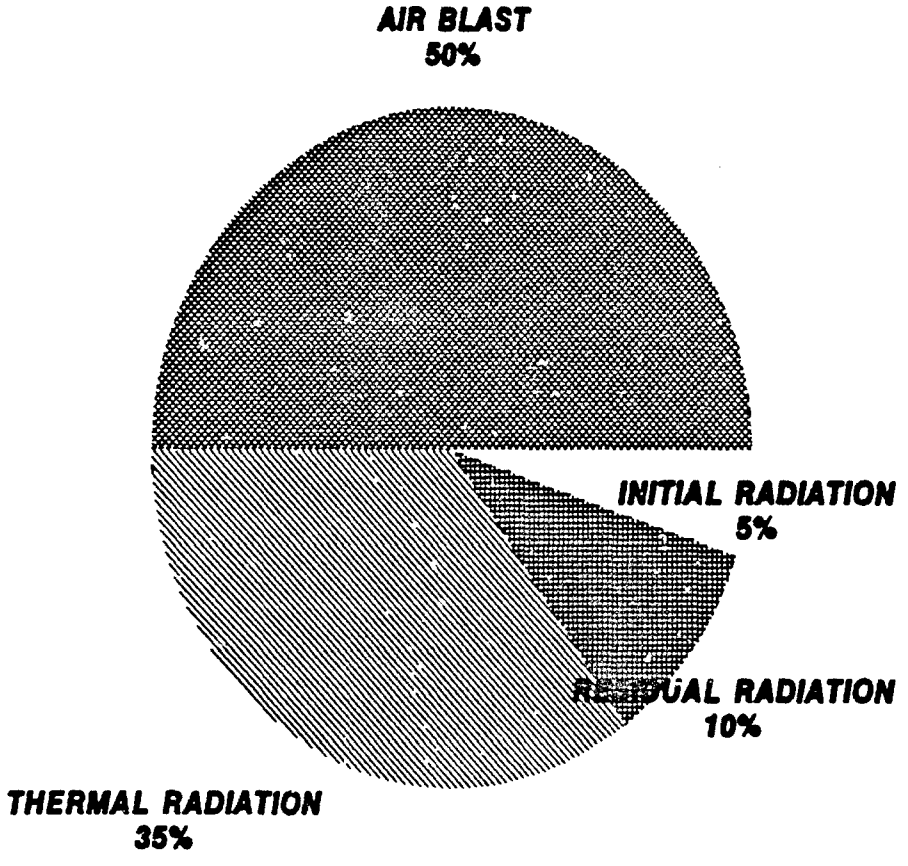


FIGURE #A-1: NUCLEAR WEAPON ENERGY DISTRIBUTION.

A.1 Blast Effects.

The blast effects of a nuclear weapon is extremely similar to those caused by a conventional weapon explosion, but possessing a much larger

magnitude and longer duration. The blast wave travels radially in all directions from Ground Zero (GZ), initially at a speed greater than sound, but decreases as a function of radial distance to subsonic and finally to zero. Blast effects are considered the most damaging to exposed military equipment except armor. Blast effects are typically the greatest cause of collateral damage, but is not typically the greatest personnel casualty producer.

A.2 Thermal Effects.

The thermal pulse of a nuclear weapon is characterized by an intense blinding flash and an immense thermal pulse. The great intensity of this flash can cause blindness to military personnel, either temporary or permanent. The thermal radiation is emitted in two distinct separate pulses. The first thermal pulse occurs as a result of X-ray interaction with weapon materials and is insignificant since it contains very little energy. The second pulse contains tremendous energy and is considered militarily significant and generally the largest casualty producer of exposed personnel. The thermal pulses have two damage producing mechanisms which are: direct damage produced by generated heat and, secondary damage caused by fires and explosions from the ignition of surrounding materials. The blast wave may suppress some fires caused by these thermal pulses. The blast wave combined with the thermal pulse may create synergistic effects.

A.3 Initial Nuclear Radiation Effects.

The INR pulse of a nuclear weapon consists of gamma photons and neutrons which are emitted within a few tens of nanoseconds after the event. These highly penetrative gamma photons and neutrons are extremely damaging to military personnel and electronics. The magnitude of this radiation at a given distance from GZ is dependent upon weapon yield, type and height of burst, terrain and atmospheric conditions. For middle to high yield weapons, the damaging effects generated by the blast wave and thermal radiation greatly surpasses INR effects for unprotected equipment and personnel.

A.4 Residual Radiation Effects.

The residual radiation effects of a nuclear weapon consists of radioactive weapon debris, radioactive fallout, rainout, and Neutron Induced Activity (NIA) which sustains for longer than one minute after weapon detonation. The two militarily significant radiations which compose residual radiation are beta particles and gamma photons. Residual radiation has essentially no damaging effects on military systems, but presents major difficulties on military personnel in the area surrounding GZ, downwind of GZ and troop movement through contaminated areas.

A.5 Electromagnetic Effects.

The electromagnetic environment of a nuclear weapon consists of the ionization of the surrounding atmosphere and Electromagnetic Pulse (EMP).

The gamma photons, neutrons, beta particles, X-rays, and positive ions emitted from the nuclear detonation causes electrons to be ejected from their perspective atoms, thus ionizing the atmosphere in the burst vicinity. This increase in electron density attenuates or refracts all electromagnetic signals from a few seconds to several hours depending on weapon yield and HOB. A nuclear detonation distributes approximately one millionth of its energy in the form of an intense EMP with a frequency content of a few hertz (Hz) to several hundred megahertz (MHz). The two EMP situations which are based upon weapon HOB are Endo-Atmospheric (SREMP) and Exo-Atmospheric (HEMP). SREMP occurs with an atmospheric event at an altitude of less than 40 km above sea level, possessing an extremely large electric and magnetic field over the burst vicinity. HEMP occurs from an event occurring at an altitude greater than 40 km above sea level and possesses a large electric and magnetic field over a diverse area. Of the two EMP situations, HEMP is considered the most militarily significant. In fact, HEMP is a line-of-sight phenomenon and can cause damage over hundreds of thousands even millions of square miles. HEMP has the greatest range of damage of all nuclear effects.

A.6 Time History of Effects.

All effects produced by a nuclear weapon are dependent upon weapon yield, type of weapon, HOB, atmospheric conditions, and distance from GZ. See Figure #A-2 on the following page for the sequence and time history of nuclear weapon effects from an example 27 kT weapon detonation at a HOB of 180 m at a distance of 1 km.

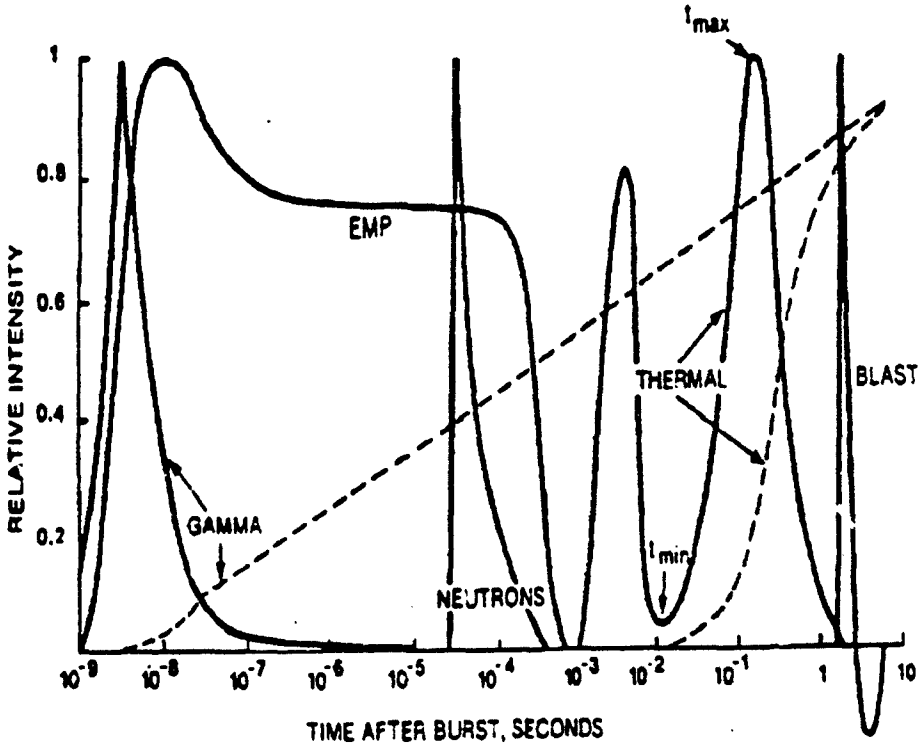


FIGURE #A-2: Example Time History From 27 kT Nuclear Weapon.

The information provided in Appendices B through E where referenced from the following publications:

a. The Effects of Radiation of Electronic systems[f].

b. The Effects of Nuclear Weapons[g].

c. Nuclear Weapons and Their Effects[h].

APPENDIX B. NUCLEAR AIRBLAST ENVIRONMENT AND EFFECTS

Approximately fifty percent of the total energy generated by an Endo-Atmospheric detonation (HOB less than 40 km above sea level) of a normal type of nuclear weapon is in the formation of a tremendous blast or shock wave. Since the air density is relatively high up to 40 km above sea level, the nuclear weapon detonation generates extremely high velocity atoms which transfer tremendous energy to the closest layer of air, compresses a layer of surrounding air, and causes it to propagate outward from the center of the explosion. In the process of compressing a layer of air, a rarefaction occurs in the vacated space creating, in effect, a negative pulse, which propagates outward. Energy is then transferred to each successive air layer and upon emerging from the fireball, this energy release has assumed the characteristics of a blast or shock wave. Initially exceeding the speed of sound, this transfer of energy and momentum forces the air layers to form the shock front of the blast wave.

The blast wave generates five significant damage parameters: static overpressure, dynamic pressure, impulse, duration, and negative overpressure. The first damage parameter overpressure which is defined as the transient pressure above the ambient pressure that acts on objects from all sides and tends to crush inwardly due to pressure differences. The variation of the overpressure with time depends on the energy yield of the explosion, the distance from the point of burst, and the medium in which the weapon is detonated. The second damage parameter is dynamic pressure which is defined as the air pressure which results from the mass air flow or wind behind the shock front of the blast wave that tends to overturn, tumble, or tear apart materiel. It is equal to the product of one half of the air density through which the blast wave passes and the square of the wind velocity behind the shock front as it impinges on the object or structure. The third significant damage parameter is impulse which is defined as the product of the over-pressure or dynamic pressure from the blast wave and the time during which it acts at a given point. More specifically, it is the integral, with respect to time of overpressure or dynamic pressure, between the time of arrival of the blast wave and where that parameter returns to zero at a given point. The fourth significant parameter is duration which is the time in which a phase of the overpressure or dynamic pressure acts upon an object. The final damage parameter is defined as the transient pressure below the ambient pressure that oftentimes enhances damage by pulling back on objects that may be unstable and experiencing forces in the opposite direction. Blast damage will increase with an increase in any of the above parameters. A typical blast wave is illustrated in Figure# B-1.

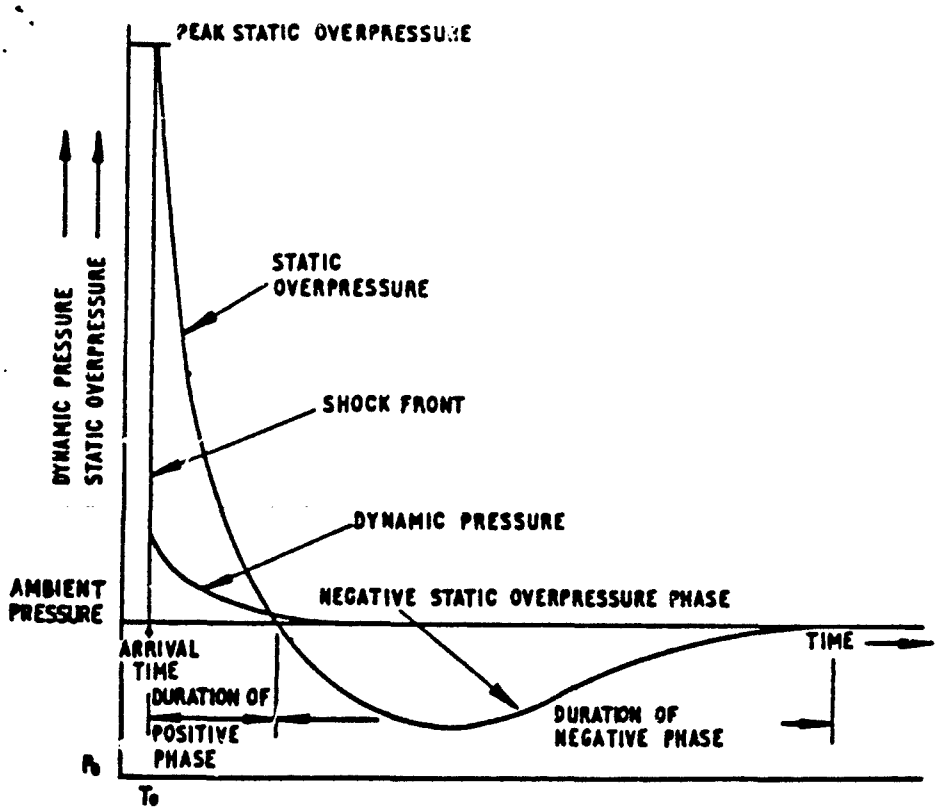


FIGURE #B-1: Typical Blast Wave with Respect to Time at a Fixed Location.

Peak static overpressure decreases with increasing range from GZ, but the duration of the positive and negative phases of the overpressure increases with range. Since target damage caused by overpressure is a function of pressure multiplied by the duration, the magnitude of potential damage does not decrease at the same rate as overpressure attenuation. Many military materiel that have volume with thin walls are damaged by peak static overpressure and are referred to as "diffraction sensitive" targets.

The dynamic pressure is applied on a target for a longer duration than the overpressure because the moving air has mass and therefore momentum which causes it to take longer to come to rest. Most military materiel targets are damaged primarily by dynamic pressure and are referred to as "drag sensitive" targets. The relationship between the peak dynamic pressure and the peak static overpressure is expressed by the Rankine-Huguenot equation which reduces to the following equation on the next page:

$$q = \frac{5}{2} X \frac{P^2}{7Po + P}$$

q = dynamic pressure
P = overpressure
Po = ambient pressure

See Table B-1 for examples of the relationships between peak static overpressure, dynamic pressure, and wind velocity for an Ideal Shock Front.

TABLE B-1. Overpressure and Dynamic Pressure Relationships.

Peak Overpressure (PSI)	Peak Dynamic Pressure (PSI)	Maximum Wind Velocity (MPH)
100	123	1,415
72	74	1,168
50	41	934
30	17	669
20	8.1	502
10	2.2	294
5	0.6	163
2	0.1	70

The HOB of weapon detonation is highly significant in maximizing blast damage. In order to inflict the greatest blast damage on a specific target, the optimum HOB is calculated which will obtain the most effective Mach Stem. Near GZ, the incident and reflected ground shock fronts are separate. But, as the initial blast wave compresses and heats the surrounding air, it generates a swifter medium to which the reflected wave can propagate. Since the reflected wave travels faster because of this heated medium, it joins the initial blast wave and forms an almost vertical and reinforced shock front called the Mach Stem. The location where the incident and reflected waves converge is called the Triple Point. The formation of the Mach Stem produces an immediate and significant rise in exerted pressures which decreases with increasing range from GZ.

In addition, the shock front is also reflected by the face of the target.

The pressure of this reflected target wave is added to the initial over-pressure exerted on the target resulting in a greater overpressure than the original shock front. See Figure #B-2 for Mach Stem formation and Figure #B-3 for ground pressure against increasing range from GZ.

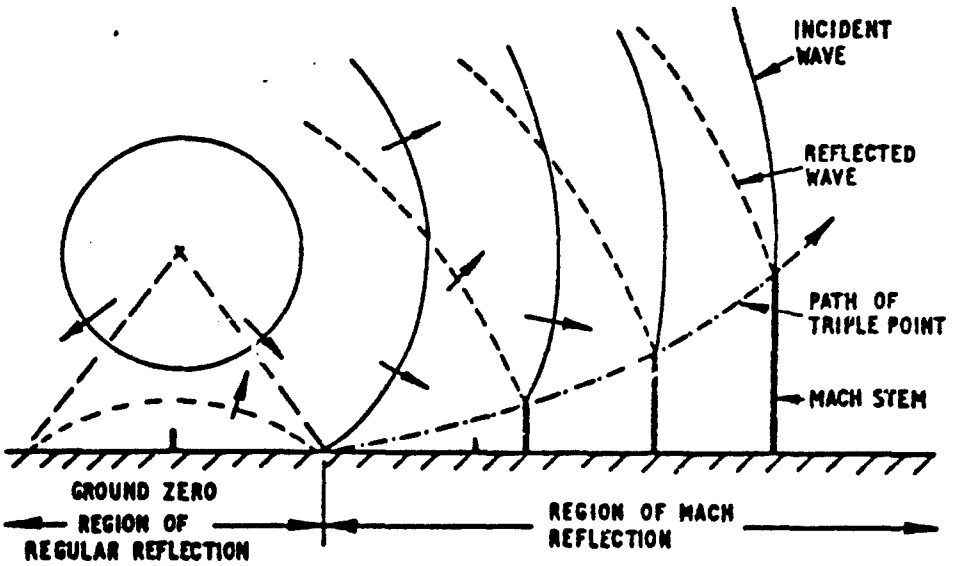


FIGURE #3-2: Formation of the Mach Stem.

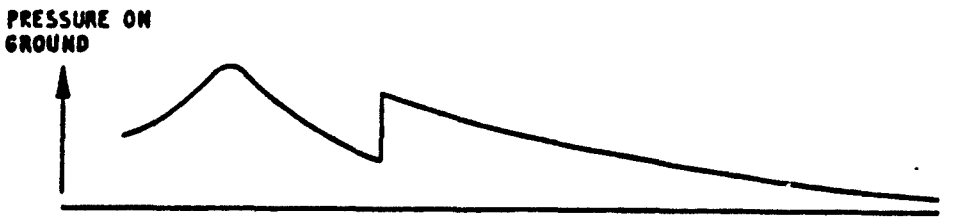


FIGURE #B-3: Ground Pressure versus Increasing Distance from GZ.

A nuclear detonation, particularly a burst that occurs under or near the surface, will transmit a shock wave through the surrounding earth. Ground shock is important in damaging underground targets and shelters, but its effect on materiel targets located on the surface is insignificant in comparison to the effects caused by airblast. Thus, ground shock is not normally considered in the evaluation of survivability/vulnerability of tactical military materiel.

In conclusion, military targets which are exposed to the effects of a nuclear airblast will have the following two distinct sequential effects. First, the overpressure will attempt to crush the target. If the target contains openings, this pressure difference will quickly diminish until equilibrium is established and the crushing effect will be minimized; if the target is closed, it will experience crushing forces for a short period of time. The combination of the blast wind and diffraction loading acting upon the object will exert a force on the object causing it to translate from GZ. Diffraction loading is the force of the static overpressure acting on the front face before the shock front envelops the target. Second, the dynamic pressure will apply drag loading on the object. Drag loading is the force on an object due to the transient winds accompanying the passage of the blast wave. Damage caused by drag loading depends upon the duration and strength of the positive phase of the blast wave.

Nuclear airblast testing requires the use of both experimental and analytical techniques to determine the response of systems and components to the blast wave. Adequate testing of a system requires the accurate simulation and analysis of the nuclear airblast environment in terms of overpressure, dynamic pressure, impulse, duration, and negative overpressure of the entire system under study. Detonation altitude, weapon yield and type, and system configuration, deployment, and mission essential functions must be considered to adequately determine the damaging effects on military systems caused by the blast wave.

APPENDIX C. NUCLEAR THERMAL RADIATION ENVIRONMENT AND EFFECTS

Approximately thirty-five percent of the total energy generated by an endo-atmospheric detonation of a generic nuclear weapon is in the form of thermal radiation. After the detonation of a thermonuclear weapon, the core of the explosion attains an exceedingly high temperature in the tens of million degrees. As a consequence of these exceedingly high temperatures, the core radiates electromagnetic energy which peaks to the soft X-ray spectrum. The absorption of these X-rays by the surrounding air produces tremendous heat which creates the fireball. This generated fireball radiates electromagnetic energy from 250 nanometers in the ultraviolet to 4000 nanometers in the infrared and produces the damaging thermal effects upon military targets. These damaging effects have two governing mechanisms, the total heat delivered and the rate of delivery. As weapon yield is increased, the larger the fireball becomes which significantly increases the total amount of energy that must be dissipated and the duration of energy dissipation. Since this duration is significantly greater for higher yields, the delivery rate of thermal radiation is greatly reduced; therefore, reducing the damaging effects to a military target receiving similar thermal doses from different weapon yields.

In other words, for a specific thermal dose (total energy), a smaller yield weapon can inflict greater damage upon a specified target than a higher yield weapon because the smaller yield delivers the thermal radiation quicker. The three distinct factors which affect the damaging effects of thermal radiation are blast wave screening, inverse square law, and, absorption and scattering due to the atmosphere.

The first factor is blast wave screening. As discussed earlier, the thermal radiation is emitted in two distinct separate pulses. The first pulse is generated by the interaction of the fireball radiating maximum energy and the departure of the shock front. As the fireball's radius increases, the shock front departs from the fireball heating the surrounding air to incandescence which absorbs the thermal radiation from the fireball. This incandescence screens the fireball and causes the shock front to emit thermal radiation instead of the fireball. This process is called blast wave screening. The result is a thermal pulse of little energy and significance in regards to damage effects. As the shock front expands, the cooling of the air allows the fireball to become visible and generates the second thermal pulse. Since this second pulse contains tremendous energy, it is militarily significant. See Figure #C-1 for an example of the thermal radiation output of a nuclear weapon.

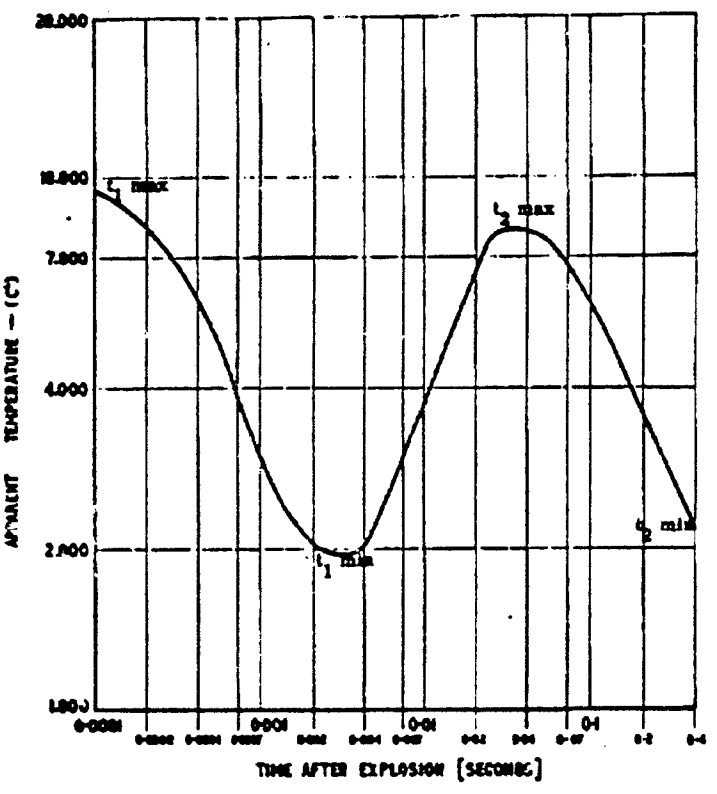


FIGURE #C-1: Fireball Temperature Versus Time During 1 kT Explosion.

The second factor affecting thermal radiation is the inverse square law effect. The inverse square law pertains to all forms of electromagnetic radiation and states that the thermal dose varies as the total energy emitted and inversely as the square of the range from the point of burst. See Figure #C-2 for inverse square law equation and Figure #C-3 on the following page for slant ranges for specified thermal exposures.

$$Q\ (cals/cm^2) = \frac{E^{\tau}}{4\ \pi\ R^2}$$

E = Total Energy Emitted
R = Range in centimeters
τ = Transmissitivy of the Surrounding Atmosphere from the Burst to the Target

FIGURE #C-2: Inverse Square Law Equation.

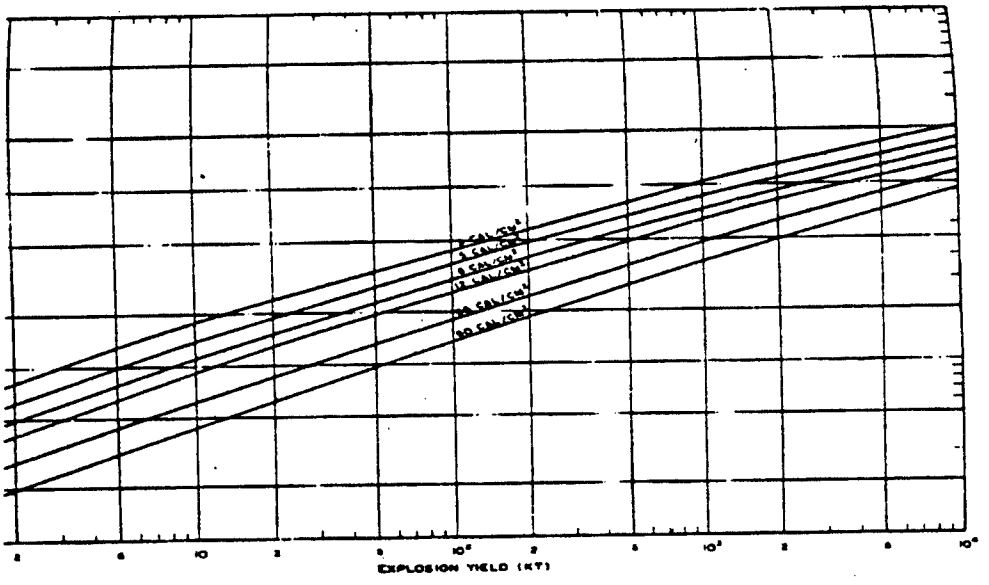


FIGURE #C-3: Slant Ranges for Specified Thermal Doses.

The third factor affecting thermal radiation is absorption and scattering due to the atmosphere. As the thermal radiation passes through air, the air molecules absorb a portion of the energy in the X-ray and ultra-violet frequency spectrum. Scattering of the thermal radiation occurs when air contains water droplets and/or dust particles. These droplets and particles reflect the thermal radiation from a single line of sight direction to a multitude of directions. This scattering effect only reduces the thermal radiation applied upon a target slightly, because the scattered energy from other directions reinforces this line of sight radiation. Visibility is an extremely important parameter in determining the effectiveness of thermal radiation upon its target. In poor visibility conditions such as fog or smoke, the effects of thermal radiation is greatly reduced if the weapon HOB is above these conditions. In this circumstance, the thermal radiation is not only affected by absorption, but also by reflection. In the case of ground bursts, the thermal radiation effects are significantly diminished by the absorption and scattering caused by greater amount of generated debris and the shielding effects of terrain and surface irregularities.

The thermal effects of a nuclear weapon are an intense blinding flash and an immense thermal pulse. The great intensity of this flash can cause

blindness to military personnel, either temporary or permanent. The severity of blindness is dependent on individual reflexes, flash intensity, pulse duration, and the protective posture of personnel. The thermal radiation is emitted in two distinct separate pulses. The first thermal pulse contains little energy, therefore it is insignificant. The second pulse contains tremendous energy, it is militarily significant and generally the largest casualty producer. The thermal pulse have two damage producing mechanisms which are direct damage produced by generated heat and, secondary damage produced by fires and explosions caused by ignition of surrounding materials. The blast wave may suppress some fires caused by the thermal pulses. Also, smoking of the exposed object will attenuate the undelivered energy of the thermal pulse. See Figure #C-4 for fireball power and thermal energy emitted versus normalized time.

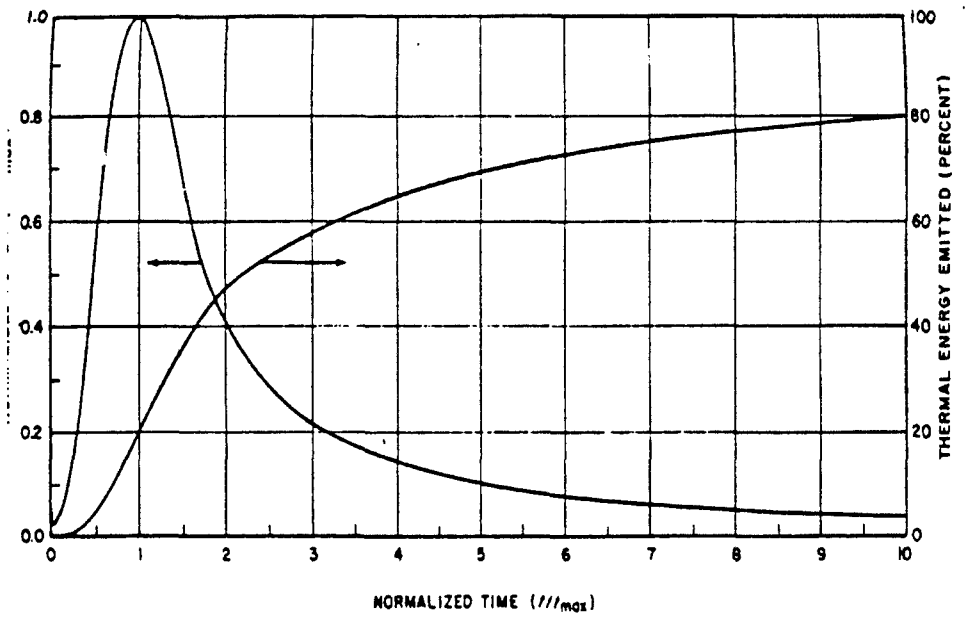


FIGURE #C-4: Normalized Fireball Power & Thermal Energy Emitted Versus Normalized Time.

To determine the resistance of an item of materiel to thermal radiation, the test system must first be examined to determine potential problem areas. These are usually associated with combustible materials such as plastics, exposed ammunition, casing and containers, fabrics, rubber, and wood. Non-

combustible materials include optics, sensors, and low melting point materials. Charring of paint is of no consequence, nor is the charring or discoloration of any material, provided that such damage does not interfere with the operation of the equipment. The fact that gasoline may spill out when motorized equipment is overturned should not be interpreted as suggesting that it will be ignited by thermal radiation, because the thermal pulse will have passed by the time the spilling occurs. Adequate resistance to thermal radiation can sometimes be confirmed by a visual examination that proves the item free of heat-sensitive areas. At other times, it may be necessary to expose components of the item to facilities which simulate the thermal pulse. Typical problems that may be associated with thermal radiation are: destruction of insulation on wires, distortion of plastic moving parts, burning of rubber on tires and tracks, blackening and/or cracking of optical devices, weakening of materials, ignition of exposed propellants and ammunition, burning of tarpaulins and other fabrics, and ignition of combustibles which could lead to fire damage. Thermal damage is of little consequence when a system will suffer more severe damage from blast effects. See Table #C-1 for examples of thermal radiation exposure required to ignite certain materials. Smaller yield weapons require less cal/cm^2 to ignite the same materials because of the faster rate or flux (cal/cm^2-sec) that the thermal energy is deposited on the material.

TABLE #C-1: Approximate Thermal Radiation Exposure Required for Material Ignition.

Material	Radiant Exposure (Cal/cm^2) from 1kT Weapon	Radiant Exposure (Cal/cm^2) from 20 kT Weapon	Radiant Exposure (Cal/cm2) from 1MT Weapon
Tan Cotton Shirting	5	7	11
Newspaper	2	3	6
Battle Dress Uniform	15	20	30
NBC Suit	15	20	30
Truck Canvas Canopy	15	20	30
Dry Grass and Undergrowth	2 - 3	3 - 4	5 - 7
Cardboard	6	8	13
Plastics	4 - 6	8 - 10	9 - 13
Heavy Burlap	6	8	12

APPENDIX D. ELECTROMAGNETIC ENVIRONMENT AND EFFECTS

The electromagnetic environment produced by a nuclear weapon consists of the ionization of the atmosphere and generation of an EMP. The gamma rays, neutrons, beta particles, X-rays, and positive ions emitted from the nuclear detonation causes electrons to be ejected from their perspective atoms, thus ionizing the atmosphere in the burst vicinity. This increase in electron density attenuates or refracts all electromagnetic signals from a few seconds to several hours depending on weapon yield and HOB. Radio communications depend on propagation of transmitted waves through the atmosphere. Depending on the specific frequency, this propagation occurs in one of two paths, ground or sky waves. Low frequencies utilizes the ground wave path, while the high frequency band utilizes the sky wave path which is reflected back to earth by the ionosphere. Very High Frequency (VHF) and Ultra High Frequency (UHF) penetrate the ionosphere, therefore, any disturbance in the ionosphere does not affect communications in these frequency bands. See Table# D-1 for frequency band effects caused by atmosphere ionization.

TABLE #D-1: Frequency Band Effects Caused by Atmosphere Ionization.

BAND	FREQUENCY RANGE	EFFECTS ON COMMUNICATIONS
VLF	3 - 30 kHz	Limited Effects
LF	30 - 300 kHz	Drastic Reduction of Sky Wave Path, but No Effects on Ground Wave Path
MF	300 - 3000 kHz	Same as LF
HF	3 - 30 MHz	Considerable Effects
VHF	30 - 300 MHz	Limited Effects, but Propagation Enhancement Possible
UHF	300 - 3000 MHz	Limited Effects
RADAR	3000 - 10000 MHz	Attenuated and Refracted

A nuclear detonation distributes approximately one millionth of its energy in the form of an intense EMP with a frequency content of a few hertz (Hz) to several hundred megahertz (MHz). The area affected by EMP and the characteristics of the pulse, are a function of burst altitude and weapon design and yield. Typical EMP intensity is in the order of tens of thousands of volts/meter. This compares with the order of 200 volts/meter for nearby radars, 10 volts/meter for communication equipment, and 0.01 volts/meter for typical metropolitan area ambient. Two characteristics of EMP which result in a threat to electrical equipment are field amplitude and broad frequency spectrum. There are three basic mechanisms for EM coupling to a conducting structure: electrical induction, the basic mechanism for linear conductors; magnetic induction, the principal mechanism when the conducting structure forms a closed loop; and earth transfer impedance for buried conductors. Devices which may be susceptible to functional damage due to electrical transients include active electronic devices, passive electronic components, semiconductor devices, squibs and pyrotechnic devices, meters, and power cables. Operational upset can be expected in digital processing systems, memory units, guidance systems, and power distribution systems. Damage mechanisms include dielectric breakdown, thermal effects and interconnection failures. The two EMP situations which are based upon burst altitude are (Endo-Atmospheric) SREMP and (Exo-Atmospheric) HEMP.

The first EMP situation, SREMP, occurs within the atmosphere at an altitude of less than 40 km above sea level, and possesses an extremely large electric and magnetic field over the burst vicinity. Of particular concern is events at or within 1 km of the surface. Only within these limits are tactical surface systems close enough to the event to have the potential to be adversely affected by SREMP. SREMP is generated by collisions between photons from gamma radiation and molecules of the atmosphere. These highly energetic photons eject electrons from the surrounding air molecules, producing ionized air molecules. This immense separation of charge creates an intense E-Field of several 100,000 volts/meter and a large associated H-Field of 500 ampere-turns/meter. Ninety percent of its energy is contained in the 100 Hz to 10 kHz range. See Figure# D-1 for an example of the SREMP waveform and Figure #D-2 for relative energy versus frequency for an Endo-Atmospheric Burst on the following page.

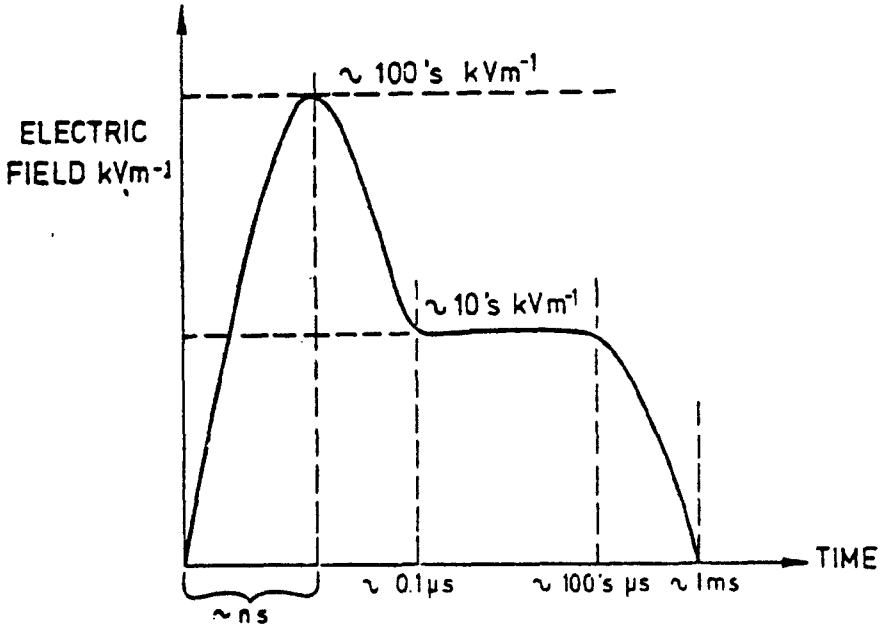


FIGURE #D-1: Endo-Atmospheric EMP Waveform..

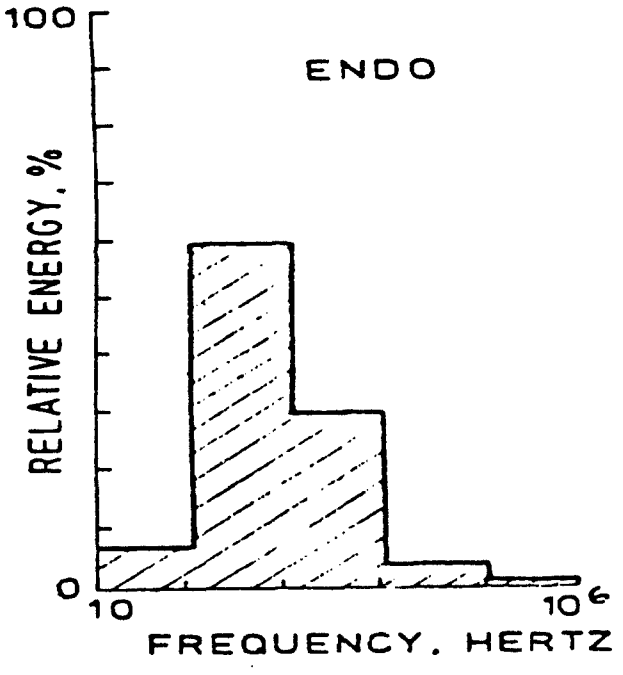
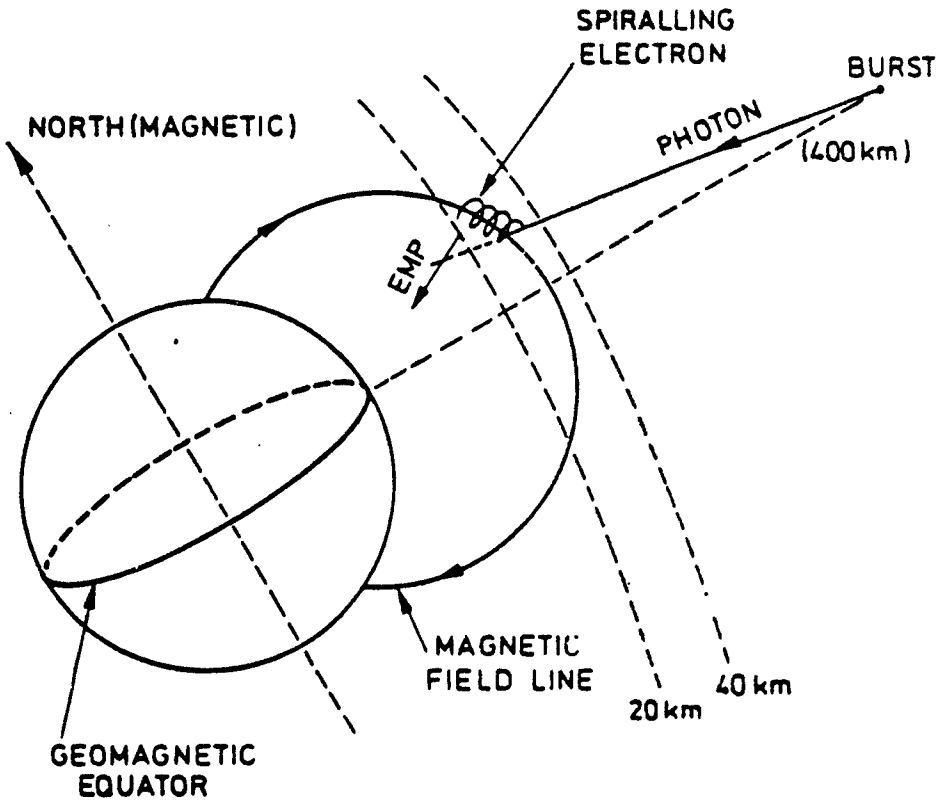


FIGURE #D-2: Endo-Atmospheric Relative Energy Versus Frequency.

The second EMP situation, HEMP, occurs at an altitude greater than 40 km above sea level, and possesses a large electric and magnetic field over a diverse area. This tremendous area of effects is the reason HEMP is considered militarily significant and the most damaging of the two EMP situations. The HEMP is generated by gamma photons being absorbed by the atmospheric molecules at altitudes from 20 to 40 kilometers. This absorption causes electrons to be deflected by the earth's magnetic field into a spiral path about the field lines, causing them to radiate electromagnetic energy. See Figure #D-3 for formation of HEMP and Figure #D-4 on that next page for the detailed geometry of this phenomenon.



FIGURE# D-3: Formation of Exo-Atmospheric EMP.

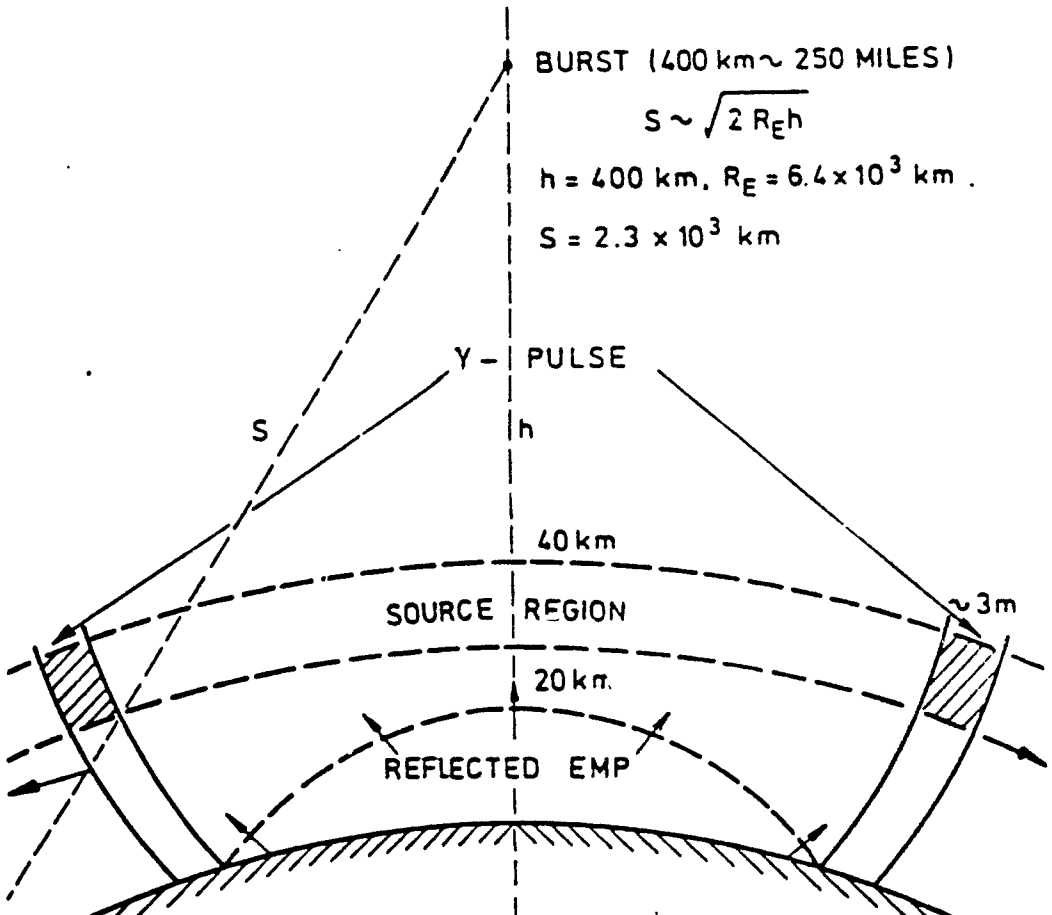


FIGURE #D-4: Detailed Geometry for Exo-Atmospheric Burst.

The waveform and frequency content of a HEMP is drastically different from its SREMP counterpart. This electron radiated energy creates a large, diverse E-Field in the range of tens of kilovolts/meter and an associated H-Field in the range of 10 to 100 ampere-turns/meter. Ninety percent of its energy is contained in the 100 kHz to 10 MHz range. See Figure #D-5 for an example of the HEMP waveform and Figure #D-6 for relative energy versus frequency for an Exo-Atmospheric Burst on the following page.

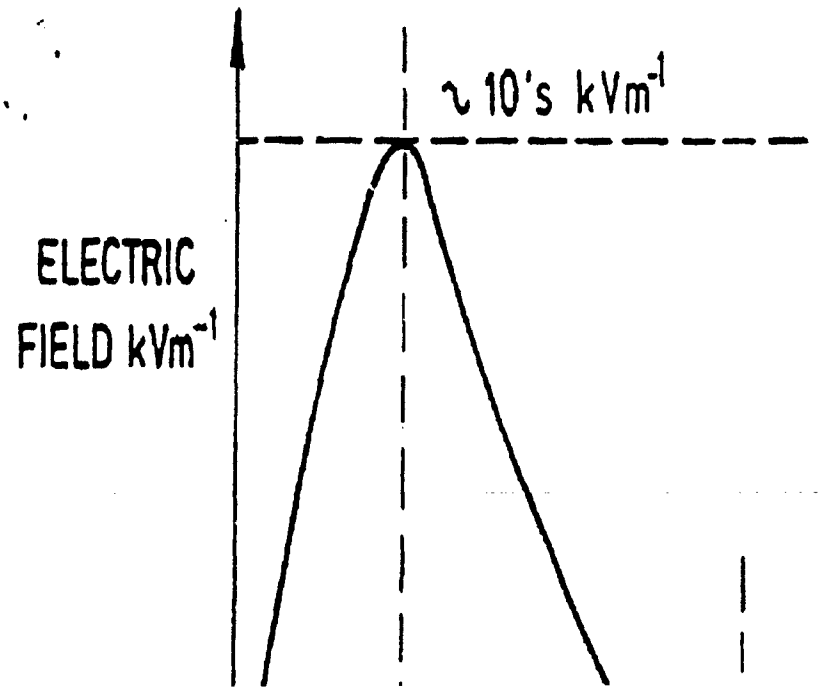


FIGURE #D-5: Exo-Atmospheric EMP Waveform.

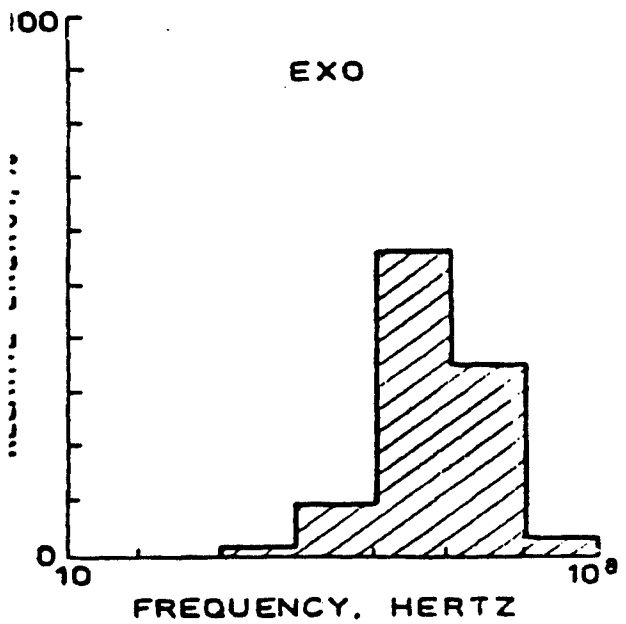


FIGURE #D-6: Exo-Atmospheric Relative Energy Versus Frequency.

See Figure #D-7 for an example of the diverse coverage in area and corresponding generate E-Field contours by an Exo-Atmospheric burst.

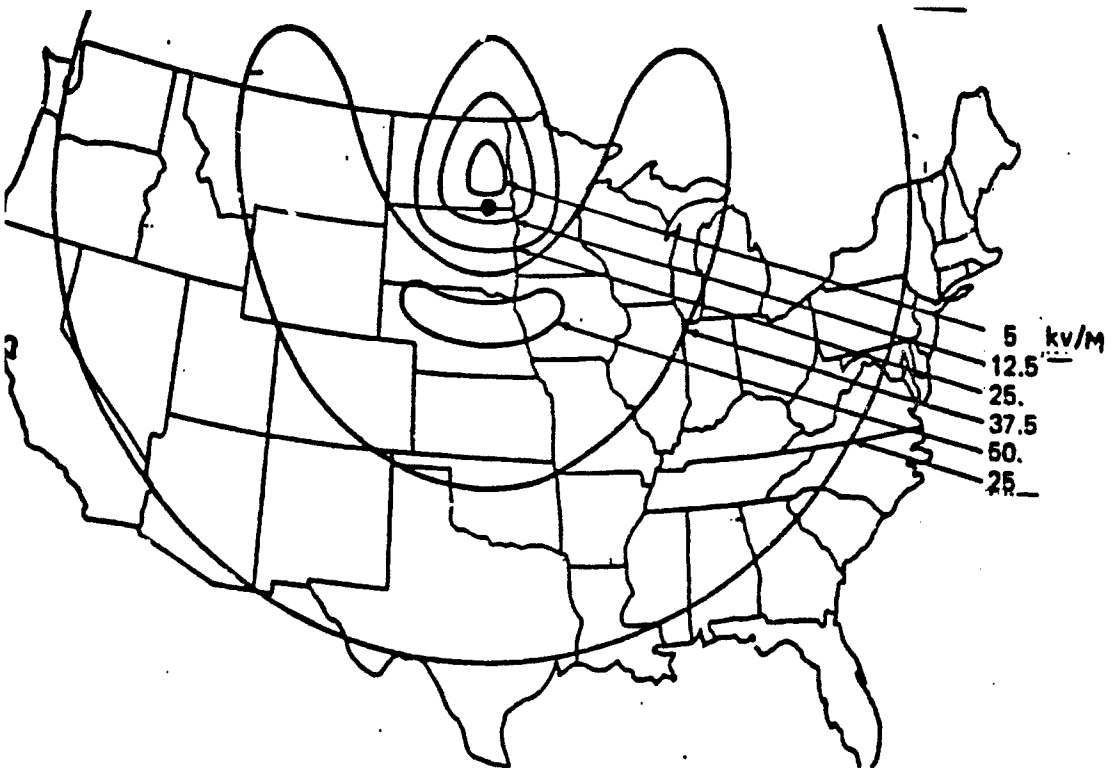


FIGURE #D-7: Generated E-Field Contours at the Earth's Surface from a HEMP.

EMP testing requires the use of both experimental and analytical techniques to determine the response of systems and components to the EMP. Adequate testing of a system requires simulation of the EMP environment in terms of amplitude, time and geometrical effects of the entire system under study. Detonation altitude, angles of arrival and polarization of the field must be considered. Frequency domain calculations may be applied to determine critical resonant frequencies inherent to the test system. Current injection techniques must be utilized for distributed systems as an integral part of the EMP test. Current injection is greatly beneficial in the context of determining safety margins and, enhancing and verifying HEMP simulator results. But, current injection should not be the primary means of obtaining accurate HEMP data.

Also, deliberate hardening devices like terminal protection devices must be analyzed, tested if necessary, to determine safety margins. Likewise, the attenuation afforded by enclosures must be analyzed so that its effects on the survivability of the enclosed electronics can be quantified.

APPENDIX E. NUCLEAR RADIATION EFFECTS

E.1 GENERAL RADIATION CHARACTERISTICS.

Approximately fifteen percent of the energy delivered by the detonation of a nuclear weapon is produced as (non-thermal) radiation. There are four types of radiation which are worthy of attention.

The first type of radiation is called alpha radiation and is comprised of a stream of alpha particles which are essentially the nuclei of helium atoms. This type of radiation has exceeding slight penetrating power causing essentially no effects on material or on military personnel because it can be stopped by a single sheet of paper. Military casualties are only produced by alpha radiation when it is internally introduced into the body. Therefore, alpha radiation is not considered militarily significant to equipment.

The second type of radiation is called beta radiation and is comprised of a stream of beta particles which are electrons. This type of radiation has slight penetrating power and can just barely penetrate the skin. The only effect caused by initial beta radiation on military personnel are skin burns called "Beta Burns." Since there are essentially no notable effects on material or on military personnel, initial beta radiation has little military significance.

The third type of radiation is called gamma radiation which is comprised of photons or electromagnetic waves very similar to X-rays, but have shorter wavelengths, usually more energetic and, therefore, has substantially greater penetrating power. Since gamma radiation can travel great distances through air and pass through extremely thick materials, gamma radiation is extremely significant to military systems containing electronics.

The last type of radiation is called neutron radiation and is comprised of a particle stream of neutrons. Neutrons are one of the elementary particles which comprise the nucleus of all atoms and possess no charge. Since neutrons usually have much greater penetrating power than gamma radiation, neutrons are extremely significant to military systems containing electronics.

E.2 RESIDUAL RADIATION ENVIRONMENT AND EFFECTS.

The residual radiation effects of a nuclear weapon consists of radioactive weapon debris and fallout, and NIA which sustains for longer than one minute after weapon detonation. The effects of residual activity can cover an extensive area and can persist for long durations which are dependent upon weapon yield and design, HOB, soil composition, and atmospheric conditions. The radiation composition of residual radiation consists of alpha particles, beta particles, and gamma radiation. A more detailed examination of the two primary residual radiation effects, NIA and fallout follow:

The first effect, NIA occurs in the vicinity of GZ and is caused by neutron capture in the system and various materials which exist on the earth's surface near GZ. This process of neutron capture produces radioactive isotopes that emit beta and/or gamma radiation. The duration of significant radiation emission is dependent upon the isotopes created.

The normally predominant effect, fallout, is highly dependent upon the type of weapon burst. In air bursts, the vaporized radioactive products condense into small particles in the range of 20 μm in diameter. These extremely small particles are conveyed high in the atmosphere and descend to earth over an exceedingly prolonged time. By this process, the fallout has significantly decayed and has been greatly dispersed by winds resulting in a very low radioactivity level which is militarily insignificant.

On the other hand, during ground or near ground bursts, vast quantities of soil and debris are drawn into the fireball forming condensation centers for vaporized radioactive products. This results in a massive cloud of radioactive particles with diameters up to 500 μm. The rate at which these particles descend to earth is based upon increasing mass and atmospheric conditions. In other words, the denser the particle, the quicker it will fall to earth unless adverse atmospheric conditions prevail. The outcome of this type of burst is steadily increasing radioactivity the closer to GZ the measurement point because of the decrease in decay time and the increase in radioactive particles.

Residual radiation has essentially no damaging effects on military systems, but presents major difficulties on military personnel in the area surrounding GZ and downwind of GZ. Gamma radiation is the primary concern when providing protection for military personnel against residual radiation. The effects of both alpha and beta radiations may be made insignificant for military concerns by thin layers of materials. Combat vehicles, particularly tanks and armored personnel carriers, because of their armor and massive metal construction, inherently provide a considerable amount of shielding against residual radiation.

The amount of shielding provided is almost a direct function of the mass or material between the individual and the radiation source. The effectiveness of material in attenuating radiation may be represented by its "half-value thickness", the thickness of the particular material which absorbs half of the gamma radiation incident upon it. The amount of shielding provided for each crew member is expressed in terms of "protection factor" defined as follows:

$$\text{Protection Factor} = \frac{\text{Free Field Radiation level at 3 feet above the ground}}{\text{Radiation level at personnel location}}$$

The protection factor is the ratio of the radiation dose a person would receive if he were standing in the open in a fallout field to the dose he would receive in the vehicle at the same location. Some tanks may provide protection factors against residual radiation as high as 20, whereas a 1/4-ton truck may provide a protection factor of 1.25. The term "transmission factor" is also used. It is essentially the inverse of the protection factor and is defined as:

$$\text{Transmission Factor} = \frac{\text{Dose inside Shield}}{\text{Dose outside Shield}}$$

Typical transmission factors for shelters and vehicles against initial and residual radiation are contained in Table #E-1.

TABLE #E-1: Typical Transmission Factors for Nuclear Radiation Effects.

Shielding Item	Residual Radiation Transmission Factor	Neutrons Initial Radiation Transmission Factor	Gamma Initial Radiation Transmission Factor
Armored Personnel Carrier	0.6	0.7	0.7
Light Tank	0.2	0.3	0.2
Medium Tank	0.1	0.3	0.1
¼-Ton Truck	0.8	1.0	1.0
¾-Ton Truck	0.7	1.0	1.0
2½-Ton Truck	0.6	1.0	1.0
4- To 7-Ton Truck	0.5	1.0	1.0
Foxhole	0.1	0.3	0.2
Open Trench	0.1	0.3	0.2
Shelter with 3ft of Earth Cover	0.005	0.05	0.02

E.3 INITIAL NUCLEAR RADIATION ENVIRONMENT AND EFFECTS.

Initial nuclear radiation is defined as that nuclear radiation which is emitted by a nuclear explosion within the first minute after the nuclear weapon burst. Initial nuclear radiation is composed of alpha particles, beta particles, gamma radiation and neutrons. Only, the highly penetrative gamma rays and neutrons are extremely damaging to military personnel and electronics in military systems. The magnitude of this radiation is dependent upon weapon yield, type and HOB, and distance from GZ. For middle to high yield weapons, the damaging effects on systems generated by the blast wave and thermal radiation surpasses INR effects. However, for tanks, APCs, and similar systems, and for small yield weapons, INR is the more dominant effect on electronics and personnel.

The gamma radiation that is produced by a nuclear detonation comes from various sources, such as the initial fission reaction, fission product decay and NIA in the warhead debris and in the surrounding air molecules. Prompt gamma photons are those produced during fission and as a result of neutron interactions with weapon materials in the first μsec. Capture gamma photons are those emitted as the result of the capture of a neutron by a nucleus. Other examples of gamma radiation sources are delayed and in elastic gamma photons.

The neutron radiation produced by a nuclear detonation comes from two main sources, prompt neutrons and delayed neutrons. Prompt neutrons constitute over 99 percent of the total neutron production and are released in the initial μsec during the warhead fission and/or fusion processes. Delayed neutrons are emitted within the first minute and are produced by the interaction of the prompt neutrons with atoms in their path. Neutrons are also produce by the action of high energy gamma photons on the weapon materials, but they are insignificant.

As the distance from GZ increases, the effects of INR is significantly reduced by two factors. These factors are that the intensity of INR decreases according to the inverse square law, and air scattering and absorption. The inverse square law is the principle factor for decreases in INR levels. The factor of air scattering and absorption has very little effect on neutron dose, but affects gamma radiation dose significantly. Figure #E-1 is an example of initial radiation effects from a 1kT airburst and Figure #E-2 provides INR scaling factors versus weapon yield.

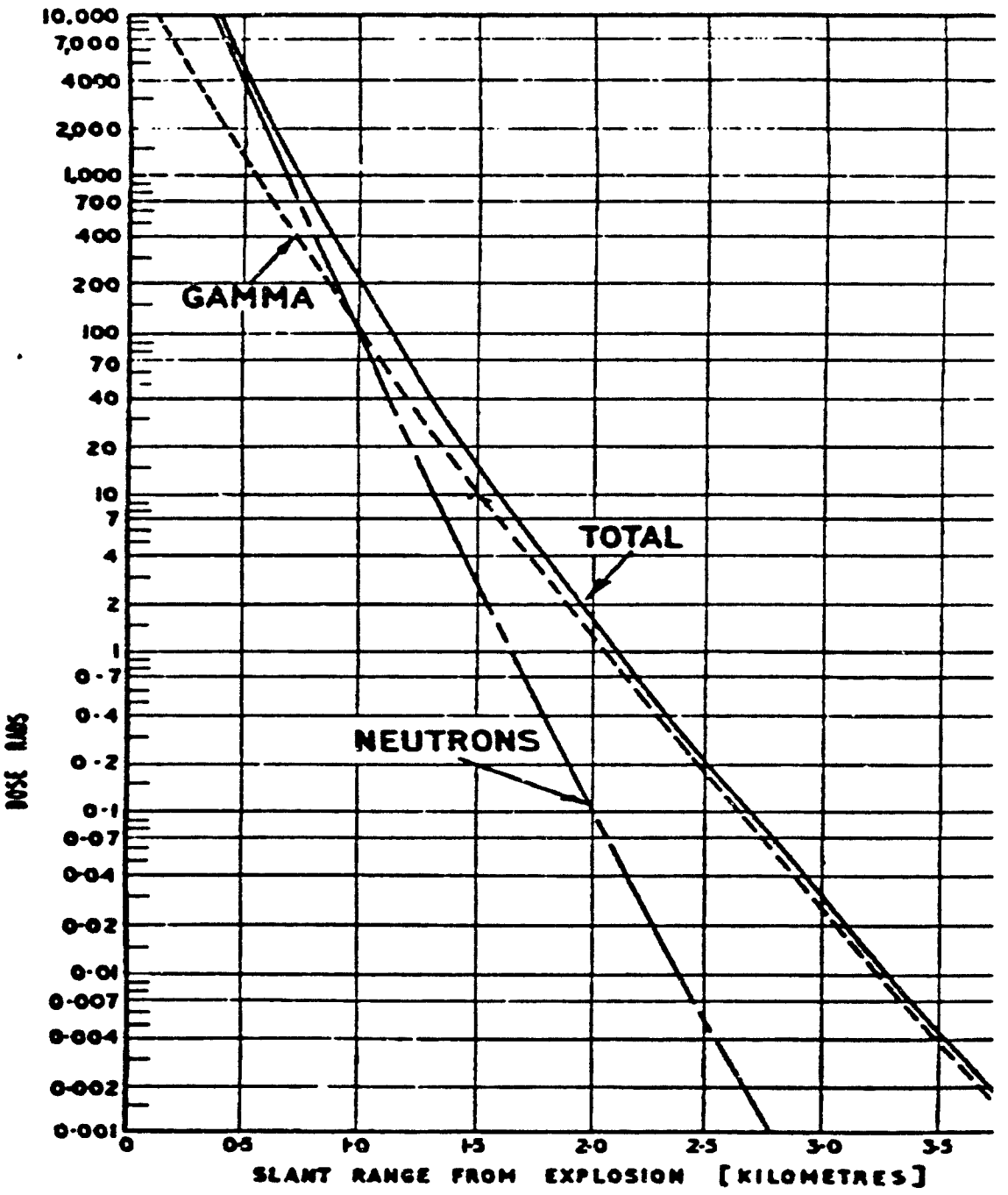


FIGURE #E-1: Initial Radiation Effects From 1-kT Air Burst.

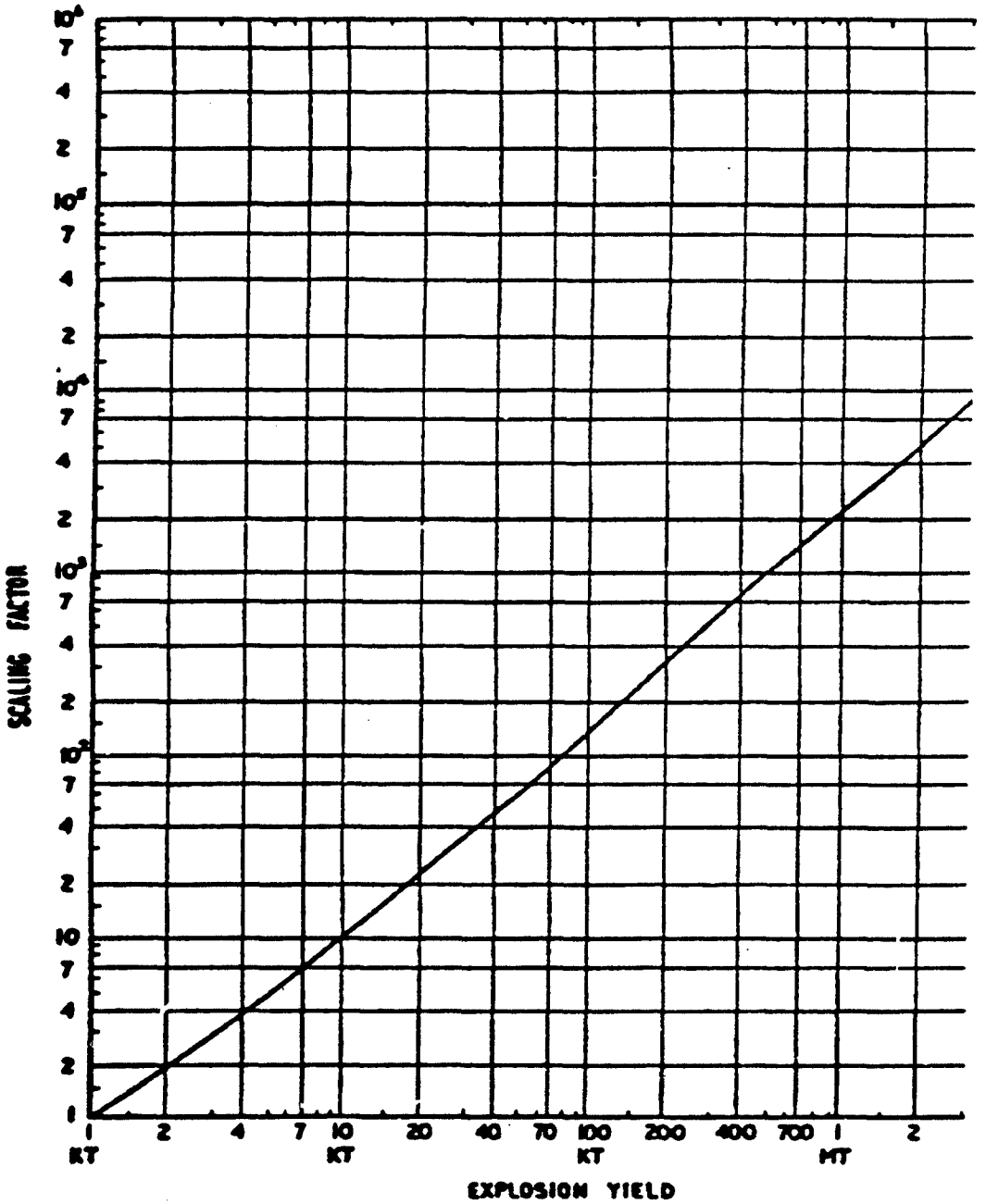


FIGURE #E-2: INR Scaling Factors Versus Weapon Yield.

The INR shielding tests involve the exposure of materiel to neutron and gamma radiation sources to measure the protection afforded to the crew and the most vulnerable electronic components by the walls of the vehicle. These radiation sources must have spectra that collectively approximate the spectra from nuclear weapons. See Table #E-1 on page 48 for typical transmission factors of INR effects on military equipments and shelters.

The INR tests are only concerned with the effects on military personnel and equipment from gamma radiation and neutrons. The damaging effects produced by INR are only militarily significant in the consideration of the drastic effects it induces on electrical properties of semiconductor devices. To adequately test and analyze these drastic effects, three test environments based upon the time history of nuclear weapon radiation effects have been developed. These tests are: gamma dose rate, total gamma dose, and neutron fluence.

The gamma dose rate test determines the effects of the initial gamma pulse created by a nuclear detonation on powered semiconductor devices primarily of the Metal-Oxide-Semiconductor (MOS) technology. The gamma dose rate pulse generates damaging photocurrents which produces transient upsets, latchup, and burnout in semiconductor devices.

The neutron fluence test determines the effects of lattice displacement damage generated by neutron fluence on semiconductor devices primarily of the bipolar technology. The semiconductor piece-parts of a test system generally receives the most damage by neutrons. Neutron damage results in a decrease of the minority carrier lifetime and an increase in bulk resistivity of the semiconductor material. These effects severely alters the electrical characteristics of the piece-parts, and, in some cases, the induced damage is severe enough to cause complete device failure or failure in its circuit application.

The total gamma dose test determines the effect of total ionizing dose deposited on semiconductor devices. The production of hole-electron pairs through ionization creates trapped charge in the semiconductor material. The total dose effects in semiconductors are exhibited either as a change in electrical parameters or as a catastrophic failure. Of particular concern is N-channel MOS technology which is the sensitive to gamma dose.

See Table #E-2 for the testing requirements on specific semiconductor technologies at tactical damage levels and Table #E-3 for testing requirements on generic part families.

TABLE #E-2: Testing Requirements for Technologies in INR Environments.

Generic Damage Levels:
Gamma Dose Rate: Upset < 1E9 cGy(Si)/sec Based Upon 20 nsec Pulsewidth
Damage < 1E9 cGy(Si)/sec
Total Gamma Dose: < 1500 cGy(Si)
Neutron Fluence : < 1E12 n/cm^2

Technology	Gamma Dose Rate		Total Gamma Dose Damage	Neutron Fluence Damage	Comments
	upset	damage			
1. ALS	No	No	No	No	
2. CCD	Yes	Yes	No	Yes	
3. CML	No	No	No	No	
4. CMOS	Yes	Yes	** No	No	Burnout can occur during dose rate if not circumvention protected. ** Some manufacturer,s processes present problems.
5. CMOS/SOS	No	No	No	No	
6. CMOS/SOI	No	No	No	No	
7. ECL	No	No	No	No	
8. FAST	No	No	No	No	
9. I^2L	No	No	No	No	
10. LST^2L	No	No	No	No	
11. MNOS	No	No	No	No	
12. MNOS/SOS	No	No	No	No	
13. NMOS	Yes	No	Yes	No	
14. PMOS	Yes	No	No	No	
15. PMOS/SOS	Yes	No	No	No	
16. TTL	No	No	No	No	

TABLE #E-3: INR Testing Requirements for Generic Part Families.

Based upon Table #E-2 Generic Damage Levels.

Generic Part Family	Gamma Dose Rate Testing	Total Gamma Dose Testing	Neutron Fluence Testing	Comments
1. Diodes	No	No	No	
2. PIN Diodes	Yes	No	No	
3. Temperature Compensated Diodes	No	No	Yes	
4. Zener Diodes	No	No	No	
5. High F_T (> 50 MHz) Transistors	No	No	No	
6. Low F_T (< 50 MHz) Transistors	No	No	Yes	
7. Power Transistors	No	No	Yes	
8. Crystals	No	Yes	Yes	
9. Crystals Oscillators	** Yes	Yes	Yes	** Technology Dependent
10. Operational Amplifiers	No	No	Yes	
11. Comparators	Yes	No	Yes	
12. CMOS Analog Switches	Yes	** Yes	Yes	** Certain Manufacturers
13. Fixed Regulators	No	No	Yes	
14. DC to DC Converters	** Yes	** Yes	** Yes	** Technology Dependent

TABLE #E-3: INR Testing Requirements for Generic Part Families (Continued).

Based upon Table #E-2 Generic Damage Levels.

Generic Part Family	Gamma Dose Rate Testing	Total Gamma Dose Testing	Neutron Fluence Testing	Comments
15. ADC	** Yes	** Yes	** Yes	** Technology Dependent
16. DAC	** Yes	** Yes	** Yes	** Technology Dependent
17. JFETs	Yes	No	Yes	
18. MOSFETs	Yes	Yes	Yes	
19. Discrete Timers	No	No	No	
20. Linear Timers	No	No	Yes	
21. SCRs	Yes	No	Yes	
22. Unijunction Transistors	No	No	Yes	
23. Discrete Opto-Electronics	No	No	Yes	
24.Opto-Couplers	No	No	Yes	
25. EE PAL	** Yes	** Yes	No	** Technology Dependent
26. TTL PAL	No	No	No	
27. UV PAL	No	Yes	No	
28. EE PROM	** Yes	** Yes	No	** Technology Dependent
29. UV PROM	** Yes	No	No	** Technology Dependent
30. TTL PROM	No	No	No	
31. NMOS PROM	No	Yes	No	
32. Static RAMs	Yes	Yes	No	
33. IDT RAMs	Yes	Yes	No	

APPENDIX F. DETAILED TEST PLAN SUBTEST EXAMPLE

1.1 Gamma Dose Rate Test.

1.1.1 Objective. To analyze the gamma dose rate survivability of the test and baseline system when exposed to a gamma dose rate environment specified in its NHC.

1.1.2 Criteria.

a. The gamma dose rate criterion for the test and baseline system is expressed in the following parameter and unit:

Peak gamma dose rate = [cGy(Si)/sec]

b. Performance criteria requirements of the test system must be considered such as allowable downtime, operate through, acceptable damage and degradation of mission capabilities, and the availability of repair and replacement parts.

c. The production, operation, maturity, maintenance, storage and ambient environment must not introduce any gamma dose rate susceptibilities or unacceptable levels of degradation into the system.

1.1.3 Test Procedures.

1.1.3.1 General.

1.1.3.1.A Piece-Part Level. Survivability of the test system's electronic piece-parts when exposed to the gamma dose rate test environment will be analyzed by:

1. Requiring test of all HCI vendor-parts that are identified in the pr test analysis as high risk and for which inadequate test data exists.

2. Characterization of all critical performance parameters of each high risk HCI requiring test.

3. Establishing HCI performance characteristics by repeating the pretest performance baseline checks after each exposure.

4. Performing a detailed circuit analysis.

5. Irradiating the vendor-parts while energized. Measuring the response of each DUT.

6. Establishing design margins (99/90) utilizing the results of the circuit analysis and the characterization/test program conducted at 1X, 5X, and 10X, unless consistent piece-part failures dictates other reasonable design margins.

7. Accepting/rejecting high risk HCIs based on Design Margins (DM) which are defined as:

$$DM = \frac{\text{Effects Threshold Level}}{\text{Criteria Dose Rate Level}}$$

1.1.3.1.B System Level. Survivability of the test system to the gamma dose rate test environment will be analyzed by:

1. Performing a detailed pretest analysis.

2. Utilizing DMs on all HCIs.

3. Analyzing deliberate hardening devices and/or techniques for adequacy.

4. Establishing performance and configuration baseline of the test system prior to testing.

5. Irradiating the system while energized and operating.

6. Establishing the system' operational status by identifying and quantifying performance differences after each gamma dose rate exposure by repeating the baseline and diagnostic checks as necessary.

7. Irradiating the test system in different configurations, orientations, and modes.

8. Documenting all upsets and/or damage, downtime, mission performance impacts, and necessary corrective action procedures.

9. Stressing the system by utilizing multiple exposures at each level.

10. Exposing mission critical items to levels that can be utilized to verify a specified DM of at least 2X with 4X as the target.

11. Determining and quantifying differences between critical parameters of the test and USANCA environments.

12. Determining survivability of the test item/system to the test environment.

13. Establishing the system's baseline configuration.

14. Determining all serious effects on mission performance.

If a problem occurs, the power will be recycled in an attempt to return the unit to an operational status.

1.1.3.1.C Baseline Configuration. The survivability of the baseline system configuration when exposed to the gamma dose rate USANCA environment will be analyzed by:

1. Analyzing the differences between the test and USANCA environments.

2. Analyzing the differences between the test and baseline configurations.

3. Determining the response of the baseline configuration to the USANCA environment.

1.1.3.2 Approved Test Facilities. Approved Department of Defense (DOD) or other gamma dose rate facilities which are available for gamma dose rate testing are listed in Defense Nuclear Agency (DNA) publication, DASIAC SR-90-252, "Guide to Nuclear Weapons Effects Simulation Facilities and Techniques"(1990 Edition) on pages 5-63 through 5-128 and approved DOD facilities since the publication of that DNA publication. Facilities such as the WSMR LINAC should be utilized for piece-parts, WSMR REBA for small systems, and HERMES III for large systems. The PE must ensure that the gamma dose rate test facility utilized is the foremost facility to accurately simulate desired criteria that will maximize effects on the test system configuration.

1.1.3.3 Pretest Analysis. During the pretest analysis, the PE must analyze and identify HCIs and high risk areas of the test system to the gamma dose rate environment. To do this the PE must effectively perform the following tasks:

a. Identify all potentially susceptible electronic piece-parts based upon technology.

b. Identify the most realistic and severe test setup/circuit with respect to the radiation exposure.

c. Identify all circumvention and/or gamma dose rate hardening applications.

d. Identify the type, number, and location of all dosimetry and data acquisition.

e. Establish the baseline configuration of the test system.

f. Perform a detailed circuit analysis.

g. Determine DMs based upon HCI test data and circuit analysis.

h. Identify high risk HCI requiring test data.

1.1.3.4 Test Setup.

1.1.3.4.A Piece-Part Setup. The high risk HCIs identified in the pretest analysis as requiring test data will be characterized and tested. Prior to testing, a detailed pretest performance characterization of each of the high risk HCIs in its specified test circuit will be performed. Characterization data will be collected on eleven samples of each vendor-part. Characterization of digital parts will be accomplished utilizing either a LTX Trillium, LTX HPC Synchromaster, LTX AC Synchromaster, or a Genrad 125. Characterization of analog parts will be accomplished utilizing either a LTX HPC Synchromaster, LTX AC Synchromaster, LTX HT, or a Teradyn A580. Characterization of mixed signal parts will be accomplished by a LTX HPC or AC or a Teradyn A580. Before testing, the desired Source-To-Target (STT) distances and pulsewidths required for each test level and configuration will be mapped and calibrated utilizing CaF_2 (Mn) TLDs and a PIN Diode respectively. Each of the DUTs will then be positioned in turn centered upon the LINAC's beamwidth at the determined STT distance to receive the first required test level. Next, the DUT's test circuit will be energized and its performance accurately established. The PIN diode will then be positioned next to the DUT to measure each individual pulsewidth. Calibrated probes to measure the response of the DUT are positioned on individual pins of the DUT to monitor currents, voltage, and induced photocurrents during irradiation. These probes are the input to a Data Acquisition System (DAS). The DAS will utilize either double shielded data cables or fiber optics to transmit signals to the transient digitizers and waveform processors. Protection of the DAS against Radio Frequency (RF) fields generated by the LINAC must be provided for, otherwise, instrumentation may be damaged or data corrupted by spurious signals.

1.1.3.4.B System Setup. Prior to testing, a performance baseline for the test system will be established. Problems identified will be documented and corrected if detrimental to the gamma dose rate analysis program. The various STT distances will be determined from previous test data, then refined by measurements, and an area equal to and at the location of the COM of the active electronics will be mapped using CaF_2 (Mn) TLDs. The selection of each STT distance will also include the requirement that the gamma dose rate gradient across the target area is less than 10%. The system will be positioned in a realistic configuration at the first STT distance to receive a specified percent of the criterion gamma dose rate level based upon the pretest analysis. In place and prior to irradiation, the test system's operational status will be re-verified. The TLDs and pulse shape measuring devices such as Compton Diodes will be positioned at selected locations on the test system to measure the received gamma dose and pulsewidth. If required to

adequately determine the gamma dose rate response of the test system, a DAS will be setup and calibrated. The DAS will consist of various sensors, double shielded data cables or fiber optics, transient digitizers, and waveform processors. Protection of the DAS against RF fields must be provided for, otherwise, instrumentation may be damaged or data corrupted by spurious signals. The test system will be powered during each irradiation.

1.1.3.5 Test.

1.1.3.5.A Piece-Part Level. Ten samples of each vendor-part will be characterized, irradiated at 1X the criterion level while biased, and characterized again. This procedure will be repeated at 2X, 5X, and 10X the criterion level unless a valid failure occurs such as the vendor-part failing to meet manufacturer's specifications, upset, latch-up or burnout. An eleventh sample will be characterized and kept as a control device. If a valid failure occurs, at or below the criterion level, the vendor-part fails qualification. If a valid failure occurs above the criterion level, then this information along with the circuit analysis will be utilized to establish the DM which, in turn, will be utilized to determine acceptance/rejection of the part. After the DUTs has been irradiated by gamma dose rate pulses, all circuit operational checks will be initiated within 3 minutes after the irradiation IAW MIL-STD-883 (REF 30), Methods 1020, 1021, and 1023; and MIL-STD-750 (REF 21), Method 1015. The major parameters of the test environment will be analyzed against the USANCA environment and a criteria compliance will be obtained. This criteria compliance must be utilized in determining the survivability of the vendor-part against the USANCA criteria.

1.1.3.5.B System Level. After the energized system has been irradiated at 1X the criterion level by a pulse of bremsstrahlung photons, all operational checks will be initiated within 3 minute after the irradiation. If determined to be operational within acceptable guidelines, the test system's dosimetry will be replaced and the test system will be pulsed again. Following a successful checkout, the dosimetry will be replaced will unexposed ones, the system repositioned and irradiated again. All necessary performance baseline checks between gamma dose rate pulses should be thorough, but as abbreviated as possible to achieve an efficient test program. This process will be repeated until all configurations, modes, orientations and levels identified by the pretest analysis or on-going test results have been accurately tested, analyzed, and documented. Testing at 1X, 2X, 3X, and 5X the criterion level will be accomplished unless unacceptable problems occur. If an upset or latchup occurs, the problem will documented and diagnosed. Testing will not be continued until the problem is completely understood and its effects on the system has been determined. The affected subsystem(s) will be identified and, depending on the PE's analysis, testing may be repeated to ensure that the problem was environment induced. Test/diagnostic circuits will be employed to collect information required to determine the cause and impacts on the system's mission. Work arounds, as necessary, will be implemented to complete the testing. A follow-up investigation will be performed to identify the failure to the vendor-part level. A final operational baseline check will be

performed on the test system at the end of the test. If possible, additional test systems will be tested, analyzed, and documented as specified above to achieve extremely important statistical confidence in the gamma dose rate survivability of the test system. The test environment will be analyzed against the USANCA environment and a criteria compliance obtained. This criteria compliance must be utilized in determining the survivability of the test configuration against the USANCA criteria.

1.1.3.6 Dosimetry. The gamma dose at selected locations on the test system will be measured using CaF_2 (Mn) TLDs. The measured gamma dose values will be in cGy(CaF_2(Mn)) and must be converted and expressed in cGy(Si) and cGy(tissue) by the ratios:

$$cGy(Si)/cGy(CaF_2) = 1.02 \text{ and } cGy(tissue)/cGy(CaF_2) = 1.13, \text{ respectively.}$$

Each radiation pulse will be measured using a PIN diode (LINAC) or Compton Diode (HERMES-III and REBA), and digitized on a transient digitizing system. The pulsewidth (FWHM) of each radiation pulse will be obtained from this digitized signal. The gamma dose rate for each pulse will then be determined from the gamma dose recorded on the TLDs and the pulsewidth obtained from the digitizers.

1.1.4 Data Required.

a. Detailed description of the method and facility of producing the gamma dose rate test environment including photographs of the test facility setup showing test system location relative to the gamma radiation source.

b. Complete set of pretest mapping data in radiation absorbed dose (cGy) in silicon (cGy(Si))(±10%) and cGy(tissue) (±10%) for each expected test location.

c. Risetime and pulsewidth (FWHM) of each gamma pulse.

d. Data from other gamma dose rate test/analysis programs performed on similar military systems.

e. Results of pretest analysis.

f. Test data and/or analytical data and analysis on the test system from contractor such as design parameter reports.

g. List of all active electronic piece-parts utilized in the test system.

h. Available test data for all HCIs from existing databases.

i. Detailed description, serial numbers, and dimensions of each

subsystem of the test system.

j. Detailed description and electrical schematics of test circuits utilized.

k. Results of all circuit analysis to include design margins.

l. Detailed description of all mission essential functions.

m. Copies of documentation such as the nuclear program plan, nuclear test plan, nuclear test report, hardness assurance plan, maintenance/ surveillance assurance plan.

n. Duration of each gamma radiation pulse (sec) (±5%).

o. Total gamma dose expressed in cGy(Si) and cGy(tissue) (±10%).

p. Detailed description of all utilized data acquisition procedures, hardware and software.

q. Detailed description of expected system configurations, orientations, and modes for testing.

r. Detailed description and documentation of all inspections, downtime (sec) (±10%), operational checks, and maintenance procedures.

s. Type and location of dosimeters on the test system for each test exposure.

t. Conversion factors (±10%) used to convert cGy(CaF_2) to cGy(Si) and cGy(tissue).

u. Complete list of possible safety and environmental concerns.

v. Test Incident Reports (TIRs).

x. Test data on all high risk HCI's.

y. Diagnostic data on all failure(s) or unacceptable degradation(s).

1.1.5 Data Analysis/Procedure.

1.1.5.1 Data. Results from the pretest analysis and other applicable gamma dose rate piece-parts and survivability programs will be analyzed and, whenever possible, incorporated into all facets of the NSA on the test system. The incorporation of all available test data will be used to enhance and reduce the overall scope of the test program. Pertinent data will be included in the detailed test report.

1.1.5.2 Pretest Analysis. Based upon the technology, screening, database searches, and circuit hardening determination, high risk HCIs will be identified for test and analysis. The DMs (99/90) will be established utilizing the results of the circuit analysis and the characterization/test program conducted at 1X, 5X, and 10X, unless consistent piece-part failures dictates other reasonable DMs. With this information, and the results of the circuit analysis, the test system baseline will be identified. This control of the test system baseline will drastically increase the statistical confidence of the gamma dose rate survivability analysis for the test system.

1.1.5.3 Criteria Compliance. Data from free-field environment measurements will be utilized to quantify and analyze differences between the test and USANCA environments. Primary parameters are peak gamma dose rate, pulsewidth, and spectrum. Differences greater than fifteen percent between these primary parameter values and the corresponding criteria values must be analyzed to determine the effect on the test results. Where necessary, the test results will be corrected to compensate for the environment differences.

1.1.5.4 Test System Performance. The comparison of pretest and post-test and performance and operational checks; damage analysis, HCI DMs, and applicable data from the pretest analysis and previous gamma dose rate tests/programs will be utilized to determine the effects of the gamma dose rate test environments on the test system. All recognized failures and/or degradations will be identified and analyzed with respect to their effect on all mission essential functions of the test system. The cause(s) of each failure and/or unacceptable degradation will be identified and analyzed. Actual susceptible vendor-parts will be identified and verified utilizing piece-part test data. The results from the criteria compliance are integrated into the analysis to determine survivability of the test system to the USANCA environment. The impact on the measured results must be analyzed and clearly explained, particularly if the analyzed damage and/or degradation exceeds the actual affect.

1.1.5.5 System Analysis. Results from the test system performance corrected to the USANCA criterion environment and pretest analysis will be integrated into a clear survivability analysis of the baseline system's configuration to the USANCA criterion environment. The final analysis must utilize, incorporate, and integrate all available data and results to effectively determine and analysis the gamma dose rate survivability of the baseline system to the USANCA environment. This system configuration analysis may show different damage and mission impacts than the test system's results due to extrapolations and corrections for configuration and environment differences.

1.1.5.6 LCNS Database. Both the configuration for the test system and proposed baseline production system will be stored for LCNS control and future analyses. The test results and extrapolated results will be stored for LCNS control and future analyses.

APPENDIX G. DATA DOCUMENTATION

TESTING DOCUMENTATION EXAMPLE.

TEST CONDUCTOR: DATE:

FACILITY: PAGE____ OF ____

Facility Shot # and Item #	Utilized Equipment Serial #s	Expected Test Level	Test Mode	Test Configuration	Pretest / Post-test Results	Test Points and Comments
					pre - post -	
					pre - post -	
					pre - post -	
					pre - post -	
					pre - post -	

General Comments:

TABLE# G-1: EXAMPLE HEMP CURRENT DATA.

Shot #	Long Range Antenna Current (Amps)	W2 Current (Amps)	Power Cable Current (Amps)	Peak E-Field kV/m	Comments
3	11.59	16.68	3.646	52.06	
4	11.52	14.31	3.885	50.54	
5	12.00	17.81	3.664	51.88	
6	11.10	12.27	3.835	52.36	
7	11.55	14.19	3.993	52.18	
8	12.13	12.27	3.624	52.13	
9	11.12	12.53	3.718	53.03	
10	11.87	12.65	3.768	52.58	
11	12.06	12.56	4.029	52.99	
12	11.69	12.76	3.879	51.38	
13	12.09	12.38	3.867	52.27	
14	11.93	12.72	4.140	53.29	
15	12.00	12.64	3.739	51.73	
16	12.21	12.58	3.557	51.94	
17	12.37	12.59	4.019	51.24	
18	11.82	12.55	4.025	53.69	
19	11.86	12.53	4.260	52.81	
20	11.89	12.49	3.971	52.15	
21	11.63	12.49	4.005	52.15	
22	12.64	12.29	4.005	53.03	
23	11.96	12.09	3.835	52.44	
24	12.85	12.59	4.164	53.00	
25	11.84	12.36	3.974	53.65	
26	12.18	12.23	3.849	52.84	
27	11.76	12.09	4.240	53.08	

TABLE# G-1: EXAMPLE HEMP CURRENT DATA (Continued).

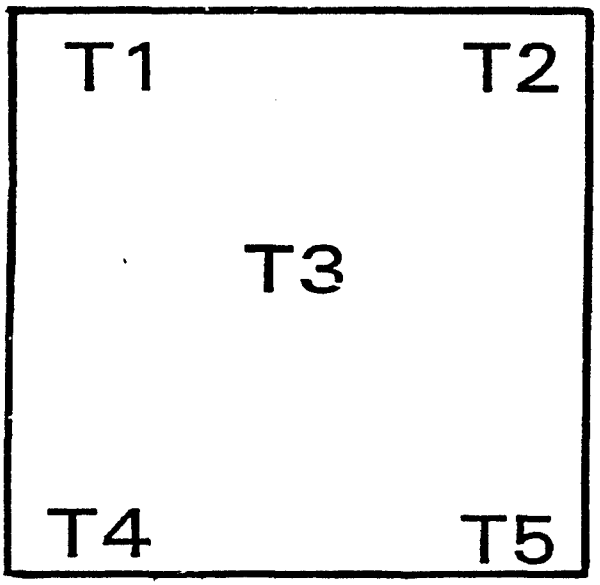
Shot #	Long Range Antenna Current (Amps)	W2 Current (Amps)	Power Cable Current (Amps)	Peak E-Field kV/m	Comments
28	11.65	12.17	3.852	52.52	
29	12.01	12.28	3.756	52.84	
30	13.02	12.77	3.841	52.84	
31	15.05	13.34	4.011	53.17	
32	14.43	12.89	3.841	53.34	
33	15.11	13.00	3.923	53.32	
34	16.06	13.39	4.158	52.73	
35	15.14	12.73	4.220	53.07	
36	14.90	12.39	4.424	53.13	
37	14.85	12.38	4.637	52.60	
38	14.87	12.20	4.674	53.58	
39	15.47	12.60	4.354	52.71	
40	14.78	12.49	4.348	53.29	
41	15.52	13.08	4.339	53.21	
42	15.54	13.04	4.620	52.90	
43	15.32	12.93	4.561	53.00	
44	14.84	12.58	4.555	53.80	
45	14.90	11.98	4.161	53.23	
46	14.99	11.80	4.087	53.35	
47	14.82	12.04	4.356	52.37	
48	14.55	11.84	4.110	53.13	
49	14.95	11.46	4.359	50.80	
50	14.74	11.77	4.337	52.12	

TABLE# G-1: EXAMPLE CURRENT DATA (Continued).

Shot #	Long Range Antenna Current (Amps)	W2 Current (Amps)	Power Cable Current (Amps)	Peak E-Field kV/m	Comments
51	14.24	11.87	4.388	52.96	
52	14.76	11.73	4.288	52.41	
53	15.07	11.91	4.325	53.05	
54	15.56	11.58	4.141	52.52	

TABLE# G-2: STATISTICAL MANIPULATION ON EXAMPLE HEMP CURRENT DATA.

	Long Range Antenna Current (Amps)	W2 Current (Amps)	Power Cable Current (Amps)	Peak E-Field kV/m
Mean	13.5183	12.6726	4.0877	52.650
Standard Deviation	1.59162	1.07913	0.2823	0.6961



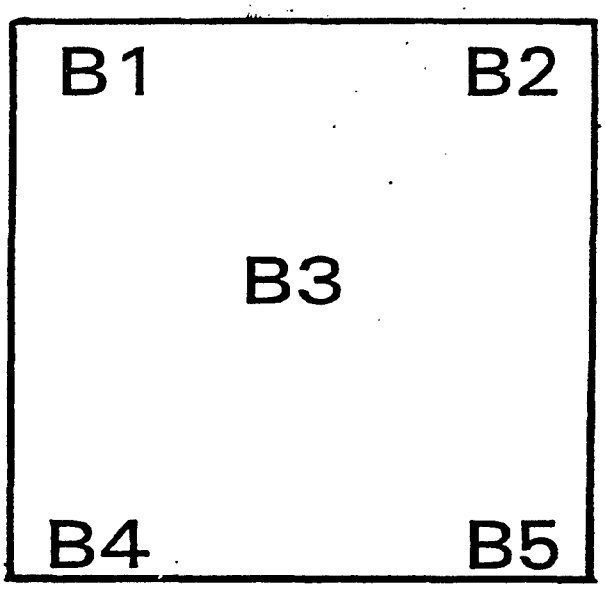


FIGURE G-1: EXAMPLE DOSIMETRY LOCATIONS.

TABLE# G-3: (U) INITIAL DOCUMENTED PROBLEMS/FAILURES EXAMPLE.

Equipment without any Problems / Failures	Equipment with a BIT Test Failure
1. S/N# 0001 2. S/N# 0003 3. S/N# 0005 4. S/N# 0007 5. S/N# 0031	1. S/N# 0002 2. S/N# 0004 3. S/N# 0006 4. S/N# 0008 5. S/N# 0009 6. S/N# 0010 7. S/N# 0011 8. S/N# 0012 9. S/N# 0030

All Problems and Failures are documented in the Table. S/N# 12 and 30 not Utilized because Effects on the NSA.

TABLE# G-4: (U) EXAMPLE EQUIPMENT TEST MATRIX.

	Gamma Dose Rate Environment	Neutron Fluence Environment	Total Gamma Dose Environment	HEMP Environment
Equipment Tested at Each of the Environments	# 0001 # 0003 # 0005 # 0004 # 0046	# 0001 # 0003 # 0007 # 0006	# 0001 # 0003 # 0031 # 0008 # 0010	# 0001 # 0003 # 0009 # 0011

APPENDIX H. ABBREVIATIONS

ALS	- Advanced Schottky Logic
amp	- Ampere
AMSAA	- U.S. Army Materiel Systems Analysis Activity
APG	- Aberdeen Proving Ground
APRF	- Aberdeen Pulse Radiation Facility
AR	- Army Regulation
ARES	- Advanced Research Electromagnetic Simulator
ARL	- Army Research Laboratory
ASAP	- As Soon As Possible
BOBs	- Breakout Boxes
$CaF_2(Mn)$	- Calcium Fluoride (Manganese)
Cal	- Calorie
CCD	- Charge Coupled Device
cGy	- centiGray
CI	- Current Injection
cm	- centimeter
CML	- Current Mode Logic
CMOS	- Complimentary Metal Oxide Semiconductor
CMOS/SOS	- Complimentary Metal Oxide Semiconductor/Silicon on Sapphire
CMOS/SOI	- Complimentary Metal Oxide Semiconductor/Silicon on Insulator
COM	- Center Of Mass
DAS	- Data Acquisition System
DM	- Design Margin

DNA - Defense Nuclear Agency

DOD - Department of Defense

DODI - Department of Defense Instruction

DT - Development Test

DT-II - Development Test II

DUT - Device Under Test

E - Total Energy Emitted

ECL - Emitter Coupled Logic

ECP - Engineering Change Proposal

EED - Electro-explosive Device

E-Field - Electric Field

EM - Electromagnetic

EMP - Electromagnetic Pulse

FAST - Fairchild Advanced Schottky TTL

FBR - Fast Burst Reactor

FFT - Fast Fourier Transform

FPS - Frames Per Second

FSD - Full Scale Development

F_T - Gain Bandwidth Product

FWHM - Full Width Half Maximum

GHz - Gigahertz

GRF - Gamma Radiation Facility

Gy - Gray (100 RADs)

GZ - Ground Zero

HCI - Hardened Critical Item

HE	- High Explosive
HEMP	- High Altitude Electromagnetic Pulse
HERMES	- High Energy Radiation Megavolt Electron Source
HF	- High Frequency
H-Field	- Magnetic Field
HOB	- Height of Burst
HPD	- Horizontal Polarized Dipole
HQ	- Headquarters
Hz	- Hertz
IAP	- Independent Assessment Plan
IAW	- In Accordance With
IEP	- Independent Evaluation Plan
INR	- Initial Nuclear Radiation
I^2L	- Current Injection Logic
KAFB	- Kirtland Air Force Base
kHz	- Kilohertz
kPa	- Kilo Pascals
kT	- Kilo-ton
kV/m	- Kilovolts Per Meter
LCNS	- Life Cycle Nuclear Survivability Program
LF	- Low Frequency
LINAC	- Linear Accelerator
LRU	- Line Replaceable Unit
LST^2L	- Low Power Schottky TTL
m	- Meter

mA - Milliampere

MeV - Mega-electron Volt

MF - Middle Frequency

MHz - Megahertz

MIL-STD - Military Standard

mm - Millimeter

MNOS - Metal Nitride Oxide Silicon

MNOS/SOS - Metal Nitride Oxide Silicon/Silicon on Sapphire

MOS - Metal Oxide Semiconductor

ms - millisecond

MSDS - Materiel Safety Data Sheets

NIA - Neutron Induced Activity

NLT - Not Later Than

NMOS - N-Channel Metal Oxide Semiconductor

ns - Nanosecond

NSA - Nuclear Survivability Analysis

NHC - Nuclear Hardening Criteria

ORD - Operational Requirements Document

P - Overpressure

PE - Project Engineer

PM - Program Manager

PMOS - P-Channel Metal Oxide Semiconductor

PMOS/SOS - P-Channel Metal Oxide Semiconductor/Silicon on Sapphire

Pc - Ambient Pressure

Psi - Pounds per square inch

Psi-sec	- Pounds per square inch-second
q	- Dynamic Pressure
Q	- Thermal Fluence
Q_{dot}	- Thermal Flux
QMR	- Qualitative Materiel Requirement
QSTAG	- Quadripartite Standardization Agreement
R	- Range in centimeters
REBA	- Relativistic Electron Beam Accelerator
RF	- Radio Frequency
RAD	- Radiation Absorbed Dose
Ref	- Reference
REG	- Regulation
ROC	- Required Operational Capabilities
s, sec	- second
SCTs	- Shielded Cable Tests
Si	- Silicon
SN	- Serial Number
SNL	- Sandia National Laboratories
SREMP	- Source Region Electromagnetic Pulse
STT	- Source-to-target
Subj	- Subject
τ	- Transmissivity
TECOM	- Test and Evaluation Command
TEM	- Transverse Electromagnetic wave
TEMP	- Test and Evaluation Master Plan

TIR - Test Incident Report

TLD - Thermoluminescent Dosimeter

TOP - Test Operations Procedure

TPD - Terminal Protection Device

TTL - Transistor - Transistor Logic

UHF - Ultra High Frequency

USA - United States Army

USANCA - United States Army Nuclear and Chemical Agency

μsec - microsecond

UV - Ultraviolet

VHF - Very High Frequency

VLF - Very Low Frequency

V/m - Volts per Minute

VPD - Vertical Polarized Dipole

WESTA - White Sands EMP System Test Array

WPAFB - Wright-Patterson Air Force Base

WSMR - White Sands Missile Range

APPENDIX I. GLOSSARY

Absorption	The process by which radiation imparts some or all of its energy to any material through which it passes.
Attenuation	The process by which a beam of radiation is reduced in intensity when passing through some material. It is the combination of absorption and scattering processes and leads to a decrease in flux density of the beam when projected through matter.
Blast Wave	A pulse of air in which the pressure increases sharply at the front, accompanied by winds, propagated continuously from an explosion.
Beta Particle	Charged particle emitted from the nucleus of an atom, with a mass and charge equal in magnitude to that of the electron.
Calorie (gram-calorie)	Amount of heat necessary to raise the temperature of one gram of water 1 deg C (from 14.5 deg C) (abbreviation: cal)
Curie	The unit quantity of any radioactive nuclide in which 3.7 x 10E10 disintegrations occur per second.
Decay, Radioactive	Disintegration of the nucleus of an unstable nuclide by spontaneous emission of charged particles and/or photons.
Dose	A general term denoting the quantity of radiation or energy absorbed. For special purposes, it must be appropriately qualified. If unqualified, it refers to absorbed dose.
Dosimeter	Instrument to detect and measure accumulated radiation exposure. A common dosimeter is a pencil-size ionization chamber with a self reading electrometer, used for personnel monitoring.
Dynamic Pressure	The air pressure which results from the mass air flow (or wind) behind the shock front of

	a blast wave. It is equal to the product of half the density of the air through which the blast wave passes and the square of the particle (or wind) velocity behind the shock front as it impinges on an object, or structure.
F·ssion, Nuclear	A nuclear transformation characterized by the splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy.
Fusion, Nuclear	Act of combining two or more atomic nuclei into a heavier element, releasing substantial amounts of energy.
Gamma, Prompt	Gamma radiation emitted at the time of fission of a nucleus.
Gamma Ray	Short-wavelength electromagnetic radiation of nuclear origin (range of energy from 10 Kev to 9 Mev) emitted from the nucleus.
Impulse (per unit area)	The integral, with respect to time, of the overpressure (or dynamic pressure), the integration being between the time of arrival of the blast wave and that at which the overpressure (or dynamic pressure) returns to zero at the given point.
Ionization	The process by which a neutral atom or molecule acquires a positive or negative charge.
Isotopes	Nuclides having the same number of protons in their nuclei, and hence the same atomic number, but differing in the number of neutrons, and therefore in the mass number. Isotopes of the same element have almost identical chemical properties.
Mev	One million electron volts (10E6 ev). An electron volt is the amount of energy acquired by an electron when it falls through a potential of 1 volt.
Neutron	A neutral particle of approximately one atomic mass unit, present in all atomic nuclei except those of ordinary hydrogen.

Neutron Flux	The product of the neutron density and the neutron velocity, expressed as neutrons per unit area per unit time.
Nuclear Radiation	Particulate and electromagnetic radiation emitted from atomic nuclei in various nuclear processes. The important nuclear radiations from the weapon detonations are gamma, alpha and beta particles, and neutrons.
Overpressure	The transient pressure that exceeds ambient conditions. It is manifested in the shock or blast wave from an explosion. Usually expressed in pounds per square inch (psi).
Thermal Radiation	Electromagnetic radiation emitted (in two pulses from an air burst) from the fireball as a consequence of its high temperature; it consists essentially of ultraviolet, visible, and infrared radiations. In the early stages (first pulse of an air burst), when the temperature of the fireball is extremely high, the ultraviolet radiation predominates; in the second pulse, the temperatures are lower and most of the thermal radiation lies in the visible and infrared regions of the spectrum. From a high-altitude burst, the thermal radiation is emitted in a single short pulse.
X-rays	Penetrating electromagnetic radiations whose wavelengths are shorter than those of visible light. They are usually produced by bombarding a metallic target with fast electrons in high vacuum. In nuclear reactions, it is customary to refer to photons originating in the nucleus as gamma rays and those originating in the extranuclear part of the atom as x-rays. These rays are sometimes called roentgen rays after their discoverer, W. C. Roentgen.

APPENDIX J. REFERENCES

REQUIRED REFERENCES

1. DASIAC SR-90-252, 1990 Edition, Guide to Nuclear Weapons Effects Simulation Facilities and Techniques.

2. Annual Book of ASTM Standards, Section 12.

3. TECOM Pamphlet 73-1, Developmental Test and Assessment Guide, 30 Sep 93.

4. AR 70-60, Nuclear Survivability of Army Materiel, 1 Nov 84.

5. DODI 5000.2, Defense Acquisition Program Procedures, 11 May 90.

6. MIL-STD-461C, Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference.

7. MIL-STD-461D, Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference.

8. MIL-STD-883, Test Methods and Procedures for Microelectronics, 18 Dec 89.

9. MIL-STD-750, Test Methods and Procedures for Semiconductor Devices, 17 Dec 87.

10. QSTAG 244, Edition 3, Nuclear Survivability Criteria for Military Equipment, 27 Oct 80.

11. QSTAG 244, Edition 4, Nuclear Survivability Criteria for Military Equipment, 19 January 1993.

12. QSTAG 620, Nuclear Survivability Criteria for Communications-Electronics Equipment, 27 Oct 80.

13. QSTAG 620, Edition 2, Nuclear Survivability Criteria for Communications-Electronics Equipment, 29 January 1993.

14. MIL-STD-2169A, Fast Electromagnetic Pulse, Oct 87.

15. Draft TOP 1-2-615, Nuclear Effects Testing of Army Materiel (EMP), 30 Sep 92.

16. TOP 1-2-618, Initial Nuclear Radiation Testing, 15 Feb 93.

17. Draft TOP 1-2-620, High-Altitude Electromagnetic Pulse Tests, 30 Sep 92.

REFERENCES FOR INFORMATION ONLY

a. TECOM Regulation 37-1, TECOM Test Cost Estimates, 24 March 1984.

b. Draft TECOM Regulation 70-8, Test Resource Management System, 20 May 92.

c. AR 200-1, Environmental Protection and Enhancement, 23 May 90.

d. AR 200-2, Environmental Effects of Army Actions, April 90.

e. AMR-C 385-100, Safety Manual, 8 May 92.

f. G.C. Messenger and M.S Ash, The Effects of Radiation on Electronic Systems, published by Van Nostrand Reinhold, 1986.

g. S. Glasstone and P.J. Dolan, The Effects of Nuclear Weapons, published by United States Department of Defense and United States Department of Energy, 1977.

h. L.W. McNaught, Nuclear Weapons and Their Effects, published by Brassey's Defence Publishers, 1977.

Recommended changes of this publication should be forwarded to Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-CT-T, Aberdeen Proving Ground, MD 21005-5055. Technical information may be obtained by the preparing activity: Commander, U.S. Army White Sands Missile Range, ATTN: STEWS-NE-A, WSMR, NM 88002. Additional copies are available from the Defense Technical Information Center, Cameron Station, Alexandria, VA 22304-6145. This document is identified by the accession number (AD No.) printed on the first page.

SUPPLEMENTARY

INFORMATION

DEPARTMENT OF THE ARMY
HEADQUARTERS, U.S. ARMY TEST AND EVALUATION COMMAND
Aberdeen Proving Ground, Maryland 21005-5055

Change 1
TOP 1-2-612
AD No. A278230

ERRATA AD-A278230

5 February 1997

Test Operations Procedure
NUCLEAR ENVIRONMENT SURVIVABILITY

TOP 1-2-612, 15 April 1994, is changed as follows:

1. Make the following pencil/ink changes:

a. Block 9 of Standard Form 298, Report Documentation Page, and Address Change Block on last page of document, changed to: Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-TM-T, Aberdeen Proving Ground, MD 21005-5055.

b. Page 3, paragraph 2.1.2, lines 26-28. Change "SR-90-252" to "SR-94-009"; on line 27/28, change "(1990 Edition) on pages 2-4 through 2-48." to "(1995 Edition) on pages 2-7 through 2-41."

c. Page 5, paragraph 2.2.2, line 35. Change "SR-90-252 on pages 3-4 through 3-18." to "SR-94-009 on pages 3-4 through 3-17."

d. Page 7, paragraph 2.3.2: Delete under facility item 5.

e. Page 7, renumber item "6" to "5" and change under Comments column "MIL-STD 2169A" to "MIL-STD 2169B".

f. Page 7, renumber item "7" to "6".

g. Page 7, last paragraph, line 2/3. Change "SR-90-252" to "SR-94-009" and on line 3, page number "4-54" to "4-32."

h. Page 9, paragraph 2.4.2, line 19/20. Change wording "SR-90-252 on pages 5-63 through 5-128." to "SR-94-009 on pages 5-58 through 5-122."

i. Page 11, paragraph 2.5.2, line 19/20. Change wording "SR-90-252 on pages 5-42 through 5-62." to "SR-94-009 on pages 5-42 through 5-51."

j. Page 12, paragraph 2.5.3, line 8. Change to read after the number E722 "(specifically E722-93) must be referenced."

k. Page 12, paragraph 2.6.1, line 13/14. Delete the following sentence "With this value of D_1, the PE must subtract the neutron dose contribution." and replace with "In addition, the correct utilized value should have in quotes (single pulse duration of 60 seconds)."

l. Page 13, paragraph 2.6.2, line 22/23. Change wording "SR-90-252 on pages 5-9 through 5-41." to "SR-94-009 on pages 5-8 through 5-34."

m. Page 14, paragraph 3.1.2, change line 1 through 4 to read: Cost Estimates. Upon devising an appropriate test scenario a TECOM cost estimate (STE Form 1195) must be prepared IAW TECOM REG. 73-3[b], Test Resource Management System (TRMS).

n. Page 52, paragraph 6.1.e: Change subparagraph e "MIL-STD-2169A: Fast Electromagnetic Pulse[14]." to "MIL-STD-2169B: High Altitude Electromagnetic Pulse (HEMP) Environment[14]."

o. Page J-1, item 1, line 1: Change "SR-90-252, 1990" to "SR-94-009, 1995"

p. Page J-1, item 4: Change to read: AR 70-75, Survivability of Army Personnel and Materiel, 10 Jan 95.

q. Page J-1, item 5: Change to read: DODI 5000.2-R, Defense Acquisition Management Policies and Procedures, 23 Feb 91.

r. Page J-1, item 6: Delete all.

s. Page J-1, renumber "7 through 17" to "6 through 16"

t. Page J-1, new item 6: Add at end "11 Jan 93"

u. Page J-1, new item 7: Change to read: MIL-STD-883D(3) Microcircuits, 14 Mar 95.

v. Page J-1, new item 8: Change to read: MIL-STD-750D(1) Test Methods and Procedures for Semiconductor Devices, 18 May 95.

w. Page J-1, new item 13: Change to read: MIL-STD-2169B High Altitude Electromagnetic Pulse (HEMP) Environment, Dec 93.

x. Page J-1, new item 15: Change date "15 Feb 93" to "29 Oct 93"

y. Page J-2: Delete all of item "a"

z. Page J-2, change all b. to read: "a. TECOM Regulation 73-3, Test Resource Management System (TRMS), 12 Nov 93 and change 1, 9 Aug 95".

aa. Page J-2, enter new item: "b. TECOM Pam 73-3, Test Resource Management System (TRMS), 15 Jul 96".

bb. Page J-2, item c: Change date "23 May 93" to "23 Apr 93".

cc. Page J-2, item d: Change date "Apr 90" to "23 Dec 88".

dd. Page J-2, item e: Change to read: AMC-C 385-100, Safety Manual, 26 Sep 95.

ee. Last page, change address block, lines 7 through 9 to read: "the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page."

2. After posting the changes, file Change Sheets in front of the TOP for reference.

END

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DATE:
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