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This TOP supersedes TOP 10-2-508, Safety and Health Hazard Evaluation – General Equipment, dated 6 May 1980.

Marginal notations are not used in this revision to identify changes, with respect to the previous issue, due to the extent of the changes.

14. ABSTRACT
This TOP provides guidance for the safety and health hazard evaluation of general equipment. It describes developmental test procedures required to determine whether general equipment is free from design, operational or maintenance hazards. Safety checklists and a hazard analysis format are provided to assist in the assessment of hazards.

15. SUBJECT TERMS
Air Exchange; Lift Limits; Noise Level; Toxic Hazards; Whole Body Vibration; Hazardous Materials; Placards

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 10-2-508A 11 February 2022
DTIC AD No.

SAFETY AND HEALTH HAZARD EVALUATION OF GENERAL EQUIPMENT

*This TOP supersedes TOP 10-2-508, Safety and Health Hazard Evaluation – General Equipment, 6 May 1980.

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1. SCOPE.

1.1 Purpose.

The purpose of this Test Operations Procedure (TOP) is to provide general guidance for identifying and evaluating hazards associated with operating and testing general equipment. The general equipment category is quite extensive and includes Force Sustainment Systems (Field Feeding, Field Services, Tents and Shelter Systems), Force Projection Systems (Wet and Dry Gap Bridging Equipment, Construction Equipment, Material Handling Equipment, Sets, Kits, Outfits, and Tools (SKOT)), and Chemical, Biological, Radiological, and Nuclear (CBRN) Protection Equipment, Decontamination Equipment, Analytical Laboratories, and Detectors.

1.2 Terms and Conditions.

Due to the variety of equipment included in this category, some of the information in this document may not apply. A complete evaluation is based on physical examination and testing, review of available documentation, and observations made by all participants during the test. The goal is to determine if the item is safe to test, transport, operate and maintain. For some commodity areas (i.e., Water Supply and Treatment Equipment), there are additional safety considerations found in the applicable commodity-specific TOP that should be addressed.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

Item	Requirement
Inspection facility	Shop area or level ground for inspecting test items.
Noise test facility	Per TOP 01-2-608B[1**].
Gantry-type crane	Means to lift test system for center of gravity measurements.

2.2 Instrumentation.

The following listing includes common measurements used in the safety and health hazard evaluation of general equipment.

Devices for Measuring	Permissible Measurement Uncertainty [a]
Voltage	± 0.5% of full scale (FS) range
Electric current	Amps, ± 0.1% FS
Weight	± 0.5% of reading
Temperature	± 2 °Celsius (°C) (± 3.6 °Fahrenheit (°F))
Relative humidity (RH)	± 1% of reading
Sound level	± 1 decibel (A-weighted sound level) (dB(A))
Wind speed	± 1% of reading
Distance/length	± 1 centimeter (cm) (± 0.5 inch (in.))
Toxic fumes	± 10% of reading

[a] Values may be assumed to represent ± 2 standard deviations. Thus, the stated tolerances should not be exceeded in more than one (1) measurement out of 20.

3. REQUIRED TEST CONDITIONS.

Unless otherwise specified by the procurement agency, all testing shall be performed at standard ambient test conditions as described in Military Standard (MIL-STD)-810H[2] and presented in Table 1.

** Superscript numbers correspond to Appendix D, References.

TABLE 1. STANDARD AMBIENT CONDITIONS

PARAMETER	CONDITION
Temperature	25 ± 10 °C (77 ± 18 °F)
RH	20-80%
Atmospheric pressure	Site pressure

3.1 Test Planning.

a. This TOP identifies tests and inspections commonly used to identify and assess safety hazards associated with the use of general equipment as listed in Table 2. Some tests will be needed to prepare a Recommendation for Safety Release (RSR), others for a Recommendation for Safety Confirmation (RSC), and the Health Hazard Assessment Report (HHAR).

TABLE 2. SAFETY INSPECTIONS AND TESTS

TEST PARAGRAPH	TEST TITLE	REFERENCE(s)	TOP(s) OR TEST METHODOLOGY
4.1	Inspections	Various – Appendix B Form 1183 Handbook	Appendix A Checklists
4.2	Noise/Sound Levels	MIL-STD-1474E[3]	TOP 01-2-608B ITOP 04-2-822[4]
4.3	Air Exchange Ventilation	MIL-STD-1472H[5]	TOP 02-2-622[6] TOP 02-2-614A[7]
4.4	Toxic Hazards	See Note a	TOP 02-2-622 TOP 02-2-614A
4.5	Thermal Contact Hazards	MIL-STD-1472H	Verify by measurement
4.6	Hazardous Materials	MIL-STD-882E[8]	Inspection
4.7	Physical Configuration	Test System Requirements, Vehicle/Trailer Capabilities	TOP 02-2-800[9] TOP 02-2-801[10]
4.8	Lift Limits – Individual Equipment	MIL-STD-1472H	Verify by measurement

TABLE 2. CONTINUED

TEST PARAGRAPH	TEST TITLE	REFERENCE(s)	TOP(s) OR TEST METHODOLOGY
4.9	Whole Body Vibration	International Organization for Standardization (ISO) 2631-1[11], ISO 2631-5[12]	TOP 01-1-014B[13]
4.10	Hand-Arm Vibration	MIL-STD-1472H Health Hazard Assessor's Technical Guide 351C[14]	ISO 5349-2[15]
4.11	Caution and Warning Placards	American National Standards Institute (ANSI) Z535.3[16], OSHA 29 CFR1910.145[17], MIL-STD-1472H	Verify by inspection
4.12	Safety Devices & Equipment	MIL-STD-882E, MIL-STD-1472H	Verify by test or inspection
4.13	Maintenance	MIL-STD-1472H	TOP 02-2-508[18]
4.14	Thermal Stress and Vehicle Climate Control Testing	MIL-STD-1472H	TOP 01-2-807[19] TOP 02-2-820[20]
4.15	Software Safety	MIL-STD-882E	ITOP 01-1-057[21]
4.16	Electromagnetic Interference (EMI)	MIL-STD-461G[22] MIL-STD-464A[23]	TOP 01-2-511[24]
4.17	Electromagnetic Radiation Hazards (RADHAZ)	MIL-STD-464A	TOP 03-2-616A[25]

Note a: American Conference of Government Industrial Hygienists, Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices[26].
U.S. Department of Health and Human Services, NIOSH Pocket Guide to Chemical Hazards[27].
Occupational Safety and Health Administration (OSHA), 29 CFR 1910, Permit-Required Confined Spaces for General Industry[28].

b. RSRs are prepared for participation of military personnel using the test item in an operational test, logistics demonstration, in-theater assessment, or training event at a specific location. The RSR must consider the conditions specific to the planned use and must address the safety of use under those conditions. An Operational Test planned for Cold Region Test Center in January will require different environmental safety testing than one planned for Fort Bragg, North Carolina, in July.

c. RSCs are prepared in support of program milestones such as type classification and fielding. The RSC must consider the Army-wide use of the test item and address all the safety concerns likely or possible to be encountered by Soldiers.

d. Health Hazard Assessment (HHA). The U.S. Army Public Health Center (APHC) is responsible for the Army's HHA Program. The APHC prepares the HHAR for the Program Executive Office (PEO) to support milestone events. Tests of particular interest for the HHA include noise, whole body vibration, hand-arm vibration, lift limits, ventilation, thermal stress, and toxic hazards. Test procedures should be coordinated with the APHC through the U.S. Army Test and Evaluation Command (ATEC) to ensure that their data requirements are met.

e. Ensure that a suitable test site and test facilities are available for conducting the test. For a new commodity/technology, it's possible that the test center will need to develop a suitable test site or modify an existing facility.

3.2 Preliminary Safety Review and Document Preparation.

a. Prepare the safety subtest for the detailed test plan for all Developmental Tests (DTs). For test items where the only input is safety, a test report may not be required if the RSR and/or RSC will serve as the test report.

b. For a DT, the materiel developer is required to provide a safety assessment report (SAR), operator manuals, and maintenance manuals. The SAR should be reviewed before the start of the test and include Safety Data Sheets (SDSs) for all potentially hazardous materials. It will list the safety and health hazards identified by the manufacturer and materiel developer. If available, review the HHAR. All hazards identified in the safety documentation must be considered in test planning.

c. If the system contains personnel occupied enclosures and/or gas emitting subsystems, a ventilation and/or toxic fumes tests should be executed. If the system contains a noise generating source(s), interior and/or exterior noise tests should be executed. Safety testing should be conducted early in the test program to ensure the test team is not exposed to toxic fumes or noise in excess of permissible limits. If the test results identify hazards to personnel, mitigations can be implemented by crew members (personal protective equipment (PPE)). Depending on the results, the materiel developer may require the system to be modified onsite or returned to the manufacturer to facilitate hardware improvements, followed by retesting to verify improved performance.

d. Ensure that specific tests are included in the test plan to verify compliance with the safety and health criteria established for the system. These tests will differ for the various types of equipment under test, and are usually described in the TOP for the specific commodity being tested, if one is available.

e. Review the system support package, instructional material, technical manuals, and schematics. The manuals (typically draft) should summarize all of the warnings and cautions in the front of each document and repeat them throughout for applicable operator and maintenance inspections and procedures. Cross-reference the SAR and manuals to ensure that all hazards identified in the SAR have been addressed in the manuals.

f. Review previous test reports of similar or related items to identify existing and potential hazards associated with the item(s) in order to develop procedures to mitigate or eliminate the hazards. If provided an opportunity, visit the manufacturer's location to inspect the

item prior to delivery to the test center to familiarize yourself with the physical configuration, operator and maintainer positions, warning placards, and safety devices and equipment.

g. Develop a Risk Assessment. Ensure required Standard Operating Procedures (SOPs) are available. If an SOP is not available for a particular test, coordinate with subject matter experts and develop a Job Hazard Analysis (JHA). Present the Risk Assessment to a Hazard Analysis Working Group (HAWG) meeting with all involved test center personnel (testers, safety, environmental, range control, and test support representatives). At the meeting, the Risk Assessment will be finalized prior to routing the 1045R Risk Assessment package through all applicable offices and management team members.

3.3 Training and Familiarization.

a. Ensure the developer or contractor conducts new equipment training (NET) for the test officer, all test crew members, and applicable support personnel. Coordinate with the materiel developer to ensure that the training curriculum includes all preventive maintenance, inspection and repair procedures, operational procedures, and unique operating conditions applicable to the planned subtests (for example, low temperature preparation).

b. Present a pretest safety briefing to all test participants. The briefing should include the hazards identified in the Risk Assessment. The briefing should also include range safety concerns, especially if the test involves supporting contractors (field system representatives) accessing controlled test ranges and facilities.

4. TEST PROCEDURES.

4.1 Inspections.

a. Method. If possible, conduct the safety inspections at the start of testing. Systems should be tested in the configuration(s) and at conditions in which they are expected to be deployed and operated by user troops. The system is to be inspected to confirm that the design and safety devices are adequate to protect the users and maintenance personnel from hazards without interfering with system operation.

b. Checklist. Form 1183, the Communications-Electronics Lifecycle Management Command (C-E LCMC) Directorate for Safety (DS) System Safety Design Verification Checklist (Appendix A), is to be used as a tool. No single checklist will be all-inclusive for this purpose, but Form 1183 addresses 13 subject areas and was the most comprehensive listing identified when this TOP was revised. The System Safety Design Verification Checklist Handbook (Appendix B) provides explanations regarding each requirement and identifies relevant military and commercial standards. The system design and requirement documents should be investigated to determine all applicable items affecting the safety and health hazards evaluation. The checklist should be examined for exclusion of non-applicable subject areas which do not require consideration. Any hazards identified will be photographed and documented (i.e., Test Incident Report (TIRs)). Perform follow-up inspections throughout testing, as required, if the test system is modified or adjusted during testing. In some cases, the hazards may be corrected through modifications.

c. Determine which subcomponents are commercial off-the-shelf (COTS) or government off-the-shelf (GOTS). Verify that COTS have an Underwriters Laboratory, Incorporated ® (UL®) listing (or comparable). For COTS, verify that the intended users (Military Occupational Specialty (MOS)-qualified Soldiers) will operate and maintain the subcomponent in the same fashion it was intended. For example, if the Soldier will not perform internal COTS maintenance, the item does not have to be evaluated for internal maintenance hazards.

d. Although many systems will consist of a collection of safe COTS and GOTS products, it is essential to examine and test the integration of the products for potential hazards. Examples include mounting bracket, rack, and fixture adequacy; routing of cabling, power sufficiency and circuit protection to include a ground fault circuit interrupter; maintenance procedures for removal and replacement of awkward or heavy equipment, grounding and bonding of equipment to avoid shock, protection of and adequacy of equipment for the required weather environments, adequacy of lighting, adequacy of environmental control systems, appropriate use of warning and caution labels, and potential hazards of equipment due to operation in an electromagnetic environment.

e. Data Required. The data from the inspections will be recorded in the Appendix A checklists and summarized in narrative form. Photographs or videos will be taken to document hazards. TIRs will be used as applicable.

4.2 Noise.

a. Method. Sound level measurements, as listed in TOP 01-2-608B or ITOP 04-2-822 (as applicable), will be recorded. With the system assembled/configured per the Technical Manual (TM) and NET, measure the 85-dB(A) contour(s) and peak noise levels at all operator and maintainer personnel occupied areas. The system should be operated at its highest pressure/volume/fan speed to capture the most significant noise signature. Consideration must also be given to capturing the noise generated from intermittent (e.g., air compressors, pneumatic valves, analytical equipment) and impulse (e.g., jackhammer, pile driver, other tools) noise sources. Where the impulse noise level exceeds 140-dBP, the distances and directions from the noise source at which the noise levels are equal to 140-dBP will be recorded.

b. Data Required.

(1) System identification and configuration.

(2) List of calibrated instrumentation (nomenclature, model, serial number, manufacturer, and calibration date).

(3) Date, location, air temperature, RH, wind speed, and background noise level.

(4) Steady-state noise contour(s), 85 dB(A).

(5) Noise levels at operator and maintainer positions.

(6) Noise contour(s), 140-dBP.

(7) TIRs, as applicable.

4.3 Air Exchange Ventilation.

a. Self-Propelled Vehicles/Construction Equipment/Material Handling Equipment. The test method and data required are provided in TOP 02-2-614A, Test Procedure 4.1.

b. Tents, Shelters, and Sheltered Equipment. The test method and data required are provided in TOP 02-2-622, Test Procedure 4.4.

4.4 Toxic Hazards.

a. Self-Propelled Vehicles/Construction Equipment/Material Handling Equipment. The test method and data required are provided in TOP 02-2-614A, Test Procedure 4.3.

b. Tents, Shelters, and Sheltered Equipment. The test method and data required are provided in TOP 02-2-622, Test Procedure 4.6.

4.5 Thermal Contact Hazards.

a. Method. Identify potential thermal contact hazards (e.g., motors, pumps, heaters, air conditioners, refrigeration units, power generators, fluid piping) for both high and low temperature conditions through physical inspection or document identification (e.g., SAR, TM). Operate the test system until it reaches a steady-state operating condition. Employ a suitable temperature measurement device (e.g., infrared thermometer, contact thermocouple) to measure surface temperatures. Provision of warning decals, signs, or labels identifying contact hazards will be confirmed.

b. Data Required.

(1) System identification and configuration.

(2) Component identification and primary material of composition (e.g. plastic, wood, glass or metal).

(3) Calibrated instrumentation (nomenclature, model, serial number, manufacturer, and calibration date).

(4) Date, location, air temperature.

(5) Surface temperatures.

(6) Results of warning label inspection.

(7) Photographs of tested/inspected areas.

(8) TIRs, as applicable.

4.6 Hazardous Materials.

a. Method. Review the Hazardous Materials Management Plan (HMMP) supplied by the system vendor or hazardous materials (HAZMAT) list in the SAR and cross-match it with the inventory list for verification that all required materials have been supplied for inspection and use during test. If not identified during NET, review the TM (or discuss with a subject matter expert from the manufacturer or materiel developer) to identify the intended use of each hazardous material provided. Verify that the TM includes procedures for proper handling, use, storage and disposition of each material. Inspect all of the HAZMAT containers and match the labels with the SDSs supplied in the SAR to verify the materials are properly marked. Review the SDSs to identify the hazards and the PPE specified for handling. Verify the materials are suitable for use and storage in all of the required environmental and planned test conditions (low and high storage temperatures, humidity). Verify that the required PPE was supplied with the Basic Issue Items (BII) and supplied in a range of sizes (5th through 95th percentile). The PPE will be employed by the test team during all required hazardous material-handling operations. Any instances of difficulty in donning, use, or doffing the PPE will be recorded.

b. Data Required.

(1) Identification of hazardous materials and their intended use/function.

(2) Inventory of SDSs to match the hazardous materials.

(3) TM verification results (use, handling, storage and disposition).

(4) Results of chemical labeling and packaging inspections.

(5) Results of environmental condition use and storage verification (SDS review).

(6) Results of PPE form, fit, and function assessment.

(7) TIRs, as applicable.

4.7 Physical Configuration.

a. Method. For test equipment that is transported via wheeled vehicles or trailers, measure the weight, weight distribution, and center of gravity (CG) per TOPs 02-2-801 and 02-2-800, respectively. Repeat the measurements for all unique system (weight) and vehicle and trailer configurations. Compare the data to the load capabilities of each vehicle and trailer identified to transport the test system. If the weight or CG configuration exceeds published or previously tested and proven configurations, additional automotive safety testing may be required including tilt table (static roll-over threshold), steering performance, braking, gradeability and side slope performance. The system will be inspected to verify the provision of CG and weight labels per MIL-STD-1472H, paragraph 5.7.2.6 and ANSI Z535.3.

b. Data Required.

(1) System and vehicle/trailer configurations.

(2) Weight.

(3) Weight distribution.

(4) CG location.

(5) CG and weight label verification results.

(6) TIRs, as applicable.

4.8 Lift Limits - Individual Equipment.

a. Method. For test systems with man-portable equipment, each item will be weighed on a floor or table mounted calibrated scale of suitable load capability. The weight of each item will be compared to MIL-STD-1472H, paragraph 5.20.3 and Table XLI, to assess the maximum design weight limits. After the number of lifters are identified, the equipment and its carrying containers will be inspected to determine if the number of handles or lifting bars supplied are sufficient to safely lift and carry each item. For equipment requiring more than a one-person lift, the equipment will be inspected to determine if each item or storage container is prominently labeled with the weight and lift limitation per MIL-STD-1472H, paragraph 5.20.4.6, Labeling.

b. Data Required:

(1) Equipment identification.

(2) Weight.

(3) Number of lift handles.

(4) Results of weight limit assessment (number of lifters, multipliers).

(5) Results of label assessment.

(6) TIRs, as applicable.

4.9 Whole Body Vibration (WBV).

This test requirement is suitable for self-propelled vehicles/construction equipment/material handling equipment. The test methods and data required are identified in TOP 01-1-014B. The TOP describes methods for evaluating the ride dynamics or ride quality of ground vehicles and the vehicle occupants' exposure to WBV.

4.10 Hand-Arm Vibration.

Operating machinery may expose personnel to hand-transmitted mechanical vibration which can interfere with comfort, working efficiency and, in some circumstances, health and safety. The requirements for measuring and evaluating hand-transmitted vibration exposure are identified in ISO 5349-1. The ISO describes the methods and precautions to make representative vibration measurements and to determine the daily exposure time for each operation in order to calculate the 8-hour energy-equivalent vibration total value.

4.11 Caution and Warning Placards.

a. Method. The SAR and TM will be reviewed to verify that all potential equipment hazards that were identified, and require a caution or warning placard, are so equipped. The caution and warning placards will be checked for appropriate location and means of security. The content, format and readability of each placard will be checked for conformance to the applicable standard(s) listed in Table 2 or the test system specification.

b. Data Required.

(1) Identification of warning and caution placards and locations.

(2) Results of placard inspection/verification.

(3) Photographs of representative placards.

(4) TIRs, as applicable.

4.12 Safety Devices and Equipment.

a. Method. Safety and warning devices supplied on the system will be identified including type, location, and rating/certification. The adequacy and functionality of the devices will be verified, to the maximum extent possible, without causing harm to the item. For example, pressure relief valves will be inspected to determine if they discharge down and away from personnel occupied areas. Hazardous material detectors/alarms will be tested to verify functionality. The fire safety cabinet for storage of flammable liquids will be inspected to verify certification to National Fire Protection Association (NFPA) Code 30, Flammable and Combustible Liquids Code[29]. The type, size, storage location, and means of positive securement of the fire extinguisher(s) will be inspected and recorded.

b. Data Required.

(1) Identification of safety and warning devices and their intended use/function.

(2) Results of warning device inspections/tests.

(3) TIRs, as applicable.

4.13 Maintenance.

a. Method. Only maintenance actions intended to be performed by the Soldier need to be assessed for safety. A review of the maintenance allocation chart will identify all operator and maintainer maintenance tasks, but it is rarely available during DT. Generally the test center is only provided sufficient time to assess safety for the maintenance and repair procedures accomplished during test conduct to return the test system to working order. TOP 02-2-508, paragraph 4.10, addresses the safety aspects of maintenance for automotive equipment and it is applicable for self-propelled construction, material handling, and field service equipment. The Form 1183 Checklists (paragraph 4.1 and Appendix A) address potential mechanical and electrical hazards. MIL-STD-1472H, paragraph 5.9, Design for Maintainability, will serve as a great reference if the system requirement documentation lacks maintainability criterion.

b. Data Required. Observations of all maintenance tasks indicating insufficient provisions or conditions to permit safe performance of maintenance.

4.14 Thermal Stress.

This testing is applicable to equipment with vehicle operator and passenger workspaces. The test methods and data required to assess vehicle cabs are provided in TOP 01-2-807.

4.15 Software Safety.

If the test system has software that controls safety significant functions, the test methods described in ITOP 01-1-057 shall be applied.

4.16 Electromagnetic Interference (EMI).

MIL-STD-461G identifies the verification requirements for the control of EMI emission and susceptibility characteristics of electronic, electrical and electromechanical equipment and subsystems. EMI test methods and data required are provided in TOP 01-2-511A.

4.17 Electromagnetic Radiation Hazards (RADHAZ).

MIL-STD-464C electromagnetic environmental effects (E3) which encompasses hazards of electromagnetic radiation to personnel (HERP), ordnance (HERO) and volatile materials (HERF). The RADHAZ test methods and data required are provided in TOP 03-2-616A. PPE such as insulated gloves and/or shoes will be provided to all personnel for protection against electromagnetic field shock and burns or for insulation from the ground plane, and approved to comply with the induced current limits found in IEEE Standard C95.1-2345.

5. DATA REQUIRED.

Data required for each test procedure are presented in paragraph 4.

6. PRESENTATION OF DATA.

6.1 Inspections.

The results of the applicable safety checklists will be summarized in tables supported by TIRs, photographs, or videos, as applicable. Each hazardous condition will be assigned a hazard severity and hazard probability as outlined in MIL-STD-882E, and assigned an overall risk based on the risk assessment matrix in MIL-STD-882E, or the safety assessment report.

6.2 Noise.

The noise contour and operator/maintainer position data will be presented in tables supported by graphics of test configurations.

a. Exterior Noise. The exterior noise data will be compared to the noise contour criterion of 85 dB(A) to determine if hearing protection is required.

b. Interior Noise. The interior noise data will be compared to the 85 dB(A) criterion for single hearing protection and a time weighted average (TWA) or time-weighted average level (Lavg) of 103-108 dB(A) for double hearing protection per Section 7-13 of the Department of the Army Pamphlet (DA PAM) 40-501[30]. The Lavg calculation is presented in TOP 01-2-608B, para 4.1.6. The system specification will often have an interior noise criterion to satisfy the mission scenario. MIL-STD-1474E, Table A-I, identifies the steady-state noise categories and noise limits for personnel-occupied areas to guide materiel developers to properly facilitate communication.

6.3 Air Exchange Ventilation.

a. Self-Propelled Vehicles/Construction Equipment/Material Handling Equipment. The presentation of data and analytical procedures are provided in TOP 02-2-614A.

b. Tents, Shelters, and Sheltered Equipment. The presentation of data and analytical procedures are provided in TOP 02-2-622.

6.4 Toxic Hazards.

a. Self-Propelled Vehicles/Construction Equipment/Material Handling Equipment. The presentation of data and analytical procedures are provided in TOP 02-2-614A.

b. Tents, Shelters, and Sheltered Equipment. The presentation of data and analytical procedures are provided in TOP 02-2-622.

6.5 Thermal Contact Hazards.

The temperature data will be presented in tables. Compare the results to the temperature exposure limits of MIL-STD-1472H, Table XXVII (currently missing from the MIL-STD), reproduced as Table 3. Per MIL-STD-1472H, paragraph 5.7.5.9, surfaces that reach the prolonged contact or handling exposure limits in Table 3, or are less than 0 °C (32 °F), will be

identified if physical mitigations (i.e., shields, insulation) are not supplied. Provision of warning decals, signs, or labels identifying contact hazards will be confirmed.

TABLE 3. TEMPERATURE EXPOSURE LIMITS

EXPOSURE	MATERIAL COMPOSITION					
	Metal		Glass		Plastic or Wood	
	°C	°F	°C	°F	°C	°F
Momentary contact	60	140	68	154	85	185
Prolonged contact or handling	49	120	59	138	69	156

6.6 Hazardous Materials.

The results of the inventories and inspections will be summarized in tables and narrative descriptions. Any discrepancies, missing instructions, or missing or insufficient PPE items will be identified.

6.7 Physical Configuration.

The results of the measurements will be summarized in data tables. Weight and CG comparisons with the load capability of the trucks, trailer, and/or shelter will be identified in narrative descriptions. Reference will be made to previously published test reports documenting similar test configurations and automotive safety test results.

6.8 Lift Limits – Individual Equipment.

The results of component weight and lift handle inspections will be summarized in data tables. An assessment will be made and force multipliers will be assessed per MIL-STD-1472H, paragraph 5.20.3 and Table XLI to characterize the number of lifters required for each man-portable test item.

6.9 Whole Body Vibration (WBV).

The presentation of data and analytical procedures are provided in TOP 01-1-014B.

6.10 Hand-Arm Vibration.

The presentation of data and analytical procedures are provided in ISO 5349-2 and Technical Guide 351C.

6.11 Caution and Warning Placards.

The results of the inspections will be summarized in tables supported by photographs of representative placards.

6.12 Safety Devices and Equipment.

The results of the inspections and functional verification tests will be summarized in tables and narrative descriptions.

6.13 Maintenance.

The results of the observations and inspections will be summarized in tables and narrative descriptions.

6.14 Thermal Stress and Vehicle Climate Control Testing.

The presentation of data and analytical procedures are provided in TOP 01-2-807 and TOP 02-2-820.

6.15 Software Safety.

The presentation of data and analytical procedures are provided in ITOP 01-1-057.

6.16 Electromagnetic Interference.

The presentation of data and analytical procedures are provided in TOP 01-2-511A.

6.17 Radiation Hazards.

The presentation of data and analytical procedures are provided in TOP 03-2-616A.

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

NOTE: This checklist is derived from Communications-Electronics Command Directorate for Safety (CECOM DS) Systems Engineering Laboratory (SEL) Form 1183, February 2014, with U.S. Army Test and Evaluation Command (ATEC) changes incorporated in blue font.

Applicability

This checklist is a tool used to help verify the safety of systems design. This checklist is not a requirements document in itself, but is used to verify certain design requirements detailed in the system specification. This checklist should not be considered to be all-inclusive, or as a substitute for items requiring verification through test.

Identification of Inspected Item		
Name/Nomenclature:		
Parent System:		
National Stock Number: (NSN):		
Serial Number:		
Contract Number:		
Contractor:		
Software Version:		
Specification Number:		Date:
Program/Equipment Phase:		
Completion State of the Equipment:		
Date of Inspection:		Inspector:
Organization and Address:		
Telephone:	DSN:	COM:
Facsimile:	DSN:	COM:
EMAIL:		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

INSTRUCTIONS

1) Enter the system information on the first page.

2) Review available safety data, to include the System Specification, Hazard Analysis Reports, Safety Assessment Reports, Test Reports, Schematics, Drawings, and Technical Manuals.

3) Select the sections of this checklist that apply to the item to be inspected, and document this in the table below. Sections 1 – 5 are to be completed for all equipment and systems, whereas sections 6 – 13 are to be completed when applicable. Refer to page 3 for a description of each section.

4) Review each question and eliminate those that do not apply by marking NA (not applicable) in the Conformance block.

5) Evaluate each applicable question and record conformance or non-conformance by a Y (yes) or N (no), respectively. Questions should be considered from an individual equipment standpoint, as well as from a systems integration standpoint.

6) Where a NO response is recorded, provide details in the remarks column specifying the reason of non-conformance, and mitigated actions taken or required to ensure safety.

7) The proponent of this form is the CECOM Directorate for Safety. Users are invited to send comments on DA Form 2028 (Recommended Changes to Publications and Blank Forms) to CECEOM Directorate For Safety, ATTN: AMSEL-SF, Bldg 3200, Rm 4500, Raritan Ave, Aberdeen Proving Grounds, MD 21014-1850. Questions and comments can also be forwarded via email to: usarmy.APG.cecom.mbx.amsel-sf@mail.mil

Sec	Subject Area	Requirement
1	Electrical Safety	Applicable
2	Mechanical Safety	Applicable
3	Other Safety	Applicable
4	Health Hazards	Applicable
5	Environmental Impact	Applicable
6	Radiation Safety	
7	Antennas and Masts	
8	Batteries	
9	Generators	
10	Equipment Integration of Shelters and Trailers	
11	Equipment Integration of Vehicle Cabs	
12	Transit Case Mounted Equipment	
13	Software Safety	

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Below is a brief summary of each section.

1. ELECTRICAL SAFETY – *completion of this section is mandatory. This section addresses voltage and current hazard protection, grounding, wiring, switches, overcurrent protection, and other electrical safety aspects. Commercial off-the-shelf equipment that has been safety evaluated by industry is also addressed.*

2. MECHANICAL SAFETY – *completion of this section is mandatory. This section addresses enclosure and guard design, interlocks, mechanical stops, pinch points, sharp edges, loading, equipment weight and surface temperatures, and other mechanical safety aspects.*

3. OTHER SAFETY – *completion of this section is mandatory. This section addresses other equipment safety topics such as warning devices, labeling, and color-coding of indicators.*

4. HEALTH HAZARDS – *completion of this section is mandatory. This section addresses personnel health hazards such as exposure to noise, hazardous materials, heat stress, and air quality.*

5. ENVIRONMENTAL IMPACT – *completion of this section is mandatory. This section addresses the impact of the equipment, chemicals, batteries, and/or radiation on the environment.*

6. RADIATION SAFETY – *to be completed if the system is a source of nonionizing radiation (Radio Frequency (RF), microwave, etc.), ionizing radiation (X-ray; radioactive isotopes), or contains a laser system. ALL RADIOACTIVE ISOTOPES, INCLUDING UNLICENSED QUANTITIES, MUST BE REPORTED TO THE DEPARTMENT OF THE ARMY.*

7. ANTENNAS AND MASTS – *to be completed if the system uses an antenna or a mast. This section also addresses requirements for lightning protection for antenna masts.*

8. BATTERIES – *to be completed if the system uses batteries. This section addresses rechargeable and nonrechargeable batteries, battery enclosures, venting, and other related topics.*

9. GENERATORS – *to be completed if the system is integrated or fielded with a generator that is not an Army standard set. This section supplements sections 1 – 5 with additional generator specific safety topics covering shock hazards, fuel systems, fire extinguishers, interlocks, etc.*

10. EQUIPMENT INTEGRATION OF SHELTERS AND TRAILERS – *to be completed if equipment is integrated into a shelter or onto a trailer, to include the back (squad area) of a High Mobility Multi-purpose Wheeled Vehicle (HMMWV) or other vehicle platform. This section supplements sections 1 - 5 and addresses safety topics such as egress pathways, center of gravity and roadability, rack integration, multiple power sources, and operations on-the-move.*

11. EQUIPMENT INTEGRATION OF VEHICLE CABS – *to be completed if equipment is integrated into vehicle cabs. This section supplements sections 1 - 5 and addresses safety topics such as egress pathways, the potential for aggravated injuries, impact to driver field of view, durability of equipment mounts, cable runs, etc.*

12. TRANSIT CASE MOUNTED EQUIPMENT – *to be completed if equipment is integrated into and transported by transit cases. This section supplements sections 1 - 5 and addresses safety topics such as equipment exposure to rain, grounding and Ground Fault Circuit Interrupter (GFCI) protection, stacking of cases, etc.*

13. SOFTWARE SAFETY – *to be completed if the equipment contains software that could create a hazard, controls hazardous processes, or controls information upon which users make critical decisions.*

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 1: Electrical Safety	Verify	Remark
♦ COMMERCIAL OFF-THE-SHELF EQUIPMENT ♦		
1.1 Are Commercial Off-The-Shelf (COTS) equipment Listed or certified by a nationally recognized testing laboratory (NRTL)?		
1.2 Are Listed COTS used in accordance with the manufacturer's manuals, in the intended environment, and within the limitations of the Listing?		
1.3 Have any modifications to the equipment been reevaluated by the Listing NRTL?		
1.4 Is maintenance not required on Listed COTS equipment beyond that specified in the manufacturer's manuals?		
♦ PROTECTION AGAINST SHOCK AND ARCING ♦		
1.5 Are personnel suitably protected from access to hazardous voltages (>30 volts between live parts and/or ground) when setting up, operating, or tearing down the equipment?		
1.6 Are personnel suitably protected from accidental contact with hazardous voltages (>30 volts between live parts and/or ground) during maintenance and when maintenance covers are opened?		
1.7 If the answer to question 1.6 is **NO**, is a bypassable safety interlock incorporated to kill all power within the compartment once the maintenance cover is removed?		
1.8 Are enclosures or guards that protect terminals or like devices exhibiting 30-600 volts, marked "WARNING, XXX Volts" in black on an orange background?		
1.9 Are portions of assemblies operating at potentials above 600 volts completely enclosed from the remainder of the assembly, and is this enclosure provided with non-bypassable safety interlocks?		
1.10 Are enclosures for potentials, which exceed 600 volts, marked "DANGER, HIGH VOLTAGE, XXX VOLTS" in white on a red background?		
1.11 Are all terminals, conductors, etc., capable of supplying greater than 25 amperes, protected against accidental short circuit by tools, removable conductive panels and assemblies, etc.?		
1.12 Are all high voltage circuits (>600 V) and capacitors (>30 V or >20 joules energy) reliably and automatically discharged to less than 30 volts / 20 joules within two seconds after power is removed?		
1.13 Are all test points, required to be measured by maintainers, limited to less than 300 V (between test points and/or accessible dead metal/ground)?		
1.14 If voltage dividers are used to reduce test point potentials, are two resistors used between the test points and/or neutral (not ground)?		
1.15 Where test point voltages are to be measured through holes in protective barriers, is the maximum voltage labeled?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 1: Electrical Safety	Verify	Remark
1.16 Is sufficient space provided between live parts and/or dead metal parts to prevent shorting or arcing?		
1.17 Are parts and components suitably affixed to prevent loosening or rotation that could lead to shorting or arcing?		
1.18 If a tool is required to make adjustments while equipment is powered, is spacing and insulation adequate to prevent contact with energized parts by the tool?		
♦ CONNECTORS AND PLUGS ♦		
1.19 Have connectors, used for multiple electric circuits/voltages, been selected to preclude mismating?		
1.20 Has the use of similar configuration connectors in close proximity avoided?		
1.21 Are plugs and receptacles coded and marked to clearly indicate mating connectors, where those of similar configuration are in close proximity?		
1.22 Are plugs and receptacles designed to preclude electrical shock and burns while being disconnected?		
1.23 Are male plugs de-energized when disconnected?		
1.24 Is the operator protected from potential arcing if accidentally disconnecting RF power cables?		
1.25 Are all receptacles marked with their voltage, amperage, phase, and frequency characteristics where these ratings differ from the standard ratings?		
♦ WIRING ♦		
1.26 Is the wiring and insulation suitable for the intended load and operating voltage?		
1.27 Is the wiring insulation suitable for the anticipated environment, temperature, and/or possible exposure to fuel, grease, or other chemicals?		
1.28 Are wires and cables supported, protected, and terminated in a manner that prevents shock and fire?		
1.29 Is wiring protected when passing though openings, near sharp edges, and near hot surfaces?		
1.30 Is suitable strain relief provided for conductors and cords at their terminations to prevent stress from transmitting to terminals, splices or internal wiring?		
1.31 Where the user has access to wiring that carries hazardous voltage/current, does the wiring have a 2nd barrier of protection (i.e. jacketed cord, conduit, etc.)?		
1.32 Are single-phase line conductors color coded black, or otherwise clearly identified?		
1.33 Are three-phase line conductors color coded as follows: A – black, B – red, C – blue, or otherwise clearly identified?		
1.34 Are DC power conductors color coded red for positive polarity and black for negative polarity?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 1: Electrical Safety	Verify	Remark
♦ GROUNDING ♦		
1.35 Are all equipment noncurrent-carrying metal parts and surfaces at ground potential when the equipment is powered (excluding self-powered equipment)?		
1.36 Does self-powered equipment have all external surfaces at the same potential?		
1.37 Is the path from various equipment points to ground continuous and permanent (hinges and slides not relied upon as the ground path)?		
1.38 Are the noncurrent-carrying parts of internal components grounded where they can be accessed by maintainers?		
1.39 Are panels and doors containing meters, circuit breakers, etc., grounded in a reliable manner, whether in a closed or open/removed position (less than 0.1 ohm)?		
1.40 Does the grounding path have capacity to safely conduct any currents that might be imposed thereon?		
1.41 Is the impedance of the grounding path sufficiently low to limit the potential drop and to allow over-current devices to clear quickly?		
1.42 Does the path from the equipment tie point to ground have sufficient mechanical strength to minimize accidental grounding disconnection?		
1.43 Do cables that carry a grounded conductor (neutral) also carry an Equipment Grounding Conductor (EGC) that terminates in the same manner as the other conductors?		
1.44 Are insulated grounding wires color coded green with or without yellow stripes?		
1.45 Are neutral / grounded conductors color coded white or natural grey?		
1.46 Is green and white color coding applied ONLY to grounding and grounded conductors, respectively?		
1.47 Do power attachment plugs automatically ground equipment?		
1.48 When the grounded power plug is mated with the receptacle, does the ground pin contact make first/break last?		
1.49 Are noncurrent-carrying metal parts, grounding wires, etc. (except RF cable shields) not used to complete electrical circuits?		
1.50 Is the grounding wire separate from electrical circuits, i.e., not tied to neutral other than at the power source?		
1.51 If a neutral-ground bond point is provided at the equipment's secondary supply circuit, is it isolated from the primary power source neutral-ground bond point in order to prevent ground loops?		
1.52 On transmitting equipment, is a grounding stud provided that permits attachment of a portable shorting rod?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 1: Electrical Safety	Verify	Remark
1.53 Is a ground stud provided on equipment intended to be interconnected to remote systems via long lengths of signal cables?		
1.54 Has a test been conducted to verify that the equipment (as well as equipment systems) allows less than 5 Measurement Indication Units (MIU) of residual leakage current to flow to ground under the most adverse conditions of input voltage/frequency (3.5 MIU if the system can be powered from GFCI protected circuits)?		
1.55 Where equipment has excessive leakage current, are redundant EGCs provided?		
♦ POWER DISCONNECTS AND SWITCHES ♦		
1.56 Is a means provided so that power can be cut off while installing, replacing, or servicing a complete system or any Line Replaceable Unit (LRU)?		
1.57 If a main power switch is provided, does it cut off all power to the complete system?		
1.58 Is the switch located on the front panel and clearly identified?		
1.59 Are power and control switches selected and located to prevent accidental actuation or stopping of the equipment?		
1.60 Are switches provided to deactivate mechanical drive units without disconnecting other parts of the equipment?		
1.61 Are power/maintenance switches provided at equipment which can be powered or controlled remotely?		
1.62 Can lockout/tagout devices be applied to switches that are relied upon to deactivate power during maintenance?		
1.63 Is protection provided against accidental contact with the supply side of the main power switch?		
1.64 Are emergency controls readily accessible and clearly identified?		
♦ INTERLOCKS ♦		
1.65 Where safety interlocks are used, is the interlock actuator recessed or otherwise protected against contact?		
1.66 Are safety interlock circuits designed to be fail-safe?		
1.67 Are live parts of safety interlocks protected from contact?		
1.68 Where bypassable safety interlocks are used, do they automatically reset once the cover or guard is replaced?		
1.69 Are battle short interlocks provided with an indicator to show when active?		
♦ OVERLOAD AND OVERCURRENT PROTECTION ♦		
1.70 Is equipment that is designed to have multiple-input power capabilities, or powered by a generator with multiple-voltage output capabilities, protected from damage when connected to incorrect input power/voltage levels?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 1: Electrical Safety	Verify	Remark
1.71 Are overcurrent and/or overload protective devices provided to protect equipment and conductors?		
1.72 If overcurrent protective devices are provided in series with any conductor grounded at the power source, does this device simultaneously open all other load conductors in the circuit?		
1.73 Are multi-pole circuit breakers provided for multi-phase circuitry which will open all phases during a fault in any one?		
1.74 If circuit breakers are used to power up/down equipment, have they specifically been designed for this purpose?		
1.75 Do circuit breakers provide a visual indication when tripped?		
1.76 Can fuses be removed safely (no exposed live parts) and without the use of tools?		
1.77 Are fuse replacement types and ratings labeled?		
1.78 Is surge protection incorporated to protect the user and the equipment?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 2: Mechanical Safety	Verify	Remark
♦ ENCLOSURES AND GUARDS ♦		
2.1 Are equipment enclosures suitably designed to protect the equipment and personnel when considering the anticipated environment and rough handling?		
2.2 Are equipment openings and vents sized and located to prevent access to hazardous parts, as well as to prevent objects from falling inside and contacting hazardous parts?		
2.3 Are fasteners and methods of securing doors and peripheral components sufficiently strong to prevent breakaway during normal use?		
2.4 Are snag hazards due to exposed gears, cams, fans, belts, guy wires, and other moving parts avoided?		
2.5 Does the equipment enclosure material and any enclosure openings limit fire propagation?		
2.6 Are switches and other electrical components adequately protected against water entry due to rain or equipment washdown?		
2.7 Is the equipment designed to provide personnel adequate and safe access (free of obstructions) during installation, operation, and maintenance?		
2.8 Are "no step" markings provided at necessary locations to prevent injury and equipment damage?		
♦ STOPS, LIMITS AND INTERLOCKS ♦		
2.9 Are self-locking or other fail-safe devices incorporated into expandable and collapsible structures, such as shelters, jacks, masts, and tripods, to prevent accidental or inadvertent collapsing or falling?		
2.10 Are reliable stops/limits integrated to protect moving parts from damage due to over-extension or by being driven into fixed parts?		
2.11 Where pins or latches are applied during equipment stowage, transportation or maintenance to secure moveable components, is damage prevented if the pins are left in and the drive mechanism activated?		
2.12 Are doors and drawers and associated hinges, supports, slides, and stops positively locked or otherwise secured to prevent unintended movement when in the open or closed position?		
♦ PINCH POINTS AND SHARP EDGES ♦		
2.13 Are telescoping ladders and assemblies provided with adequate clearance between rungs/parts to prevent pinch points?		
2.14 Are hinged brackets and such devices designed and located so that fingers are not exposed to pinch points during adjustment?		
2.15 Are sharp corners, edges, and projections avoided?		
2.16 Is hand-held equipment designed without sharp edges or protrusions that could cause injury if hit or felled upon while carried in a pocket?		
2.17 Is the installed equipment free of overhanging edges and corners that may cause injuries?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

<table>
<tr><th>Section 2: Mechanical Safety</th><th>Verify</th><th>Remark</th></tr>
<tr><td>2.18 Are door and cover edges not at eye level when in an open position?</td><td></td><td></td></tr>
<tr><td colspan="3">♦ HANDLING ♦</td></tr>
<tr><td>2.19 Is the equipment weight limited to permit safe handling by the anticipated user/maintainer crew size per the criteria below?

<table><tr><th>No. of Soldiers</th><th>Weight, lb</th></tr><tr><td>1</td><td>37</td></tr><tr><td>2</td><td>74</td></tr><tr><td>3</td><td>102</td></tr><tr><td>4</td><td>130</td></tr></table></td><td></td><td></td></tr>
<tr><td>2.20 Is a caution label specifying weight and lifting requirements affixed to equipment exceeding the single soldier handling criteria?</td><td></td><td></td></tr>
<tr><td>2.21 Are suitable carrying handles or hand grasp areas provided?</td><td></td><td></td></tr>
<tr><td>2.22 Does the equipment’s size and weight distribution allow for easy handling, moving, and positioning?</td><td></td><td></td></tr>
<tr><td>2.23 Is the temperature of all exposed parts subject to momentary contact less than 60ºC (140ºF) for metal, 68ºC (155ºF) for glass, or 85ºC (185ºF) for plastic/wood at an ambient temperature of 25ºC (77ºF), regardless of the condition of operation?</td><td></td><td></td></tr>
<tr><td>2.24 If the answer to question 2.23 is NO, are the hot surfaces adequately labeled and protected against accidental contact?</td><td></td><td></td></tr>
<tr><td>2.25 Where prolonged contact is required (handles, controls, etc.), are surface temperatures less than 49ºC (120ºF) for metal, 59ºC (138ºF) for glass, or 69ºC (156ºF) for plastic/wood at an ambient temperature of 25ºC (77ºF), regardless of the condition of operation?</td><td></td><td></td></tr>
<tr><td colspan="3">♦ MISCELLANEOUS ♦</td></tr>
<tr><td>2.26 Is the equipment likely to remain upright under normal use and in strong wind, considering its means of support, center of gravity, and slope?</td><td></td><td></td></tr>
<tr><td>2.27 Is the weight bearing capacity of hoists, jacks, and other such equipment suitable for the expected loading conditions and is the load capacity labeled?</td><td></td><td></td></tr>
<tr><td>2.28 Are pressurized systems or components provided with relief valves that will vent in a safe direction and manner?</td><td></td><td></td></tr>
<tr><td>2.29 Are positive means provided to prevent mismating of fittings; couplings; fuel, oil, hydraulic, and pneumatic lines; and mechanical linkages?</td><td></td><td></td></tr>
<tr><td>2.30 Are there provisions to prevent injury from the implosion of cathode ray tubes?</td><td></td><td></td></tr>
<tr><td>2.31 Is all glass of the non-shatterable type?</td><td></td><td></td></tr>
</table>

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 3: Other Safety	Verify	Remark
3.1 Is the system designed to preclude injury or equipment damage due to operator induced error?		
3.2 Is equipment designed to prevent accidental ignition when used in hazardous atmospheres? (Applicable to equipment that is intended for use in atmospheres of explosive gas or vapors, combustible dusts, or ignitable fibers and flyings.)		
3.3 Are emergency controls readily accessible and clearly identified?		
3.4 Are switches, indicators, panel instruments, and control devices adequately labeled to prevent confusion which could lead to a hazard?		
3.5 Is an audible/visual warning device provided to warn personnel of impending danger, or to indicate malfunction that could cause injury or equipment damage?		
3.6 Is proper color coding provided for safety critical indicators (green: power on, ready; amber: caution; red: danger; white: info)?		
3.7 Is adequate separation provided between critical warning lights and other lights?		
3.8 Are audible warning signals distinguishable from other sounds under normal operating conditions?		
3.9 Is the display lighting of aircraft electronics (avionics) compatible to the use of night vision goggles?		
3.10 Have all equipment related mechanical, electrical, chemical, and health hazards been suitably addressed through warning labels?		
3.11 Are guards, covers, and barriers marked to indicate the hazard which may be present upon removal of such devices?		
3.12 Are labels sized and placed so that the associated hazard is identified before the user is exposed to the hazard?		
3.13 When possible, are labels located such that they are not removed when the barrier or access door is removed?		
3.14 Do warning labels comply with the marking, design, and color requirements detailed in the system specification?		
3.15 Are warning labels capable of lasting for the normal life expectancy and operational environments of the equipment to which they are affixed?		
3.16 Is PMCS established for safety critical circuits such as safety interlocks, voltage dividers, capacitor discharge circuits, etc.?		
3.17 Are all maintenance procedures within the qualifications of the designated Military Occupational Specialty (MOS)?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 4: Health Hazard	Verify	Remark
4.1 Are noise levels less than the below listed limits at both operator and maintainer locations? Steady state, 8 hr TWA: 85 dBA Impulse: 140 dBP		
4.2 Where safe noise levels can be exceeded during operation or maintenance, are appropriate warning labels provided on the equipment?		
4.3 If headsets or earphones are to be used with the equipment, are labels provided on the equipment to warn users to keep the volume at the lowest, useable level?		
4.4 Is the equipment (considering operation, maintenance, storage, and/or disposal) free from hazardous or potentially hazardous materials?		
4.5 Have non-hazardous substitute materials been utilized as much as possible?		
4.6 Are potential exposures to hazardous materials controlled to levels below the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) and/or American Conference Of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV); which ever is the more stringent requirement?		
4.7 Is the release of toxic, corrosive, or explosive fumes or vapors prevented?		
4.8 Is the equipment free of advanced composite materials (e.g. textile glass fiber, carbon/graphite fiber, aramid fiber, ceramic fiber, composite matrix)?		
4.9 Are the outer coverings of cables, wires, and other components free of glass fiber materials?		
4.10 Are personnel not required to occupy the shelter during normal operations for extended periods? If the answer is NO, answer questions 4.11 – 4.13.		
4.11 Is an environmental control unit provided that maintains temperatures within the shelter between 65-85 degrees F (18-29ºC) to prevent heat or cold stress?		
4.12 Do shelter air temperatures at the floor level and head level differ by less than 10 degrees F (6ºC)?		
4.13 Is adequate ventilation provided within the shelter (20 cfm/person of fresh air)?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

<table>
<tr><th>Section 4: Health Hazard</th><th>Verify</th><th>Remark</th></tr>
<tr><td>4.14 Where generators and vehicles are to be operated within the vicinity (<25 ft) of the shelter, has air sampling been conducted to ensure compliance with the diesel exhaust PELs listed below?

Permissible Limits (PPM)

<table>
<tr><th>Substance</th><th>8-hr TWA</th><th>STEL</th></tr>
<tr><td>Carbon Monoxide</td><td>25</td><td>N/A</td></tr>
<tr><td>Formaldehyde</td><td>-</td><td>0.3</td></tr>
<tr><td>Sulfur Dioxide</td><td>2</td><td>5</td></tr>
<tr><td>Acrolein</td><td>0.1</td><td>0.3</td></tr>
<tr><td>Nitric Oxide</td><td>25</td><td>N/A</td></tr>
<tr><td>Nitrogen Dioxide</td><td>3</td><td>5</td></tr>
</table>
</td><td></td><td></td></tr>
<tr><td>4.15 Is the system free of insulating materials (e.g., asbestos, fibrous glass, mineral wool, polystyrene foam, polyurethane foam)? If the answer is NO, are appropriate warnings and/or safeguards provided on the equipment and in the technical manuals?</td><td></td><td></td></tr>
<tr><td>4.16 Is a fixed type fire suppression system provided? If YES, specify type, concentration by volume, and answer questions 4.17 and 4.18.</td><td></td><td></td></tr>
<tr><td>4.17 Is an audible or visual alarm activated prior to release of the fire suppression agent?</td><td></td><td></td></tr>
<tr><td>4.18 Is there a time delay prior to release of the fire suppression agent?</td><td></td><td></td></tr>
<tr><td>4.19 Is the system free of all other health related hazards (vibration, shock, trauma, biological hazards, etc.)?</td><td></td><td></td></tr>
</table>

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 5: Environmental Impact	Verify	Remark
5.1 Is the item or component free of hazardous or potentially hazardous materials as defined by the Federal Standard 313, EPA (40 CFR), DOT (49 CFR), OSHA ACGIH or other federal law, regulation or standard?		
5.2 Is the item or component free of reactive or flammable chemicals such as solvents, thinners or diluents?		
5.3 Is the item or component free of toxins and carcinogens (e.g. polychlorinated biphenyl's, elemental mercury, beryllium oxide, asbestos, etc.)?		
5.4 Is it free of ozone depleting chemicals (ODC, i.e., ozone depleting substances (ODS)) refrigerant gases, chlorofluorocarbons, etc?		
5.5 Are electrical and electronic components free of lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE) (batteries excepted)?		
5.6 If the answer to any of questions 5.1 through 5.5 is "no", has every effort been made to substitute non-hazardous materials.		
5.7 Have Safety Data Sheets for all hazardous materials been completed and submitted to the government?		
5.8 Does the equipment avoid the use of batteries? If NO, complete section 8, Battery Safety.		
5.9 Is the system free of ionizing radiation sources (radioactive isotopes, etc.)? If NO, complete section 6, Radiation Safety. *All radioactive isotopes, regardless of quantity, must be reported to Department of the Army.*		
5.10 Is the system free of nonionizing radiation sources (radiofrequency, laser, etc.)? If NO, complete section 6, Radiation Safety.		
5.11 Have all components that are routinely replaced in the course of maintenance been selected so as not to require special handling or disposal?		
5.12 Have electrical and electronic components been designed to facilitate the economic recovery, reclamation and/or disposal of components?		
5.13 Have all materials that have the potential for the evolution or release of hazardous gases, vapors or fumes in violation of federal, state or local regulations been eliminated?		
5.14 Has the system been designed so as not to release combustion products, emit objectionable odors, or create airborne particulates?		
5.15 Has the potential for the release of toxic or hazardous substances onto the soil, or to surface or subsurface water been eliminated?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 6: Radiation Safety	Verify	Remark
6.1 Have electromagnetic radiation (EMR) warning signs been provided for electromagnetic emissions that exceed either the exposure reference levels (ERLs) or the dosimetric reference levels (DRLs) of IEEE Standard C95.1-2345TM, Section 4?		
6.2 For transmitting equipment, where antennas can develop RF currents on nearby dead metal objects, is the maximum current through an impedance equivalent to that of the human body for conditions of grasping the dead metal object limited to the following values: I = 1000f mA for (0.003 < f < 0.1 MHz); I = 100 mA for (0.1 < f < 100 MHz)?		
6.3 Have all devices that exceed 10,000 volts been evaluated for X radiation?		
6.4 Are X-ray producing devices shielded to reduce personnel exposure to < 2.0 mR/hour and no more than 50 mR/year?		
6.5 Are X-ray producing devices and the components in which they are located labeled with an X-radiation hazard warning symbol?		
6.6 Has the use of any amount of radioactive material in the design and manufacture of any part or component been avoided?		
6.7 If the answer to question 6.6 is **NO**, has the manufacturer identified the physical form, isotope, and quantity of ANY radioactive material utilized in each component / system?		
6.8 If the answer to question 6.6 is **NO**, does the manufacturer have the appropriate authorization (NRC License or CECOM Authorization) for radioactive material?		
6.9 Are optical products (lenses, mirrors, windows, fiber optics, etc.) free of ANY amounts of radioactive material?		
6.10 Are radiation markings and labels affixed to all parts or components containing radioactive material?		
6.11 Are filters, goggles, or other protective devices identified and/or provided, and are warning signs posted, for all sources of radio frequency, ultraviolet, infrared, high-energy visible, laser, and any other type of hazardous radiant energy?		
6.12 If lasers are used, has output power been limited to the lowest power density that could meet the performance requirements?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 6: Radiation Safety	Verify	Remark
6.13 Are warning labels affixed near the beam exit port and the laser fire button (as applicable) for all Class 3b and 4 lasers?		
6.14 Do lasers conform to the Code of Federal Regulations requirements as detailed in the system specification? If the answer is **NO**, answer questions 6.15 – 6.17.		
6.15 Has a military exemption been approved through the contracting office?		
6.16 Do exempt laser systems comply with MIL-STD-1425A?		
6.17 Are exempt laser systems provided with a permanent caution label notifying of such?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 7: Antenna and Mast Safety	Verify	Remark
7.1 Are antenna elements and terminals located and/or insulated to prevent shock hazards and RF burns?		
7.2 Are antenna tips designed to prevent puncture wounds?		
7.3 Are labels provided near the antenna to warn against contact with overhead electrical lines?		
7.4 Are antennas provided with blocking capacitors or coated with dielectric material to insulate against overhead electrical lines?		
7.5 Where whip antennas can contact overhead electrical lines, are tie down means provided and locations identified?		
7.6 Are antennas (extended or tied down) located to avoid RF shock hazards or unacceptable RF radiation levels at seats, hatches, gunner's rings, and other locations that may be occupied by personnel?		
7.7 Are lock-out devices provided for remotely-operated antennas posing a mechanical, RF hazard to maintainers?		
7.8 Are winches, collapsible parts, tensioners, and other similar devices provided with safety latches or the like to prevent unintended collapse, free-wheeling, or uncontrolled release of guy cable?		
7.9 If the answer to question 7.8 is YES, are the safety latches designed to prevent accidental or intentional bypass?		
7.10 For masts greater than 45 feet in height, is a means provided (pulley & rope, etc) to raise any warning beacons that may be required at a particular locality?		
7.11 Are level indication devices provided to ensure that the mast is level?		
7.12 Are tripping and "clothes- hanger" hazards due to guy wires minimized?		
7.13 Can the designated crew size safety setup and tear down the antenna mast?		
7.14 Are alternative methods of recovering the mast during emergencies, component failure, ice buildup, or jamming safe?		
7.15 Are maximum wind speed limits identified for safe mast assembly, removal, and maintenance?		
7.16 Are stakes suitably sized to prevent pull-out in all soil conditions for worst case wind load conditions?		
7.17 Are tripods designed so that adjustments can be safely made at any time during erection of the mast should any of the legs sink?		
Questions 7.18 through 7.22 pertain to antenna masts integrated onto vehicles or shelters.		
7.18 Is an audible and visual warning provided to the driver when movement of the vehicle is attempted while the antenna mast is extended?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 7: Antenna and Mast Safety	Verify	Remark
7.19 Are mast controls located to assure that the user can continuously and responsibly observe the environment overhead during the raising or lowering of the mast?		
7.20 Are positive means, such as momentary contact (continuous pressure) switches, used to raise and lower the mast?		
7.21 Are mast controls (hardware and software) designed to avoid unintentional extension of the mast when the vehicle is moving?		
Questions 7.23 through 7.34 pertain to Lightning Protection Adequacy. Note: if the mast is electrically continuous, treat it as the down conductor.		
7.23 If antenna acts as an aerial terminal, does conductivity equal or better that of #3 AWG solid copper?		
7.24 If the answer to question 7.23 is NO (e.g. dish antenna), is the antenna contained within a 45° cone from the tip of a provided air terminal?		
7.25 Is down conductor equivalent to #3 AWG solid copper with a minimum strand size of #17 AWG?		
7.26 Are joints mechanically strong & corrosion resistant?		
7.27 Are resistance of joints less than that of 2 ft.(0.6 m) of down conductor? [R=0.002 ohms or less – negligible resistance]		
7.28 Will the down conductor remain free of bends or kinks after repeated use?		
7.29 Is down conductor straight as possible with any turns not less than 90 degrees with 8 inch radius of turn?		
7.30 Is ground rod at least 1/2 inch in diameter, 8 ft long, copper clad steel or equivalent?		
7.31 Is ground rod free of paint?		
7.32 Does antenna mast configuration during erection, storage, take-down or operation prevent any component of the lightning protection system from mechanical damage or wear?		
7.33 If mast is electrically continuous and is acting as the down conductor, is the ground stud adequate?		
7.34 Is a safety tip cap provided for the air terminal?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 8: Battery Safety	Verify	Remark
8.1 For each battery type, identify the manufacturer, model number, chemistry, its purpose, and the quantity used.		
8.2 Are the batteries in the Government inventory? If **YES**, indicate the battery's nomenclature (BA-xxx, BB-xxx, etc.) and NSN.		
8.3 Does the equipment prevent the charging of non-rechargeable batteries when installed?		
8.4 Does the equipment incorporate a voltage cutoff to prevent over-discharge of the battery during usage or long term storage?		
8.5 Are design features incorporated to prevent charging of rechargeable batteries at high temperatures?		
8.6 Are design features incorporated to prevent overcharging of rechargeable batteries?		
8.7 Are battery terminals adequately marked with polarity and protected against accidental shorting?		
8.8 Is the battery enclosed and protected from mechanical shock and the environment?		
8.9 Are battery compartments/enclosures adequately vented to prevent the buildup of explosive gasses?		
8.10 Is the battery compartment designed to prevent any leaking liquid/gas from entering the main equipment?		
8.11 Is the use of conductive battery covers avoided?		
8.12 Where battery boxes house non-rechargeable lithium batteries, are they designed to prevent injury or damage in the event of a violent battery venting or rupture IAW CECOM TB 7, Battery Box Design?		
8.13 Has a test been conducted on a CECOM certified test apparatus to verify question 8.12 above?		
8.14 Are battery compartments oriented so that in the event of a battery venting, gasses or liquids are directed away from the user’s face and body?		
8.15 Is adequate spacing/guarding provided around battery terminals so that tools cannot create an electrical short while working near the batteries or disconnecting the battery cables?		
8.16 If the equipment utilizes two batteries in parallel, is electrical circuitry incorporated to prevent reverse or parallel battery charging and to limit any imbalance in current draw?		
8.17 Are mechanical or electrical features incorporated to prevent equipment and battery damage due to the incorrect insertion of batteries, as well as the insertion of different batteries having similar dimensions?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 9: Generators	Verify	Remark
9.1 Is a main circuit breaker provided and located in an easily accessible location?		
9.2 Are the following protective devices present with suitable indicators to safeguard against operator injury and/or equipment damage: over-speed, over-temperature, over-voltage, overload and short circuit, low oil pressure and low fuel?		
9.3 Is the battle short switch provided and located on the main control panel?		
9.4 Are all supply connection points clearly marked with terminal information and polarity?		
9.5 Are all convenience receptacles provided with overcurrent protection as well as ground-fault circuit interrupter protection?		
9.6 Are outdoor receptacles protected from the weather whether or not the attachment plug cap is inserted?		
9.7 Is a suitable grounding terminal lug provided and identified for connection to an earth grounding electrode?		
9.8 Is an Army approved grounding system fielded with the generator set and is a storage location provided for it?		
9.9 Are components, conductors and shielding appropriately located such that overheating, arching, shorting and contact with moving parts is avoid?		
9.10 Are battery terminals and cables marked for polarity and provided with nonconductive guards to prevent accidental shorting?		
9.11 Are tools to be used near high voltages, such as load terminal wrench, adequately insulated?		
9.12 Are fuel lines adequately supported and separated from live wires and cables?		
9.13 Are fuel lines projecting through metal apertures protected by grommets and secured to framing members?		
9.14 Is thermal and sound insulating material treated with fire retardant, free from noxious fumes, unaffected by battery electrolyte or petroleum derivatives, capable of maintaining it shape position and consistency inherently or by retaining methods, and replaceable?		
9.15 Where safe noise levels can be exceeded during operation or maintenance, are appropriate warning labels provided on the equipment?		
9.16 Is a type B:C Dry Chemical extinguisher provided with the generator? Specify size.		
9.17 Is CARC paint applied only to surfaces that will not exceed 400 deg. F?		
9.18 Is the generator exhaust located and directed away from operator designated areas?		
9.19 Is the air intake at a sufficient distance from the exhaust?		
9.20 Is the fuel tank designed and located in a manner that will not allow spills or overflow to run into the engine, exhaust or electrical equipment?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 9: Generators	Verify	Remark
9.21 Is the fuel tank equipped with a float valve to prevent fuel from overflowing when the set is being fueled from the auxiliary fuel connection?		
9.22 Where an auxiliary refueling system is integrated, is a fuel line and jerry can adapter provided for connection to the external fuel container.		
9.23 Is the center of gravity and weight of the set distinctly marked?		
9.24 Are tie-downs and lifting positions clearly marked?		
9.25 Are lifting rings, slings and folk-lift eyes provided?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 10: Equipment Integration of Shelters and Trailers	Verify	Remark
10.1 Is the vehicle weight properly distributed and is the vehicle laterally stable?		
10.2 Does the shelter/equipment center of gravity (COG) fall within the prime mover COG envelope?		
10.3 Is the center of gravity and equipment weight distinctly marked?		
10.4 Does the system weight (including crew gear and trailer pintle weight) not exceed the load capacity of the prime mover?		
10.5 Has the vehicle satisfactorily passed road worthiness testing (e.g. Munson road test)?		
10.6 Have no vehicle speed restrictions been placed on the prime mover as a result of system integration?		
10.7 Are adequate instructions provided for placement of detached trailers?		
10.8 Are safety chains provided to prevent the trailer from detaching from the towing vehicle?		
10.9 Will the lifting rings support the total weight of the shelter and the installed equipment?		
10.10 Are entries and exits free of obstructions?		
10.11 Do the entryway ladders or steps allow safe entrance and exit?		
10.12 Is an emergency exit provided and is its location and means of operation labeled?		
10.13 Is the emergency exit readily accessible and simple to operate in a high stress, zero visibility situation?		
10.14 Where extended operations are required on top of the shelter, are ladders, non-slip surfaces, and guardrails or chains provided for the shelter roof?		
10.15 Are egress paths and stairs provided with permanent non-skid surfaces?		
10.16 Is adequate illumination provided in all areas?		
10.17 Are wall, floor, and ceiling fastenings sufficient to prevent equipment from breaking away, falling, or accidentally dislodging?		
10.18 Are accessories secured or stowed to prevent damage when the vehicle is moving?		
10.19 Is equipment that is designed to have multiple-input power capabilities, or powered by a generator with multiple-voltage output capabilities, protected from damage when connected to incorrect input power/voltage levels?		
10.20 Is an Army approved earth grounding system (ground rod, SWGK, etc) provided?		
10.21 Do the grounded and grounding circuits remain isolated throughout the shelter, including at the supply side of the power panel?		
10.22 Where a switch is provided to switch between different power sources, is the grounded/neutral conductor also switched to avoid ground loops?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 10: Equipment Integration of Shelters and Trailers	Verify	Remark
10.23 If commercial inverters are used to generate AC voltage, do they internally provide a neutral-ground bond that is disconnected when an external AC power source is connected?		
10.24 Is a ground stud provided at the power entry box and is it suitably identified?		
10.25 Are no parts of the vehicle/shelter enclosure or frame used as the AC ground path?		
10.26 Are the ground pins of the convenience outlets hard wired to the shelter/system ground point?		
10.27 Is lightning surge protection provided at the power and signal entry panels for all cables?		
10.28 Are all outdoor receptacles ground-fault circuit interrupter (GFCI) protected?		
10.29 If the answer to question 10.28 is **NO**, is the socket configuration of each outdoor receptacle that is not connected to a GFCI unique to its special application and unusable for other applications or as a convenience outlet?		
10.30 Are outdoor receptacles protected from the weather whether or not the attachment plug cap is inserted?		
10.31 Has the amount of residual leakage current to ground for the entire system been verified through test to be less than 5 mA (3.5 mA if system can be powered from a GFCI protected circuit)? If **YES**, indicate the amount of current that was measured.		
10.32 Is a main power switch provided at the shelter entrance?		
10.33 Are safety switches provided at remotely-located assemblies to protect maintainers?		
10.34 Are terminals, plugs, and other exposed parts located within power distribution panels that may exhibit over 30 volts or 20 amps, guarded against accidental contact if exposed during maintenance?		
10.35 Where transmitting equipment exists, and room permits, are shorting rods provided?		
10.36 Are fuel lines that are inside the shelter made as short as possible?		
10.37 Is there a heater fuel shut-off valve inside the shelter?		
10.38 Is a fuel line and jerry can adapter provided for connection to the external fuel tank or container?		
10.39 Are fuel lines and fuel sources suitably protected from potential damage and sources of heat?		
10.40 Are battery compartments designed to prevent gas buildup within the shelter (i.e. forced-air ventilated to the outside)?		
10.41 Is a warning device provided to indicate when either the battery vent lid or door is closed or when the ventilation fan is inoperable?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 10: Equipment Integration of Shelters and Trailers	Verify	Remark
10.42 Is the vehicle exhaust sufficiently separated from shelter openings to avoid an accumulation of carbon monoxide in the shelter?		
10.43 Is a Carbon Monoxide (CO) alarm provided and does it meet the storage temperature requirements for the system?		
10.44 Is a type B:C Carbon Dioxide or Dry Chemical extinguisher provided for electrical equipment and located near shelter exit? Specify size.		
10.45 Are ceilings, walls, and other surfaces adjacent to aisles free of electrical components and switches that are vulnerable to damage by being hit or snagged?		
10.46 Are controls, connectors, or other parts that project into walkways or located a foot level protected from mechanical damage?		
10.47 Are climbing rings, handholds, rails, etc., provided where needed?		
10.48 Are handles recessed rather that extended where they might be hazardous?		
10.49 Can EMI emitted by the equipment cause any degraded or erratic operation of other equipment?		
10.50 Where equipment is installed on platforms with weapons or turrets, has a test been conducted to ensure that EMI cannot cause uncontrolled turret movement or weapons misfire?		
10.51 Where shelter equipment is operated unattended with the vehicle on-the-move, is a smoke alarm provided to warn the vehicle driver of a fire condition in the shelter?		
♦ OPERATION ON-THE-MOVE ♦		
10.52 Is the shelter to be occupied and operated only when the system is stationary (No on-the–move operations)? If NO, answer questions 10.53 – 10.63.		
10.53 Have suitable seats and restraints been provided for the required number of users?		
10.54 Is equipment positioned so that personnel will not bump or rub against it when riding over rough terrain?		
10.55 Where equipment requires frequent viewing and access, is the operator not required to twist in his seat, which could diminish set belt effectiveness in an accident?		
10.56 Is the equipment suitably mounted to prevent loosening or dislodging when the vehicle is driven over rough terrain or in the event of an accident or rollover?		
10.57 Can users in the shelter maintain reliable communication with the driver at all times?		
10.58 Can operators access fire suppression systems, communications systems, and other critical controls while in a seated position?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 10: Equipment Integration of Shelters and Trailers	Verify	Remark
10.59 Is adequate air flow and temperature control maintained and can the user access the ECU controls while in a seated position?		
10.60 Is the use of batteries that can vent poisonous gasses, such as lithium sulfur dioxide batteries, avoided?		
10.61 Is emergency power and lighting available in the event of primary power loss?		
10.62 Is adequate noise protection provided for the users?		
10.63 Do critical commands that can be accidentally keyed require a second confirming action?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 11: Equipment Integration of Vehicle Cabs	Verify	Remark
11.1 Does placement of equipment or interconnecting cables avoid interference with pre-existing controls, indicators, or other equipment & panels requiring access?		
11.2 Are equipment and associated cables located so that they will not trip, snag, or significantly impede soldier egress through primary or secondary egress paths?		
11.3 Is equipment positioned so that personnel will not bump or rub against it when riding over rough terrain?		
11.4 Does the equipment location prevent increased personnel injury in the event of a vehicle accident or rollover?		
11.5 Are any required corner guards or padding suitable to protect against injury and are they designed so they are not lost or removed during LRU swap-out?		
11.6 Is the equipment suitably mounted to prevent loosening or dislodging when the vehicle is driven over rough terrain or in the event of an accident or rollover?		
11.7 Where the equipment is installed in up-armor variants, is the equipment suitably mounted to prevent dislodging in the event of blast-induced shock?		
11.8 Is the mounting hardware designed and installed such that when the equipment is removed, the remaining mounting hardware does not pose a mechanical hazard to personnel?		
11.9 Are sharp or protruding edges, surfaces, or corners avoided with equipment in operating or stowed position?		
11.10 Do hinged or adjustable mounting hardware avoid pinch/shear hazards?		
11.11 Are mounting screws and bolts properly sized to prevent projections?		
11.12 Is the equipment located so that it will not be stepped on or otherwise damaged by personnel during ingress or egress?		
11.13 Does equipment location avoid intrusion into step or standing locations?		
11.14 Are equipment controls and switches protected from accidental activation?		
11.15 Do critical commands that can be accidentally keyed require a second confirming action?		
11.16 Are interconnecting cables run neatly and tied down to avoid any tripping and snag hazards?		
11.17 Are cables routed and equipment connectors protected against damage from personnel, crew gear, and cargo storage?		
11.18 Are cable ties and adhesives suitable to withstand the environment and rough handling?		
11.19 Are power cables jacketed and rated for heavy usage?		
11.20 Are conductors that supply equipment power properly fused?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 11: Equipment Integration of Vehicle Cabs	Verify	Remark
11.21 Is the connection of equipment power cables directly to the vehicle battery terminals avoided?		
11.22 Where equipment power cables connect to the vehicle power source, are wires properly tagged to show proper polarity and connection?		
11.23 Are sharp bends in cables avoided?		
11.24 Is the vehicle alternator adequately rated for the added equipment electrical power load?		
11.25 If commercial inverters are used to generate AC voltage, do they internally provide a neutral-ground bond that is disconnected when an external AC power source is connected?		
11.26 Has the equipment been designed or shielded to prevent degraded or erratic operation of other mission equipment due to electromagnetic interference (EMI)?		
11.27 Where equipment is installed on platforms with weapons or turrets, has a test been conducted to ensure that EMI or co-hosted software cannot cause uncontrolled turret movement or weapons misfire?		
11.28 Is all equipment suitably grounded to chassis?		
11.29 Does the driver's field of view through the driver and passenger windshield and windows remain unobstructed with the equipment installed and adjusted in any position? Can the driver clearly see all mirrors?		
11.30 Where the driver's view can be obstructed by adjustable displays or equipment, can the equipment be aligned with existing vehicle obstructions to minimize impact? Are labels provided to warn the driver to do so and are the adjustable mounts designed so they don't progressively move/shift out of position due to vehicle motions and vibrations?		
11.31 Is the equipment so located that it will not divert the driver's attention?		
11.32 Where the equipment requires frequent viewing or access, is twisting or other motion by the operator avoided which could cause repetitive motion stress?		
11.33 Where equipment requires frequent viewing and access, is the operator not required to twist in his seat, which could diminish set belt effectiveness in an accident?		
11.34 Where night vision goggles are used, is direct or reflected light from indicators or displays avoided where it can interfere with driver night vision driving? Are lighting security issues avoided?		
11.35 Is equipment heat load dissipated adequately so that cab temperatures will not increase significantly?		
11.36 Is the use of batteries that can vent poisonous gasses, such as lithium sulfur dioxide batteries, avoided where the equipment cannot be readily jettisoned from the vehicle?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 12: Transit Case Mounted Equipment	Verify	Remark
12.1 Where COTS is mounted in the transit cases, is additional protection against the elements provided for when the case is open?		
12.2 Is GFCI protection integrated into the power cord?		
12.3 Are metal parts which could become energized, such as the rack-mount frame members, adequately bonded to the equipment ground?		
12.4 Are ground studs and bonding straps provided to permit bonding between cases?		
12.5 Is an earth grounding system supplied if it can be powered more than 25 feet from the power source?		
12.6 Is overcurrent protection incorporated, located on the front panel, and clearly identified?		
12.7 Can the system be stacked or secured in a manner that will prevent it from tipping?		
12.8 Does the system prevent tipping if weight is applied to a drawer or cover that can be extended?		
12.9 Are leveling systems provided for setup in uneven terrain?		
12.10 Are legs or other similar mechanisms provided with pads to prevent sinking in soft soil conditions?		
12.11 Are adequate handles and warning labels provided for repositioning the equipment with the transit box covers removed?		
12.12 Where transportation or storage orientation are important, is the transit case labeled “This Side Up”?		
12.13 Are pressure relief valves provided for the transit cases?		
12.14 Are transit cases designed, or internal equipment mounted in a manner which will protect electronics from water if placed or operated on wet or saturated ground?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 13: Software Safety	Verify	Remark
13.1 Have the requirements of MIL-STD-882E been applied in the development and testing of the software? If no, what methods were used to evaluate if and how the software contributes to or mitigates system failures, hazards, and mishaps?		
13.2 Did the methodology used determine that the software was free of Safety-Critical and/or Safety-Related functions?		
13.3 Has a Safety Assessment Report been prepared that documents the methodology used to identify Safety Critical and Safety Related functionality as well as findings and recommended mitigation?		
13.4 Has the proper level of testing been established and accomplished for all identified Safety-Critical and Safety-Related functions?		
13.5 – Have all identified hazards related to Safety-Critical and/or Safety-Related functions been mitigated to an acceptable level and entered into the program's Hazard Tracking System?		
If questions 13.1 – 13.3 are answered NO, complete the following:		
13.6 Is the system free of software that controls or influences (directly or indirectly) the pre-arming, arming, enabling, releasing, launching, firing, clear firing, or detonation of an explosive system, including mechanical deployment of subsystems?		
13.7 Is the system free of software that controls or influences (directly or indirectly) target location, identification, selection and designation functions or any related safety critical data (timing, verification)?		
13.8 Is the system free of software that controls or influences (directly or indirectly) the movement or flight path of a land, sea, or aerospace vehicle such as an aircraft, spacecraft, ship, or projectile?		
13.9 Is the system free of software that controls or influences (directly or indirectly) the movement of energy projection devices (i.e., guns, antennas, lasers), launchers, and other equipment, especially with respect to the pointing and firing?		
13.10 Is the system free of software that controls or influences (directly or indirectly) the movement of munitions and/or hazardous materials?		
13.11 Is the system free of software that controls or influences (directly or indirectly) the movement of antenna masts, dishes, and other equipment that could unintentionally move, injure, entrap, or irradiate users or maintainers?		
13.12 Is the system free of software that controls or influences (directly or indirectly) Situational Awareness (SA) or Command & Control (C2) displayed information (friendly, enemy, safe lane route, no-fire zones) which can be used to make critical decisions having safety impact?		

APPENDIX A. SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST.

Section 13: Software Safety	Verify	Remark
13.13 Is the system free of software that controls or influences (directly or indirectly) Combat ID or Identification Friend or Foe (IFF) systems or transponders used to distinguish friendly aircraft, vehicles, or forces?		
13.14 Is the system free of software that controls or influences (directly or indirectly) any function that monitors the state of the system for purposes of ensuring its safety (including energy sources)?		
13.15 Is the system free of software that controls or influences (directly or indirectly) any function that senses hazards and/or displays information concerning the protection of the system/troops/operator?		
13.16 Is the system free of software that controls or influences (directly or indirectly) outputs to displays (visual, audio, other) that indicate the status of safety-critical hardware systems or that alert users of a required critical action/intervention (critical message received, need for evasive maneuver, etc)?		
13.17 Is the system free of software that controls or influences (directly or indirectly) system elements / software used to test, evaluate, or control any of the above items?		
13.18 Is the system free of software that controls or influences (directly or indirectly) any other safety-critical functions; i.e. can the failure of any input or output device cause a critical hazard? If yes, provide the sufficient detail.		
13.19 Have all safety critical software functions been identified for specific software testing in and apart from testing of other software functions?		
13.20 Have the results of all software safety analyses, testing, and hazard abatement been formally documented for present consideration and for future changes/upgrades?		
13.21 Where systems display situational awareness data, is common warfighting symbology used as depicted in MIL-STD-2525? Is the modification of any symbols avoided?		
13.22 Does the display interface adequately address the limitations of color-blind users?		
13.23 Do nonreversible/destructive actions (zeroize) require two discrete entries?		
13.24 Are operators adequately notified of safety critical messages and alerts?		

APPENDIX B. SYSTEM DESIGN VERIFICATION CHECKLIST HANDBOOK

Note: Handbook derived from Communications-Electronics Directorate for Safety (CECOM) Lifecycle Management Command (LCMC), November 2006, with U.S. Army Test and Evaluation Command (ATEC) changes incorporated in blue font.

The System Safety Design Verification Checklist is a document used to verify safety requirements detailed in the CECOM General Safety Specification. The checklist itself does not drive safety requirements, but rather ensures that safety has been suitably addressed by posing specific questions regarding the equipment. The checklist is a direct outgrowth of the CECOM General Safety Specification, as well as lessons leaned through predecessor CECOM systems. The checklist is intended to be used as a tool by both the designer and inspector to verify the safety of CECOM developed equipment and systems.

This handbook has been developed to provide explanations, lessons learned, and other supporting information useful in assisting those concerned with safety and in understanding the intent of questions listed in the checklist. Cross-reference is made to specific military and commercial standards driving a particular requirement. The list of commercial standards is not all-inclusive; other more appropriate standards may apply based on the specific system design and its intended use.

The handbook references military and commercial standards current at the time of issue. Refer to the reference section for a complete listing of the pertinent standards and effective dates. Updated standards should be checked to ensure that requirements have not been changed, deleted, or renumbered relative to the standards in effect at the time of release of this handbook.

To simplify use of this handbook, different character fonts and sizes have been used to designate information as follows:

Bold written text identifies the question posed in SEL Form 1183.

Italic text is used for explanations and commentaries regarding a particular requirement.

Regular text is used to identify a relevant military and commercial standard that applies. The specific requirement may be loosely stated, along with additional commentary.

Since many of the SEL HDBK questions are related, it's recommended that information in related questions also be reviewed for additional references and guidance. System Designers looking for additional Product Safety guidance are strongly recommended to read the "Principles of Safety" Introduction in UL 60950 Safety of Information Technology Equipment.

APPENDIX B. SYSTEM DESIGN VERIFICATION CHECKLIST HANDBOOK

REFERENCES:

Government:

ACGIH 2006 TLV Guide The American Conference of Governmental Industrial Hygienists Threshold Limit Values and Biological Exposure Indices Guide

CA COR, Title 8, Ch 4, Sub 5, Group 2, Art 40, Sec 2980–2983 California Code of Regulations Title 8 High Voltage Electrical Safety Orders, Electronic News Gathering

CECOM TR 93-1 Lightning Protection System Design, Jan 93

Code of Federal Regulations (CFR), Title 29, Part 1910 Occupational Safety and Health Standards.

DOD Instruction 6055.11, Protecting Personnel from Electromagnetic Fields, 12 May 2021.

FED-STD 313 Material Safety Data, Transportation Data and Disposal Data for Hazardous Materials Furnished to Government Activities, 21 Mar 00.

FM 24-18 Tactical Single Channel Radio Communications Techniques, 30 Sep 87

FORSCOM Reg 385-1 Forces Command Safety Program, 31 Mar 98.

MIL-HDBK-454B General Guidelines for Electronic Equipment, 15 April 2007.

MIL-HDBK-759C Handbook for Human Engineering Design Guidelines, 30 Oct 91.

MIL-HDBK-1857 Grounding, Bonding and Shielding Practices, 27 Mar 1998

MIL-STD-686 Cable and Cord, Electrical; Identification Marking and Color Coding of, 28 Sep 1990

MIL-STD-810F DoD Test Method Standard for Environmental Engineering Considerations and Laboratory tests, 5 May 03.

MIL-STD-1425A Safety Design Requirements for Military Lasers and Associated Support Equipment, 30 Aug 91

MIL-STD-1472F DoD Design Criteria Standard Human Engineering, 23 Aug 99.

MIL-STD-3009 Lighting, Aircraft, Night Vision Imaging System (NVIS) Compatible, 2 Feb 01.

SEL Form 1183 System Safety Verification Design Checklist, Nov 06.

TB 43-0142 Safety Inspection and Testing of Lift Devices, 30 Aug 93.

TB 43-0129 Safety Requirements for Use of Antenna and Mast Equipment, 1 Jan 94

TB 43-0134 Battery Disposition and Disposal, 1 Oct 96

TM 5-690 Grounding and Bonding in C4SIR Facilities, 15 Feb 02

Commercial:

ANSI C101.1 Standard for Leakage Current for Appliances, 16 Mar 1992

ANSI Z136.1 American National Standard for Safe Use of Lasers, 2014.

ANSI Z535.4 Product Safety Signs and Labels, 6 Jun 02.

APPENDIX B. SYSTEM DESIGN VERIFICATION CHECKLIST HANDBOOK

IEC 60825-1 Safety of Laser products - Part 1: Equipment classification and requirements, 2014

IEEE C95.1-2345 Force Health Protection Regarding Personnel Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz, 16 May 2014.

IEEE C95.2 Radio-Frequency Energy and Current Flow Symbols, 27 September 2018.

IEEE 1680 Standard for Environmental Assessment of Personal Computer Products, 2006

NFPA 30-03 Flammable and Combustible Liquids Code
NFPA 37-02 Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines **NFPA 70-05** National Electric Code (NEC) Handbook.
NFPA 70B-02 Recommended Practice for Electrical Equipment Maintenance
NFPA 70E-04 Electrical Safety requirements for Employee Workplaces.

DHHS NIOSH Pub No 94-110 Applications Manual for the Revised NIOSH Lifting Equation, Jan 94

UL 73 Motor Operated Appliances, 9 Nov 1998

UL 489 Molded Case Circuit Breakers, 23 Dec 2002

UL 891 Dead-Front Switchboards, 28 Feb 2003

UL 1439 Tests for Sharpness of Edges on Equipment, 26 Feb 98

UL 1778 Uninterruptible Power Supplies, 14 Mar 2003

UL 1795 Hydromassage Bathtubs, 5 Oct 00

UL 1950 Standard for Information Technology Equipment, 31 Jan 2001

UL 2200 Stationary Engine Generator Assemblies, 7 Jul 04

UL 60950 Safety of Information Technology Equipment, 15 Mar 2002

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PART 1: ELECTRICAL

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1.1 Are Commercial Off-The-Shelf (COTS) equipment Listed or certified by a nationally recognized testing laboratory (NRTL)?

Products that have been Listed, Labeled, or otherwise evaluated by an NRTL (UL, CSA, TUV, etc) to the appropriate American safety standard (ANSI, UL, NEC, etc) are typically acceptable from a safety standpoint provided they also comply with questions 1.2 – 1.4 below. Such products do not require further evaluation other than its integration into a larger system (systems safety evaluation).

It is important to verify that the product bears the NRTL's listing mark. Having a product manufacturer state that a product complies with a UL standard is not the same as actually having UL evaluate the product to a standard.

Many NRTLs have several types of product evaluations. For instance, UL "Lists" equipment that is typically ready for use as an end product (lamps, radios, coffee makers, battery chargers, etc). UL also evaluates products that may be incomplete in construction or limited in performance capabilities. These bear the Recognized Component Mark and will often have conditions of acceptability specified (must be installed in and enclosure, must be protected by a fuse in the end product, etc). More information on these and other UL Listing categories is available online at WWW.UL.COM.

Do not mistake a CE marking on a product for a type of NRTL Listing mark. CE marking is required for products sold and used in the European community to show compliance with safety, environmental, and quality requirements as defined by European Directives. The Low Voltage Directive 73/23/EEC does not require products to be examined by an independent third party, thereby permitting manufacturers to declare their products safe without the need for independent testing.

- **NFPA 70-05 -** Article 110.2 requires all equipment to be approved by the authority having jurisdiction (AHJ), and 110.3 requires considerable evaluation of equipment. Listing or Labeling of equipment is not specifically required, however, an AHJ will often consider a product that's listed or labeled by an appropriate third party (Nationally Recognized Testing Laboratory) as acceptable. Nonetheless, the AHJ will still evaluate the suitability of the products final installation and use per 110.3(A) & (B).
- **29 CFR 1910.7 -** specifies requirements necessary for laboratories to be considered an NRTL. NRTLs can test and certify equipment or materials (products) requiring approval by certain OSHA safety standards. A list of OSHA recognized NRTLs is available on-line at WWW.OSHA.GOV
- **29 CFR 1910.303(a) -** requires that electrical equipment and conductors be approved. OSHA denotes approval by an NRTL throughout subparts of CFR 1910 in various ways, such as by use of the words approved, listed, labeled, or even designation to a test standard.
- **MIL-STD-1472F –** Par 4.8 states that the design of non-military unique workplaces and equipment shall conform to OSHA standards unless military applications require more stringent limits.

1.2 Are Listed COTS used in accordance with the manufacturer's manuals, in the intended environment, and within the limitations of the Listing?

Two points must be considered: limitations identified by the manufacturer and limitations of the product Listing category. Products must be used and installed per the manufacturer's user & installation instructions that are provided with the product. In addition, the Product Listing Category should be reviewed for limitations. For instance, products listed by UL as Automotive Type Battery Chargers (UL product category BBGQ) are not evaluated in the same manner as battery chargers for marine use (BBJY). Fans listed under the UL product category GPWV (Fans, Electric) have not been evaluated for use in hazardous locations or for installation in a firewall. Guidelines on UL Product Categories Codes is available on-line at WWW.UL.COM.

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Example of the typical problems encountered are use of light duty products in industrial applications (durability issues), improper environments (temperature, moisture, vibration and shock), improper installation (mechanical, electrical, air flow), accessibility (operation & maintenance), not classified for hazardous location, standard products used in life/fire safety critical applications, use of subcomponents not recognized by the end-product manufacturer (i.e. circuit breakers not approved for use with a specific panel board), etc.

- **NFPA 70-05 -** Article 110.3 requires listed equipment to be used and installed in accordance with any instructions included in the listing.

1.3 Have any modifications to the equipment been reevaluated by the Listing NRTL?

An NRTL marking indicates that a product was originally manufactured in accordance with applicable requirements at the factory. Once a product is modified, the NRTL can neither indicate whether such modifications "void" the Listing, nor that the product continues to meet applicable safety requirements. Most NRTLs have field services that can re-evaluate products. The authority having jurisdiction must determine if the modification is acceptable or if it is extensive enough to require NRTL reevaluation.

Modifications that can impact an NRTL Listing include many changes beyond those in the primary voltage area, such as changes in the secondary voltage circuit, enclosure material and design changes, vent redesign, different motor & transformer parts, relocation of thermostats, change of installation/use, etc.

1.4 Is maintenance not required on Listed COTS equipment beyond that specified in the manufacturer's manuals?

UL/ANSI product safety standards address protection of personnel servicing equipment to various extents. Certain standards covering industrial/commercial applications (Commercial Cooking Appliances, etc) provide specific requirements regarding access to live parts behind service panels. However, many other product standards do not address anything beyond user servicing (no covers removed). If maintenance is required beyond user servicing, it's recommended that the product standard be reviewed to determine it addresses higher level maintenance safety.

1.5 Are personnel suitably protected from access to hazardous voltages (>30 volts between live parts and/or ground) when setting up, operating, or tearing down the equipment?

This question refers to protection against shock hazards at the operator/user level. Operators are assumed to be individuals that may be oblivious to electrical hazards and safety precautions. Therefore, safety requirements for users are more restrictive than for maintainers (see question 1.6 below) who receive equipment and safety training.

When evaluating for potential shock hazards, consideration needs to be given to how the product will be used, suitability of the enclosure, voltage level of any accessible current carrying parts, etc. Can a cover be stepped on or damaged such that it contacts or exposes live parts? Covers requiring tools for removal are usually left in place during evaluation unless user level maintenance specifies its removal. Voltages need to be evaluated between all exposed parts (line to line, line to ground). Access to live parts is often determined by using an UL Articulate Probe or IEC Flexible test finger. If it's possible that an equipment part or other metal object (coin, paper clip) can fall into a crack or vent, need to ensure that it won't bridge the enclosure and/or any energized parts.

The level of shock is a function of current rather than voltage, as well as duration, frequency and current path. However, the value of current will depend on the applied voltage, current source impedance and body

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impedance. A voltage criterion is far easier to apply/verify, and historical data collected by organizations promulgating commercial safety standards supports their validity. Commercial standards often specify different criteria for DC and AC voltages. In terms of electrical shock, the greatest physiological effect occurs near 60Hz. DC voltages do not have as great an impact on the body and therefore have higher criterion specified. As frequency increases beyond a few hundred hertz, current tends to flow over the surface of the body rather than through vital organs, and physiological effects decrease.

- **NFPA 70-05 -** article 110.27 states that personnel will be guarded from live parts greater than 50 volts. Guarding is defined as removing the likelihood of approach/contact by objects or personnel to a point of danger. Article 725 and tables 11(a) and (b) of Chapter 9 address the requirements for Class 2 Voltage/Power-Limited Circuits. Class 2 circuits are considered to provide acceptable protection from an electrical shock and fire initiation standpoint. Class 2 circuits are usually limited to 30V rms, 42.4 V peak, or 60VDC. Note that higher voltages are permitted, but are limited to less than 5 mA (referred to as current limited sources). Notes 2 & 4 of the tables detail requirements for wet locations (typically half of the voltage values applied for dry locations). Many product safety standards (UL) specify the Class 2 voltage criterion rather than the 50 V criterion of the NEC.
- **UL 1950** - par 2.3.2 defines a safe voltage criterion of 30 volts rms, 42.4 V peak, or 60 VDC. Voltages less than this value are not considered to be dangerous under dry conditions, and more stringent requirements need to be applied for equipment used in wet locations. Section 2.1 contains comprehensive requirements concerning the accessibility of live circuits and components, and the maximum size of openings within barriers and enclosures. Section 4.2 contains comprehensive requirements concerning the durability of external enclosures accessible to the operator.
- **UL 60950 –** par 1.2.8.4 identifies voltages exceeding 42.4 V peak or 60 VDC as hazardous. Par 2.1.1.1 restricts operator access to hazardous voltages. Although the 30 V rms criterion is not specified, 30 V rms sinusoidal has a peak value of 42.4 V.
- **UL 1795 -** The Standard for Hydro massage Bathtubs contains stringent electrical shock requirements since personnel are immersed in water; the individual has a huge surface contact to ground. Requirements do not specify a voltage, but rather state that the current between any two parts accessible to the tub occupant shall not exceed 0.5 mA as measured through a 500 ohm resistor.
- **MIL-HDBK-454A -** Guideline 1, par 4.5.3 states that personnel should be protected from accidental contact with voltages in excess of 30 v rms or DC. Previously, MIL-STD-454N (cancelled May 95) specified this as a requirement. This requirement applied to DC and AC, rms or peak, that the operator (a person who is assumed to be oblivious to electrical hazards) may contact, to include voltages at field wire binding posts, voltages developed between accessible parts of the equipment and/or ground, and so forth. A weakness in the handbook must be noted in that it requires protection against “accidental contact”. This is not considered adequate protection at the user level. Most product safety standards require enclosures to prevent user access to hazardous voltages. Protection against accidental contact would apply to maintainer protection when a cover is removed.

1.6 Are personnel suitably protected from accidental contact with hazardous voltages (>30 volts between live parts and/or ground) during maintenance and when maintenance covers are opened?

This question refers to maintainer protection against shock hazards. Maintainers are typically trained in the skills and techniques necessary to identify and protect against electrical hazards and therefore, certain safety design requirements are relaxed.

Per NFPA 70E (I-2.1 and Part II, 1-5.4.1), a qualified individual is one that is trained and knowledgeable in the construction and operation of equipment and trained to recognize and avoid electrical hazards that might be present. The Military Occupational Specialty (MOS) descriptors need to be considered when evaluating

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whether a specified MOS is qualified to carry out a particular maintenance task. For instance, certain 31 series MOS may not be qualified to carry out live troubleshooting of line voltages.

When evaluating for potential maintainer shock hazards, consideration needs to be given which maintenance procedures will be carried out, the environment in which they will be carried out (dry, wet, hot), adequate access & lighting, location of live parts, types of tools used (see question 1.18), etc.

As previously noted in question 1.4, many UL product safety standards concentrate on operator safety and only address user level servicing. If a Listed COTS equipment will be maintained by military personnel, it is important to review the respective product safety standard to see whether it addresses higher level maintenance safety.

- **NFPA 70-05 -** article 110.26 discusses requirements to ensure that sufficient access and working space is provided for safe equipment operation and maintenance. 110.26(A)(1)(b) notes that reduced workspace is permitted where voltages are less than 30V rms, 42.4 V peak, or 60VDC. The NEC contains other articles intended to promote maintainer safety. For instance, article 408.3(A)(2) requires barriers in service switchboards so that service terminals are protected from inadvertent contact by persons or maintenance equipment while servicing load terminations.
- **UL 1950 -** par 2.1.4 states that hazardous voltages shall be protected or located so that unintentional contact is avoided while servicing other parts. In deciding whether a hazardous part can be unintentionally contacted, account has to be taken of how service personnel gain access past or near the part, the service procedure that's carried out, and tools involved.
- **UL 60950 –** par 2.1.2 applies.
- **UL 891 -** par 8.4.5 requires components involving a potential greater than 42.4V peak (30V rms) and mounted to the inside of a hinged door be provided with a guard to protect from unintentional contact. Par 23.1.4 also states that uninsulated live parts on the line side of disconnects shall be located or protected so that motor controllers can be adjusted without the risk of contacting live parts.
- **MIL-HDBK-454A –** Guideline 1, par 4.5.3.1 recommends protection against accidental contact with > 30V once a maintenance cover is removed. Protection can be through barriers, guards, or interlock that deenergize the equipment. It is assumed that maintainers will be reasonably careful in dealing with obvious hazards. However, the maintainer should be protected from accidental contact.
- **MIL-STD-1472F –** par 5.9.1.9 states that emergency shutdown devices, lockable controls, electrical cut-out switches, or warning signs or guards should be positioned to ensure safety of maintainers when it is necessary to perform maintenance on or near a live/working system. Par. 5.9.3.6 states adjustment controls should not be located close to dangerous voltages or other hazards without shielding and labeling. Par 5.9.4.3 states that sufficient space shall be provided for the use of test equipment and other required tools without difficulty or hazard.

1.7 If the answer to question 1.6 is NO, is a bypassable safety interlock incorporated to kill all power within the compartment once the maintenance cover is removed?

Where bypassable interlocks are used, it is important that they be fail-safe, that they reset when the cover is replaced, and that they are located/protected against accidental actuation while servicing the equipment. See questions 1.65 through 1.68 for more details.

- **MIL-HDBK-454A -** Guideline 1, par 4.5.4.1.b recommends the use of interlocks were hazardous voltages are exposed as a result of an access door or cover being opened.
- **UL 1950 -** par 2.8 discusses interlocks for operator and service access areas (see introduction

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section for definition of operator and service personnel). Bypassable interlocks are permitted so long as they can be bypassed only by service personnel (i.e. maintainers) - see par 2.8.5.

- **UL 60950 –** par 2.8 addresses safety interlocks.
- **UL 891 -** par 8.4.5 requires an interlock (or barrier) where components mounted to a hinged door reveal exposed live parts (greater than 30V rms) once the door is opened.

1.8 Are enclosures or guards that protect terminals or like devices exhibiting 30-600 volts, marked "WARNING, XXX Volts" in black on an orange background?

Label verbiage and location need to clearly identify the associated hazard before the user is exposed to the hazard. Labels shall also provide adequate warning where different voltages coexist and any confusion could be hazardous. COTS equipment markings complying with Product Safety standards may use different wording and format. Questions 3.12 through 3.15 address additional requirements for labels and markings.

- **MIL-HDBK-454A -** Guideline 1, par 4.8.b recommends warning labels following the format of ANSI Z535.4 and with the WARNING signal word for voltages in the range of 30-500V. Par 4.8.c covers recommends DANGER labels for voltages greater than 500V.
- **NFPA 70-05 -** article 110.27(c) requires entrances to rooms and other guarded locations that contain exposed live parts be marked with conspicuous warning signs forbidding unqualified persons to enter. A number of articles require a “Danger – High Voltage – Keep Out” label for systems operating in excess of 600V.
- **UL 1950 -** section 1.7 contains requirements for markings and instructions. Markings are required to discourage operator access, however, no requirements are detailed regarding internally accessible voltages. Label sizes and colors are not designated.
- **UL 60950 –** section 1.7 applies.
- **ANSI Z535.4 -** contains requirements concerning product safety signs and labels. Three signal words are recognized: 1) DANGER (white lettering on red background) - imminent hazardous situation which, if not avoided, will result in death or serious injury; use to be limited to the most extreme conditions, 2) WARNING (black lettering on orange background) - potentially hazardous situation which, if not avoided, could result in death or serious injury, and 3) CAUTION (black lettering on yellow background) - potentially hazardous condition which, if not avoided, could result in minor or moderate injury; also used to alert against unsafe practices. DANGER or WARNING should not be considered for property-damage accidents alone.

1.9 Are portions of assemblies operating at potentials above 600 volts completely enclosed from the remainder of the assembly, and is this enclosure provided with non-bypassable safety interlocks?

Both OSHA and the National Electrical Code designate high voltage as potentials exceeding 600 volts. MIL-HDBK-454A uses a 500V criterion as the dividing point between low voltage and high voltage circuits.

- **NFPA 70-05 -** article 110, part III requires more stringent controls for electrical installations over 600V. Other sections throughout the code provide additional guidance and restrictions regarding circuits exceeding 600V.
- **MIL-HDBK-454A -** par 4.5.3.2 recommends that circuits operating in excess of 500V be completely enclosed from the remainder of the assembly and equipped with non-bypassable interlocks.

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1.10 Are enclosures for potentials, which exceed 600 volts, marked "DANGER, HIGH VOLTAGE, XXX VOLTS" in white on a red background?

Durability and visibility of labels are addressed in questions 3.12 through 3.15.

- **MIL-HDBK-454A -** Guideline 1, par 4.8.c recommends warning labels following the format of ANSI Z535.4 and with the DANGER signal word for voltages greater than 500V.
- **NFPA 70-05 -** article 110.34 requires rooms and enclosures operating at over 600V to be marked "Danger High Voltage - Keep Out." Article 314 Part IV contains similar requirements for pull and junction boxes. Article 490 addresses equipment operating over 600V and contains a similar statement.
- **29 CFR 1910 -** 1910.303(h)(2)(ii) and 1910.304(d)(2)(ii) require appropriate warning signs for systems operating over 600 volts.
- **ANSI Z535.4 -** contains requirements concerning product safety signs and labels. The DANGER label (white lettering on red background) is specified for imminent hazardous situations which, if not avoided, will result in death or serious injury.

1.11 Are all terminals, conductors, etc., capable of supplying greater than 25 amperes, protected against accidental short circuit by tools, removable conductive panels and assemblies, etc.?

High current sources (greater than 25 amperes) are potential fire hazards due to arcing/heating effects, though associated voltages may be at safe levels from an electrical shock standpoint. For instance, a 12 volt car battery typically does not pose a shock hazard, but could instantly weld any metal parts or tools shorting across both terminals due to the hundreds of amperes available at the terminals. The emphasis is therefore to protect against accidental contact of high current circuits/parts with tools. In addition, one should ensure that parts or covers removed during maintenance cannot contact or be dropped across high current parts. Battery covers should be of a nonconductive material where battery terminals are exposed.

- **NFPA 70-05 –** Article 725 covers requirements for Class 2 and Class 3 circuits where current is limited to values considered to be safe from a fire initiation standpoint. Values are further specified in Chapter 9, tables 11(A) and (B), and are limited to 8 Amps max (typically much less). Article 411 covering Low Voltage (<30V) Lighting systems limits these systems to a maximum of 25 amps.
- **UL 1950 -** par 1.2.8.7 addresses this issue in terms of "hazardous energy levels," which is defined as a stored energy level of > 20 J, or a continuous power level of 240 VA at a voltage greater than 2 V. Par 2.1.5 does not permit operator access to hazardous energy parts (verified using the UL articulate finger). Par 2.1.4.1 addresses maintainer protection and requires hazardous energy parts to be so located or guarded that unintentional bridging by conductive materials that might be present is unlikely during servicing.
- **UL 60950 –** Par 1.2.8.8 defines hazardous energy levels. Par 2.1.1.5 states there shall be no energy hazard in operator access areas. Par. 2.1.2 addresses maintainer protection against energy hazards.
- **MIL-STD-1472F –** Par 5.13.7.1.2 states batteries that have ratings greater than 25 amp hours shall have terminal guarding to prevent inadvertent short-circuit. Such guarding shall also prevent short-circuiting the battery in spite of clearly improper but possible acts by personnel, such as placing tools across terminals, resting a heavy object on the battery cover, and standing on a battery cover.
- **MIL-HDBK-454A –** par 5.2.4.1 states all power buses supplying 25 amperes or over should be protected against accidental short-circuiting by tools, jewelry or removable conductive assemblies.

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1.12 Are all high voltage circuits (>600 V) and capacitors (>30 V or >20 joules energy) reliably and automatically discharged to less than 30 volts / 20 joules within two seconds after power is removed?

Capacitors and high voltage circuits that retain charge can pose a hazard to maintainers. Discharge devices should be incorporated that are reliable. Even larger capacitors at less than 30 V can still contain enough energy to cause a damaging arc, which is the reason for the 20 J energy criterion.

A scenario that occasionally comes up is that a particular capacitor is found to discharge to an acceptable level within a minute or so, rather than two seconds. The manufacturer may argue that the time it takes to remove all of the access panel screws would ensure the circuit is discharged and no hazard would be present. However, maintainers may power up the system with the cover off to verify a maintenance procedure or to take a reading. The access panel would not delay maintainer access to the capacitor in this case. Additional procedural controls and labels would be required to warn the maintainer, which is not the best way to control the hazard.

The above criterion is specified to protect against significant personnel injury and significant system/tool damage. It does not consider the fact that accidentally discharging smaller capacitors may still damage sensitive electronics. It also does not consider the negative impressions a maintainer could have of a system that "sparks" whenever it's maintained, even though it meets the above guidelines. Therefore, system designers may wish to go further and ensure that all parts discharge once power is removed.

- **MIL-HDBK-454A -** guideline 1, par 4.5.5.1 recommends that high voltage circuits and capacitors discharge to less than 30 volts within two seconds of power removal. The second sentence specifically states "...the capacitor or high voltage circuit..." which means the requirement applies to all capacitors, not just the ones at +500 V.
- **NFPA 70-05 -** Article 460-6 requires all capacitors to be discharged to less than 50 volts within 1 minute from source disconnection. Note that article 460-1 states that surge capacitors or capacitors included as component parts of other equipment and conforming to the requirements of such equipment are excluded from this requirement. However, equipment specific standards, which pick up where the NEC leaves off, typically have more stringent requirements in these areas.
- **UL 1950 -** sec 2.1 requires that operators and service personnel be protected from contact with live parts: 1) exceeding 42.4 V peak (30 V rms sine wave) and 60 VDC, 2) exceeding limited current requirements (par 2.4), and 3) having a stored energy level of + 20 J or a continuous power level of 240 VA at a voltage greater than 2 V. Safety interlocks can be used for this purpose IAW par 2.8. Par 2.1.10 states that equipment shall be designed so that at an external point of disconnection of the mains supply (such as a plug), there is no risk of electric shock from stored charge on capacitors connected to the mains circuit.
- **UL 60950 –** paragraphs 2.1.1.7 and 2.1.2 apply.

1.13 Are all test points, required to be measured by maintainers, limited to less than 300 V (between test points and/or accessible dead metal/ground)?

Hazards to the maintainer increase significantly as voltages increase. High voltages can bridge air gaps and lead to arc-blast hazards. Special protective equipment is required. Limiting voltages that are required to be measured reduces the hazard as well as possibility that maintainers may not wear the necessary protective equipment, use the correct equipment, or follow proper HV measuring safety procedures.

- **MIL-HDBK-454A -** guideline 1, par 4.5.3.3 recommends limiting any voltage measurements to less than 300 V to ground. Voltage dividers should be used to reduce higher voltages where necessary.

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- **NFPA 70-05 –** a requirement addressing voltage measurements is not specified in the NEC. However, it should be noted that a number of articles in the NEC use a 300V-to-ground criterion to address different levels of spacing, support, wiring, and other requirements.
- **NFPA 70E –** Chapter 1 covering Safety Related Work Practices and Chapter 2 covering Safety-Related Maintenance Requirements address various requirements for qualified personnel to access live parts. Depending on the voltage level and qualifications of the individual, various approach boundaries and personal protective equipment are specified.

1.14 If voltage dividers are used to reduce test point potentials, are two resistors used between the test points and/or neutral (not ground)?

Where the voltage divider is made up of resistors, it needs to fail in a safe manner. Since resistors tend to fail "open", a resistor failure between the test point and ground will cause the test point to rise to the actual circuit voltage. Depending on the voltage level and current throughput of the resistor, test lead & equipment insulation can be compromised and the maintainer expose to a shock hazard.

- **MIL-HDBK-454A –** guideline 1, par 4.5.3.3 recommends that two resistors of equal value be used in parallel between the test point and ground.

1.15 Where test point voltages are to be measured through holes in protective barriers, is the maximum voltage labeled?

This question is more than likely a carry-over from earlier military standard requirements but is based on sound engineering practice. As a minimum, the highest test voltage should be specified so that maintainers can take proper precautions and select the proper test equipment.

- **MIL-HDBK-454A –** though not a direct requirement, guideline 1 par 4.8 recommends that warning labels be applied to indicate the hazard which may be present upon removal of a guard. Labels are also recommended where the severity varies for a grouping of hazards (a high voltage terminal in a group of low voltage parts).
- **NFPA 70E –** Chapter 1 Safety Related Work Practices addresses various requirements for personnel accessing live parts based on the voltage level and qualifications of the individual. Having the maximum voltage specified helps to ensure that proper precautions are taken.

1.16 Is sufficient space provided between live parts and/or dead metal parts to prevent shorting or arcing?

Product safety standards go into substantial detail regarding acceptable distances between live parts and ground based on the voltages involved, types of insulation, etc. Consideration needs to be given to whether parts are separated by an air gap (clearances) or an insulator (creepage distances). In addition, contaminants and dust can bridge or cover insulation, eventually leading to insulation failure. Certain UL standards address this in their requirements. Enclosures or other parts that can be subjected to physical stress (kicked or stepped on) or bending require larger spacing to energized parts.

- **UL 1950 -** section 2.9 lists specifics concerning clearances, creepage distances, and distances through insulation. The requirements do account for different levels of dust and pollution that the equipment can be exposed to. Par 2.1.6 specifies that clearances between enclosures and hazardous parts shall not be reduced to the point where a hazard arises when a force of 250 Newtons (56 lbs) is applied.
- **UL 60950 –** section 2.10 applies.

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- **MIL-HDBK-454A -** guideline 1, par 4.5.2.4 recommends that cable shielding end at a sufficient distance from exposed conductors to prevent shorting or arcing.

1.17 Are parts and components suitably affixed to prevent loosening or rotation that could lead to shorting or arcing?

Parts that normally rotate or that could come loose and rotate (rotary switch) must maintain adequate spacing for the worst-case condition. Use of lock washers, detents, double-D holes should also be pursued to prevent rotation.

- **UL 1950 -** section 2.9.1 requires that moveable parts be evaluated when placed in the most unfavorable position. Section 4.3.5 requires handles, knobs, etc to be reliably fixed so that they will not work loose if this could result in a hazard. Section 4.3.9 also notes that equipment shall be so constructed that should any wire, nut, washer, spring, or similar part become loose or fall out of position, clearances or creepage distances will not be reduced.
- **UL 60950 –** Par. 4.3.2 applies.
- **UL 891 –** par 7.4 states an electrical component shall be securely mounted and prevented from turning.

1.18 If a tool is required to make adjustments while equipment is powered, is spacing and insulation adequate to prevent contact with energized parts by the tool?

Consideration needs to be given not only to the hazards that personnel may be exposed to (shock, arc), but also shorting of parts that could further damage equipment. Also see question 1.6 for additional guidance.

- **UL 1950 -** Par 2.3.4 requires hazardous voltages to be located or guarded so as to avoid shorting to low voltage circuits by tools or test probes. Par 4.3.2 states that manual adjustment of accessible control devices that requires the use of a tool shall not create a hazard.
- **UL 60950 –** Par. 4.3.3 states that manual adjustment of accessible control devices that requires the use of a tool shall not create a hazard.
- **MIL-STD-1472F –** Par 5.9.3.2 states that screwdriver adjustments made without visual access are permissible only if mechanical guides are provided to align the screwdriver.

1.19 Have connectors, used for multiple electric circuits/voltages, been selected to preclude mismating?

Two items need to be considered here: can connectors that are used for two different power sources (e.g. 24 VDC and 120 VAC) be mixed up, and are the connectors keyed so that polarity cannot be reversed.

Military connectors are occasionally used at the equipment end of a power cable and can pose a unique problem. Many of these connectors have multiple pins and unlike NEMA plugs, do not designate a specific pin for ground, line, or neutral; the choice of pin configuration is left up to the designer. In such cases, the power cable must be clearly identified for use with specific piece equipment only. Otherwise, the power cable may be use with other equipment having the same mil-type connector but with a different pin configuration, leading to reversed phase, line, and ground. Such incidents have been reported in the past. Designers should also consult their government PM or technical POC as they may have internal guidance regarding power cables and connectors used with equipment under their purview.

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- **NFPA 70-05 –** article 406.3(F) specifies that receptacles connected to circuits that have different voltages, frequencies, or types of current (ac or dc) on the same premises shall be of such design that the attachment plugs used on these circuits are not interchangeable. Articles 406.7, 517, 530, and 625 also contain similar requirements.
- **UL1950 -** par 3.2.1 requires that supply plug connections not be interchangeable if a hazard could result from incorrect plugging.
- **UL 60950 –** par 3.2.2 applies.
- **MIL-HDBK-454A -** guideline 1, par 4.5.6 recommends that connectors used in multiple electrical circuits be selected to preclude mismating.
- **MIL-STD-1472F –** Par 5.9.14.2 states connector design shall prevent a plug from being inserted into an incorrect receptacle and preclude damage to the plug or receptacle resulting from such an attempted insertion. Par 5.13.7.1.2 states plugs and receptacle configurations shall preclude inserting a plug of one voltage rating into a receptacle or another rating.

1.20 Has the use of similar configuration connectors in close proximity avoided?

Insertion of a male connector in a female connector other than the one intended to receive it, misalignment of connectors, etc should not result in a risk of fire, electric shock, system damage, etc.

Do not overlook communications cables. Some output signal cables may include DC power for low noise amplifiers or to power local "operator interface units". Swapping input and output signal connectors could lead to equipment damage.

- **MIL-HDBK-454A -** guideline 1, par 4.5.6 recommends that connectors used in multiple electrical circuits be selected to preclude mismating. The paragraph goes on to recommend clear marking or coding of mating plugs and receptacles where similar configurations are used in close proximity. However, this is a control measure to be followed only when the use of similar connectors cannot be avoided.
- **UL1950 -** par 3.2.1 requires that supply plug connections not be interchangeable if a hazard could result from incorrect plugging.
- **UL 60950 –** par 3.2.2 applies. Par. 4.3.5 states that plugs and sockets likely to be used by the operator or service personnel shall not be employed in a manner likely to create a hazard due to misconnection. Keying, location, or in the case of connectors accessible only to service personnel, clear markings are permitted to meet the requirement.

1.21 Are plugs and receptacles coded and marked to clearly indicate mating connectors, where those of similar configuration are in close proximity?

This control measure is to be followed only when the use of similar connectors cannot be avoided. Soldiers may be under pressure to quickly set-up a system in various lighting conditions. Depending on the hazard severity (possible electrocution, ignition of explosives, etc.), a procedural control as the only mitigating action would be unacceptable. Most commercial safety standards do not give the option of a procedural control where incorrect connection could result in a hazard (see UL 60950 below).

- **MIL-HDBK-454A -** guideline 1, par 4.5.6 recommends clear marking or coding of mating plugs and receptacles where similar configurations are used in close proximity. It also states that plugs and receptacles should not be of similar configuration if the major unit contains explosives, implying that

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a procedural control is not acceptable for significant hazards.

- **MIL-STD-1472F –** Par 5.9.14.3 states electrical plugs and receptacles shall be identified by color, shape, size, or equivalent means to facilitate identification when multiple, similar connectors are used in proximity to each other.
- **UL 60950 –** par 3.2.2 applies. Par. 4.3.5 states that plugs and sockets likely to be used by the operator or service personnel shall not be employed in a manner likely to create a hazard due to misconnection. Keying, location, or in the case of connectors accessible only to service personnel, clear markings are permitted to meet the requirement.

1.22 Are plugs and receptacles designed to preclude electrical shock and burns while being disconnected?

Since cord connected products are often disconnected from an energized plug receptacle, the plug must be designed to minimize any hazard to personnel. Standard NEMA configuration plugs meet this requirement.

- **MIL-HDBK-454A -** guideline 1, par 4.5.6 states that the design of the connector should be such that the operator is not exposed to electrical shock or burns when normal disconnect methods are used.
- **NFPA 70-05 –** Article 406.6 provides general plug design requirements to ensure that they can be used safely.
- **UL 1681 –** The standard for Wiring Device Configurations covers attachment plugs and connectors for use IAW the NEC.

1.23 Are male plugs de-energized when disconnected?

Two points need to be considered: 1) is a male plug being used incorrectly on the power supply side, and 2) can something internal to the load-side equipment cause the plug to become energized. In the first case, a male plug should never be used on the power supply side where its exposed pins may be energized. In the second case, the equipment must not energize any exposed pins be energized due to internal capacitors that may retain energy. An UPS (or other power source) must not cause backup power to energize its power supply plug. These issues should be verified with the product power switch in the on and off positions.

Consider all modes of use for the product or system. In one case, a vehicle system was built so that it could accept power from an external source or export power to another collocated vehicle. To reduce size and cost, a single power connector was to be used for both power import and export. The vehicle (load-side) connector was selected to be a female connector which protected personnel during export power operations. However, when importing power, the user would have been required to handle a plug with exposed pins that could be energized if the power source were on. This is a violation of numerous safety standards.

- **MIL-HDBK-454A -** guideline 1, par 4.5.6 states that exposed pin contacts should not be energized (hot) after being disconnected from the socket contacts.
- **NFPA 70-05 –** Article 406.6(B) states that attachment plugs shall be installed so that their prongs, blades, or pins are not energized unless inserted into an energized receptacle. No receptacle shall be installed so as to require an energized attachment plug as its source of supply.
- **UL1950 -** par 3.2.1 requires that operators not be able to touch bare parts at hazardous voltages, such as plug contacts, when one or more connectors are disconnected. Par 2.1.10 states that equipment shall be designed so that at an external point of disconnection of the mains supply (such as a plug), there is no risk of electric shock from stored charge on capacitors connected to the mains circuit.

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- **UL 60950 –** par 2.1.1.7 applies.
- **UL1778 –** par 2.1.101 states hazardous voltages shall not appear on the AC input terminals under the condition of a single fault on a component (such as in the control circuit) upon loss of the AC input voltage.
- **MIL-STD-1472F –** Par 5.13.7.1.3 states all hot contacts shall be socket contacts.

1.24 Is the operator protected from potential arcing if accidentally disconnecting RF power cables?

Signal patch panels need to be looked at if it's possible that a cable may be disconnected while a radio is keyed, thus potentially creating an arc. Connectors could be selected so that any arcing parts are away from fingers during disconnection. Labels may be required to warn users of this potential issue.

- **MIL-HDBK-454A -** guideline 1, par 4.5.6 states that the design of the connector should be such that the operator is not exposed to electrical shock or burns when normal disconnect methods are used.

1.25 Are all receptacles marked with their voltage, amperage, phase, and frequency characteristics where these ratings differ from the standard ratings?

This question originates from a requirement in MIL-STD-1472F. The requirement also contains the words "as appropriate." If a standard NEMA configuration receptacle were used in accordance with its listed rating, labeling would most likely not be necessary. However, if a standard receptacle has a limited power rating, it should definitely be labeled. For instance, certain end products may incorporate convenience outlets that have a limited load capacity (such as a stereo receiver unit). Here the maximum load capacity must be labeled.

The above does not imply that a standard NEMA type receptacle or plug can be used at a voltage other than it is Listed for (i.e. a 5-15R NEMA, 120V receptacle cannot be used to supply 240V).

- **MIL-HDBK-454A –** par 5.13.2.6 states that all receptacles shall be marked with their voltage, phase, and frequency characteristics, as appropriate.
- **NFPA 70-05 –** Article 406.2 states that receptacles shall be listed for the purpose; NEMA WD 6 identifies plug configurations for various voltage, current, and phase configurations. Per 406.2 and 110.3(B), the NEC does not permit receptacles and plugs configured for a specific voltage/current/phase to be operated from a different voltage/current/phase circuit.
- **UL 1950 -** par 1.7.5 requires that standard power outlet provided on a piece of equipment show the maximum load that is permitted to be connected to the outlet.
- **UL 60950 –** par 1.7.5 applies.

1.26 Is the wiring and insulation suitable for the intended load and operating voltage?

Temperature ratings are specified for conductors to protect the insulation from serious degradation over time. There are 4 key factors that can impact a conductor's operating temperature: ambient temperature (anywhere along the conductor and which may vary with time/season), generated heat (varies with current load and by conductor size and material), heat dissipation (impacted by insulation type, conduit or cable sheath, etc), and adjacent load-carrying conductors (raise ambient temp and impede heat dissipation).

The National Electrical Code differentiates between insulated conductors and covered conductors. Insulated conductors are encased in a material that has been evaluated and approved as electrical insulation. A

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covered conductor is one whose insulation has not been evaluated for such a purpose. Examples of covered conductors are the green covered equipment grounding conductors, or the outer jacket of SE Cable that encloses phase conductors and a bare ground wire. Such conductors are to be treated as bare conductors. This is also another reason why green covered grounding wires should never be used as phase conductors.

- **NFPA 70-05 –** Article 110.4 states that the voltage rating of equipment shall not be less that the nominal voltage of the circuit. Article 310.10 states that no conductor shall be used in a manner where its operating temperature exceeds that designated for the type of conductor insulation. Articles 400 and 402 address additional requirements for flexible cords, cables and fixture wires.

  Where higher ambient temperatures or multiple conductor grouping exist, the maximum current carrying capacity of the conductor must be reduced. The Allowable Conductor Ampacity tables in article 310 must be derated using correction factors (addresses ambient temperature variations; see tables 310.16 – 20) and adjustment factors (addresses multiple conductors; see 310.15(B)(2).

- **UL 1950 –** Par 3.1.1 states that the maximum permitted temperature of a conductor shall not be exceeded when the equipment is operating under normal load conditions.

- **UL 60950 –** par 2.9.1 addresses the properties of insulating materials, and states that the choice and application of insulating materials shall take into account the needs for electrical, thermal, and mechanical strength, frequency of the working voltage and the working environment (temperature, pressure, humidity, and pollution). Section 3.1 addresses other requirements for wiring.

1.27 Is the wiring insulation suitable for the anticipated environment, temperature, and/or possible exposure to fuel, grease, or other chemicals?

Wiring insulation is rated for different types of environments. Exposure to water, grease, oil, fuel, sunlight (UV) etc. can cause the material to degrade and eventually fail. In addition, not all types of insulation systems are rated for heavy usage necessary in an industrial or military environment. Insulated conductors and cables are marked with letter and number designations (THWN, UF, SPT-2, SJO, etc) that can be cross-referenced with tables in the NEC for details.

Not all types of wiring are suitable for all applications. For instance, individual THWN conductors are not suitable for direct user contact and must be enclosed within a raceway. Type AWM wiring is only suitable for use within equipment and is not permitted as power distribution wiring within shelters or buildings. Interconnecting communications cables routed through building ducts must be Listed for installation in plenums (such as type CMP). Flexible cords and cables addressed in NEC Article 400 are suitable for direct user contact but are not permitted for most fixed wiring applications. It's important to ensure the wiring method is suitable for the application, as well as the environment.

- **NFPA 70-05 –** Article 310.8 and 310.9 address requirements for dry, damp and wet locations, exposure to sunlight, and corrosive conditions. Markings on the conductors or jacketed cables can be checked against tables 310.13 (conductors), 400.4 (cables and chords), and 402.3 (fixture wires). In addition, Articles 320 – 398 cover specific types of wiring systems. Articles 725 – 780 cover Class 1, 2 ,3, Alarm systems, and other wiring systems. Chapter 8 covers wiring for communications circuits.

- **UL 1950 –** Par 3.1.12 states that interconnecting cables for external interconnection shall be suitable for external use with respect to voltage, current, anticipated temperature, flammability, mechanical serviceability and the like. Par 4.3.11 states that where internal wiring, windings, etc are exposed to oil, grease or similar substances, the insulation shall have adequate properties to resist deterioration.

- **UL 60950 –** paragraphs 1.5.5, 2.9.1, and 3.1 apply. Par. 4.3.9 states that where internal wiring, windings, etc are exposed to oil, grease or similar substances, the insulation shall have adequate

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properties to resist deterioration. Also see Annex NAE (U.S. and Canadian Regulatory Requirements), clause

1.28 Are wires and cables supported, protected, and terminated in a manner that prevents shock and fire?

Wiring must be supported so that it cannot contact hot surfaces, sharp edges, or other parts that could cause damage to the insulation. Where wiring or cables can be exposed to physical damage (stepped on, hit by stowed equipment, etc) supplemental protection is required. Cables need to be routed to minimize the potential of being snagged. Inspect egress areas where personnel may grab onto the cables as a handhold. Terminations must be suitable so that they do not loosen over time. Avoid wire ties secured by adhesive backed pads, as these pads don't hold up to the environments and time.

The NEC permits conductors of different voltage systems to occupy the same wiring enclosures, conduits, etc. However, there are numerous exceptions and additional requirements, especially where signal cables are concerned. In addition, wire color-coding for AC & DC wiring (AC: black-phase; DC – black – negative) can cause confusion. Therefore, mixing AC and DC power conductors is not recommended.

- **NFPA 70-05 -** articles 300 covers wiring that is not an integral part of equipment (see 300.1(B) limitation). For instance, power distribution and branch circuits within a shelter would be covered under article 300. For wiring that is integral to a specific piece of equipment, the appropriate product safety standard would apply.

  Article 300.3(C)(1) permits conductors of different circuits to occupy the same equipment wiring, cable, or raceway. However, all conductors must have an insulation rating equal to at least the maximum voltage applied to any circuit conductor. Article 725.55 addresses Class 2 and 3 circuits, which are not permitted in the same enclosure or cable as power circuits without a host of additional requirements and restrictions. Articles 800.50, 810.70, and 820.44 address additional requirements for communications circuits (typically not permitted to run with AC power circuits).

- **UL 1950 -** par 3.1.2 and 3.1.3 discuss methods of supporting and protecting wiring. Additional sections of 3.1 address requirements for wiring terminations to minimize wire damage and connections that can loosen with time.

- **UL 60950 –** Paragraphs 3.1.2 and 3.1.3 apply.

- **MIL-STD-1472F –** Par 5.9.13.6 states that cables shall be routed or protected to preclude mechanical damage and abuse, including damage by doors, lids, use as steps or handholds, or being bent or twisted sharply or repeatedly.

1.29 Is wiring protected when passing though openings, near sharp edges, and near hot surfaces?

Vibration can eventually lead to insulation wear and damage even if the wire is positioned or secured to reduce movement. Where wires pass over sharp surfaces or through openings, surfaces should be rounded or grommets installed.

- **NFPA 70-05 –** Article 300 addresses requirements for protecting wiring. In addition, the NEC article covering the specific wiring method may contain additional requirements (see 320-398). Cords and fixture wire would be covered under articles 400 and 402.

- **UL 1950 -** par 3.1.2 states that wire ways shall be smooth and free from sharp edges. Holes through which wires pass shall have well-rounded edges or bushings provided. Par 3.2.5 – 3.2.7 address methods to protect power supply cords from sharp edges and abrasion.

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- **UL 60950 –** Paragraphs 3.1.2, 3.1.3, 3.2.7 and 3.2.8 apply.
- **MIL-HDBK-454A -** guideline 9, par 4.4 states wires and cables should be positioned or protected to avoid contact with rough or irregular surfaces and sharp edges and to avoid damage to conductors and adjacent parts. Guideline 69, par 5.3 states wiring should be secured and protected against chafing due to vibration or movement.

1.30 Is suitable strain relief provided for conductors and cords at their terminations to prevent stress from transmitting to terminals, splices or internal wiring?

Conductors must have strain relief to protect against the wiring connection from pulling out and creating a hazard. Power supply connections are prime areas of concern, although internal equipment wiring must also be evaluated if flexes as part of use of the equipment (e.g. panel door with panel mounted indicators). The adequacy of strain relief will depend on the weight of equipment, potential methods of damage, etc. For instance, cords may experience extra strain where used with heavier moveable equipment. Lighter, hand-held equipment may have greater wear and flexing of the cord at the point where it attaches to the product (and therefore require a cord guard). Where a power cord contains a grounding conductor, the installation should be such that should the cord slip in its anchorage, the grounding conductor should be the last conductor to be strained.

- **NFPA 70-05 -** Article 400.10 requires flexible cords and cables to be installed so that tension is not transmitted to joints or terminals. Additional articles in chapter 3 of the NEC contain similar requirements for other wiring methods.
- **UL 1950 –** Par 3.2.5 addresses requirements for cord anchorage and strain relief. Par 3.2.7 addresses cord guards.
- **UL 60950 –** Paragraphs 3.1.9 and 3.2.6 apply. Par 3.2.8 addresses cord guards.
- **MIL-HDBK-454A -** guideline 69, par 5.9 states wire and cable should be properly supported and secured to prevent undue stress on the conductors and terminals.

1.31 Where the user has access to wiring that carries hazardous voltage/current, does the wiring have a 2nd barrier of protection (i.e. jacketed cord, conduit, etc.)?

Wiring carrying hazardous voltages and having a single layer of insulation is typically not suitable for contact by users. The wire must be enclosed within a conduit or other enclosure, or otherwise be an approved jacketed cord.

- **NFPA 70-05 –** Article 300.3 states that single conductors shall only be installed where part of a recognized wiring method of chapter 3 (raceway, conduit, etc). Limitations associated with various recognized wiring methods are covered in applicable articles of chapter 3. Limitations associated with cords and fixture wires are addressed in articles 400 and 402.
- **UL 1950 –** Par 2.1.2 states that operators shall not have access to wiring at hazardous voltages, unless it meets double or reinforced insulation requirements.
- **UL 60950 –** par 2.1.1.4 applies.

1.32 Are single-phase line conductors color coded black, or otherwise clearly identified?

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A number of military standards and handbooks specifically require single phase conductors be colored black. Industry has accepted this as a general practice, but it is not required by the National Electrical Code or UL Product Safety Standards. The NEC requires that a color other than white or green be used and that the color scheme be identified.

This requirement applies to conductors that supply power to the equipment, including the equipment's supply cord. The wiring within a shelter power distribution panel would have to comply with this requirement, just like the circuit breaker panels and branch circuits of a residential dwelling.

Proper color coding is especially critical where conductors terminate at receptacles, light fixtures, and the like, since maintainers may replace these components solely based on wire color coding without referencing a TM. The same applies for power cable pigtails for hookup to generators and facility power. Also see question 1.46 regarding use of white and green colors.

- **NFPA 70-05 -** Articles 210.5 and 310.12 require that ungrounded conductors be identified, but do not specifically require black color-coding.
- **UL 1950 –** Par 1.7.7 addresses labeling requirements at power supply connections, but does not address wire color coding. In general, UL product safety standards do not address wire color coding other than at supply connection points.
- **UL 60950 –** par Par 1.7.7 addresses labeling requirements at power supply connections, but does not address wire color coding. Annex NAE (U.S. and Canadian regulatory requirements), clause 1.7.7 also addresses color coding and identification of the grounding terminal.
- **MIL-STD-1857 -** par 3.2.8 provides examples of wire color coding methods that call out black wiring of single phase conductors.
- **MIL-STD-686 -** par 4.2 specifies color-coding for electrical cords where the first three conductors are to be designated black, white and green for phase, neutral, and ground respectively.

1.33 Are three-phase line conductors color coded as follows: A – black, B – red, C – blue, or otherwise clearly identified?

See question 1.32 for comments.

- **NFPA 70-05 -** Articles 210.4 and 310.12 require that ungrounded conductors be identified, but do not specifically require black, red and blue color-coding. However, the NEC does require certain colors to be used for specific circuits. Orange is used for the high leg delta power per article 110.15. Orange, Brown and Yellow are used for isolated power systems per 517.160(A)(5).
- **MIL-STD-1857 -** par 3.2.8 provides examples of wire color coding methods that call out black, red and blue for three phase conductors.
- **MIL-STD-686 -** par 4.2 specifies color-coding for electrical cords where the first five conductors are to be designated black, white, green, red, and blue.

1.34 Are DC power conductors color coded red for positive polarity and black for negative polarity?

Industry has accepted this as one method of identifying conductors or equipment terminals, along with using +and – or POS and NEG symbology. It is critical that cable terminations be clearly identified where they end as a pigtail for hookup to a power source or battery. The designation should be durable and should not require access to a technical manual. Vehicle mounted systems sometimes tap power directly from vehicle batteries, which creates problems for vehicle maintainers servicing the batteries and have no idea what the

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extra cables are for.

The NEC permits conductors of different voltage systems to occupy the same wiring enclosures, conduits, etc. However, there are numerous exceptions and additional requirements, especially where signal cables are concerned. In addition, wire color-coding for AC & DC wiring (AC: black-phase; DC – black – negative) can cause confusion. Therefore, mixing AC and DC power conductors is not recommended.

- **NFPA 70-05 -** Articles 210.5(C) states that where more than one nominal voltage system exists in a building, each ungrounded conductor of a multiwire branch circuit, where accessible, shall be identified by phase and system.

1.35 Are all equipment noncurrent-carrying metal parts and surfaces at ground potential when the equipment is powered (excluding self-powered equipment)?

It is important that all noncurrent-carrying conductive parts of the equipment be grounded to ensure that under any electrical fault condition, hazardous voltages are not present on the equipment enclosure and that any overcurrent protective devices can clear. For most products, this is carried out by ensuring that all exposed conductive parts are bonded to a single ground point, and that an equipment grounding conductor is run from the single ground point back to the power source ground.

A grounded conductor is defined as a current carrying conductor that is at earth potential (sometimes called the neutral). A grounding conductor is used to connect noncurrent-carrying parts back to the power source ground and is not intended to carry current. Refer to the NEC Article 100 for detailed definitions of these terms. In addition, Article 250.4 contains a good explanation of the purpose and performance requirements for grounding and bonding of electrical systems. UL Standards adopting IEC standard formats use the terms earthing and earthing conductors instead of grounding.

Equipment that is protected by a system of double insulation (as Listed/Approved by a Nationally Recognized Testing Laboratory) and that is suitably marked with ⧈ does not require grounding. However, the suitability of the environment/intended use of a double insulated tool needs to be considered, as certain environments (wet, metal dust) could degrade the integrity of the insulation.

- **NFPA 70-05 -** article 250.4 provides general performance requirements for grounding and bonding. Specific details grounding methods are addressed throughout Article 250 as well as in other articles (see table 250.3).
- **UL 1950 -** sec 2.5.1 states that accessible conductive parts which might assume a hazardous voltage in the event of a fault shall be reliably connected to an earthing terminal within the equipment (UL 1950 uses the IEC terminology of earthing rather than grounding). Sections 3.1 through 3.3 address requirements for equipment grounding conductors to the power supply.
- **UL 60950 –** par 2.6.1 applies. UL 60950 uses the IEC terminology of earthing rather than grounding. Note that this standard distinguishes between protective earthing and functional earthing. Protective earthing is required from a safety standpoint (ensuring parts that could become energized during a fault are at ground potential, etc). Functional earthing is the grounding of a point in equipment or in a system, which is necessary for a purpose other than safety. Functional earthing requirements are addressed in par 2.6.2.
- **MIL-HDBK-454A -** guideline 1, par 4.5.2 states the design of equipment should ensure that all external surfaces are at ground potential at all times during normal operation (with exceptions).

1.36 Does self-powered equipment have all external surfaces at the same potential?

For self-powered systems, none of the circuit conductors are solidly bonded to earth. Should one of the conductors short to the enclosure, a shock hazard would not exist between the enclosure and earth ground

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since that circuit path is not complete (i.e. current cannot be forced through a person if there is no return path back to the other terminal of the power supply). However, hazardous voltages could develop between isolated parts of the equipment if all surfaces are not bonded together.

Self-powered equipment includes handheld equipment as well as vehicle mounted systems. In the latter case however, supplemental grounding with a ground rod may be required if signal cables or external power cables could be interconnected to the system since power surges or electrical faults could be introduced through external systems.

- **NFPA 70-05 -** article 250.34 applies to portable generators and vehicle mounted generators where the generator frame acts as the ground reference.
- **MIL-HDBK-454A –** Guideline 1, par 4.5.2.1 – states that self-powered equipment should have all external surfaces at the same potential.

1.37 Is the path from various equipment points to ground continuous and permanent (hinges and slides not relied upon as the ground path)?

Hinges and slides typically should not be relied upon if exposed to the elements, since dirt and corrosion in the field could degrade such grounding paths. However, in certain circumstances where hinges would not be exposed to environments that could cause corrosion, hinges may be acceptable. In such cases, the hinges should be checked to make sure they are not exposed to corrosive element, and that they do not incorporate nylon spacers or other nonconductive parts.

- **NFPA 70-05 -** article 250.4(A)(5) states that electrical equipment and wiring and other electrically conductive material likely to become energized shall be installed in a manner that creates a permanent, low-impedance circuit capable of safely carrying the maximum ground fault current that may be imposed on it. Parts that could potentially corrode in a particular environment would not be suitable (see 110.3). Article 250, Parts V and VI contain specifics for bonding and equipment grounding. Individual product safety standards would apply for grounding and bonding of parts integral to a specific piece of equipment.
- **UL 1950 -** par 2.5.1 states that dead metal parts shall be reliably grounded. Though hinges are not specifically called out and prohibited, par 2.5.10 points out that corrosion of grounding parts must be considered. It will be necessary to look at the intended use of the end product.
- **UL 60950 –** par 2.6.1 states that dead metal parts shall be reliably grounded. Though hinges are not specifically called out and prohibited, par 2.6.5.6 points out that corrosion of grounding parts must be considered. It will be necessary to look at the intended use of the end product.

  UL 60950 refers to protective bonding conductors as a conductor in the equipment that connects a part of the equipment to the main protective earthing terminal (ground point) within the equipment. The protective earthing conductor is the conductor that connects the protective earthing terminal (ground point) within the equipment to the power source ground (i.e. equipment grounding conductor).
- **MIL-HDBK-454A –** Guideline 1, par 4.5.2.3 states hinges or slides should not be used as grounding paths.

1.38 Are the noncurrent-carrying parts of internal components grounded where they can be accessed by maintainers?

Certain parts, such as a motor casing, power rectifier heat sink, or relay housing may be accessible only during maintenance. Such parts should be grounded if it's possible for the parts to become energized.

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- **NFPA 70-05 –** Article 250.4 requires that non-current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, be connected together/ground.
- **UL 1950 –** Par 2.5.1 states that in service areas, parts that may become energized due to a single insulation fault shall be grounded. Where impractical, a warning label is required.
- **UL 60950 –** paragraphs 2.6.1 and 2.6.5.5 apply.

1.39 Are panels and doors containing meters, circuit breakers, etc., grounded in a reliable manner, whether in a closed or open/removed position (less than 0.1 ohm)?

Panels or doors that contain energized parts must maintain an adequate ground with the panel removed. If the door is hinged, the hinge may provide adequate grounding if corrosion and other concerns discussed in question 1.37 are addressed.

- **NFPA 70-05 -** article 250-148 states that disconnection of a device will not interrupt grounding continuity. Individual product safety standards would apply for grounding and bonding of parts integral to a specific piece of equipment. Article 250.146(A) requires a bonding jumper to a cover-mounted receptacle where the cover could become isolated when removed.
- **UL1950 –** par 2.5.8 states that grounding connections shall be so designed that they do not have to be disconnected for servicing other than for the removal of the part which they protect unless hazardous voltage is removed from that part at the same time.
- **UL 60950 –** par 2.6.5.5 applies. Par 2.6.3.3 specifies the grounding resistance requirement. For circuits with a current rating of 16 amps or less, the resistance shall not be more than 0.1 ohms. If the current rating of the circuit exceeds 16 amps, the voltage drop shall not exceed 2.5 volts.
- **MIL-HDBK-454A –** guideline 1, par 4.5.2.3 states that a panel which could be removed during maintenance and which has mounted electrical components (hazardous currents/voltages) must remain grounded whether in a closed or open position.

1.40 Does the grounding path have capacity to safely conduct any currents that might be imposed thereon?

The amount of current that can flow during a ground fault can exceed the opening rating of a circuit breaker by an order or two of magnitude for a short period of time. The grounding path must be able to withstand the fault current without failure.

- **NFPA 70-05 -** article 250-4(A)(5) requires that the ground fault current path provide a low-impedance circuit capable of safely carrying the maximum ground fault current that may be imposed on it. Table 250.122 lists the minimum size for equipment grounding conductors, based on the size of the overcurrent device in the circuit ahead of the equipment. Where overcurrent protection is less than 30 A, the EGC cannot be smaller than the circuit conductors supplying the equipment.
- **UL 1950 -** par 2.5.1 requires grounding paths within equipment to be reliable, and to be able to withstand the grounding test outlined in par 2.5.11. The grounding test is based on 150% of the available current, up to 25 amps, which proves out the ability of the grounding path to withstand a fault. Par 3.2.4 specifies grounding conductor wire sizes for power supply cords.
- **UL 60950 –** par 2.6.1 and 2.6.3.3 apply. Note that the grounding test current is two times the current rating of the circuit for at least two minutes.

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- **MIL-HDBK-454A –** guideline 1, par 4.5.2.2.b states the grounding path shall have ample carrying capacity to safely conduct any fault currents that could be internally generated.

1.41 Is the impedance of the grounding path sufficiently low to limit the potential drop and to allow over-current devices to clear quickly?

The ground path must have adequate capacity to ensure that a circuit breaker or fuse can clear quickly. The ground path must also ensure that during the fault, the voltage drop is minimal so that users contacting exposed metal parts are not subjected to a shock hazard.

Conductor impedance consists of two elements – resistance and inductance. Resistance can be reduced by ensuring a conductor is properly sized, connections are suitable and tight, corrosion is prevented, etc. Inductance (a frequency dependent element of impedance) can be reduced by running the grounding conductors (conduit, etc) along with the current carrying conductors.

An earth grounding system alone should not be relied upon as the sole ground-fault return path to the power source, since the impedance of soil is usually too high to clear the circuit breaker. The earth ground system helps to limit accessible voltages during a fault, and provides a discharge path for power surges and other transients.

It should be noted that for certain high power systems or safety critical systems, it is not wise to suddenly interrupt the current path. Large power plants require an orderly shutdown to prevent generator runaway. In addition, large surge current could cause excessive mechanical stresses to the generator windings, in turn destroying the generator. For such systems, the neutral is grounded through some external impedance. Circuitry is then incorporated to warn of a ground fault so that a safe and orderly shutdown could be initiated. There are numerous standards that detail requirements for neutral impedance grounding (refer to NFPA 70-05, article 250.36). However, most CECOM type systems and equipment will not deal with this issue.

- **NFPA 70-05 -** article 250-4 addresses general requirements. Additional details to meet these requirements are covered other parts of article 250.
- **UL 1950 -** par 2.5.11 states that resistance of connections shall be less than 0.1 ohms. The test is carried out by flowing current through ground at 1.5 times the current capacity of the circuit involved. The voltage drop is measured and resistance calculated.
- **UL 60950 –** par 2.6.3.3 applies. The test is carried out by flowing current through ground at 2 times the current capacity of the circuit involved. For circuits with a current rating of 16 amps or less, the resistance shall not be more than 0.1 ohms. If the current rating of the circuit exceeds 16 amps, the voltage drop shall not exceed 2.5 volts.
- **MIL-HDBK-454A -** guideline 1, par 4.5.2.2.c states the ground path impedance shall be sufficiently low to limit the potential above ground and to facilitate the operation of overcurrent devices in the circuit.

1.42 Does the path from the equipment tie point to ground have sufficient mechanical strength to minimize accidental grounding disconnection?

A single ground points typically provided within the equipment to which the various internal grounding conductors and the equipment grounding conductor are connected. The grounding point has to be durable to minimize any possible disconnection.

If a current carrying conductor becomes disconnected, the failure will most likely be apparent since the equipment will not function properly. That's not the case for the grounding conductor, which is often not required for proper operation. Even if the users know the grounding path is compromised, they may

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continue to operate the equipment, as is occasionally witness with equipment operated with the power plug ground pin removed. For this reason, additional steps should be taken to ensure the durability of the connection.

- **NFPA 70-05 -** articles 250.8, 250.10, 250.70, 250.148 apply depending on the application and identify accepted connection methods.
- **UL 1950 -** par 2.5.9 provides guidance to ensure the connection is durable. Par 3.2.5 also states that where a power cord contains a grounding conductor, the installation should be such that should the cord slip in its anchorage, the grounding conductor should be the last conductor to be strained.
- **UL 60950 –** sections 2.6.4 and 2.6.5 apply.
- **MIL-HDBK-454A -** guideline 1, par 4.5.2.2.d states the ground path shall have sufficient mechanical strength to minimize possibility of ground disconnection.

1.43 Do cables that carry a grounded conductor (neutral) also carry an Equipment Grounding Conductor (EGC) that terminates in the same manner as the other conductors?

*Ground**ed** and ground**ing** conductors have very different definitions and requirements from an electrical safety standpoint. Refer to question 1.35 above for additional information.*

- **NFPA 70-05 –** Article 250, part VI addresses equipment grounding and equipment grounding conductors. Article 406.3 requires receptacles installed on 15 and 20 Ampere branch circuits to be of the grounding-type. Article 300.3(B) requires all conductors of the same circuit to be contained within the same raceway (with certain exceptions).
- **UL 1950 -** par 3.2.4 requires power supply cords to contain an earthing conductor for Class I equipment (see 1.2.4.1 for definition of Class I equipment). Par 2.5.2 and 2.5.4 can be referenced regarding interconnection of equipment.
- **UL 60950 –** section 2.6.5 addresses integrity of the protective earthing path.
- **MIL-HDBK-454A –** Guideline 1, par 4.5.2.2 states that any external or interconnecting cable, where a ground is part of the circuit, should carry a ground wire in the cable.

1.44 Are insulated grounding wires color coded green with or without yellow stripes?

Grounding conductors are permitted to be bare, covered, or insulated. If covered or insulated, they must be green with or without yellow stripes. Refer to questions 1.46 regarding the difference between covered and insulated conductors.

- **NFPA 70-05 -** article 250.119 requires covered or insulated conductors to have a continuous outer finish that's green with or without yellow stripes. An insulated or covered conductor larger than 6 AWG can be permitted, at the time of installation, to be permanently identified as a grounding conductor with certain conditions. Article 400.23 has a similar requirement for flexible cords and cables, but does not permit re-identification of insulation color.
- **UL 1950 -** par 2.5.5 applies.
- **UL 60950 –** par 2.6.3.4 applies.
- **MIL-STD-1857 -** par 3.2.8 provides examples of wire color coding methods that call out green for grounding conductor.

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- **MIL-STD-686 -** par 4.2 states that green shall be used for the grounding conductor only.

1.45 Are neutral / grounded conductors color coded white or natural grey?

- **NFPA 70-05** – Article 200.6 identifies color coding requirements for grounded conductors. Article 400.22(C) permits the neutral to be light blue for jacketed cords furnished with appliances, provided the other conductors have their insulation or a readily distinguishable color other than white or grey. This exception takes into account the light blue color coding for neutral conductors used by certain foreign countries.
- **MIL-STD-1857 -** par 3.2.8 provides examples of wire color coding methods that call out white for the grounded conductor.
- **MIL-STD-686 -** par 4.2 provides color coding requirements for electrical cords and states that white shall always be used for the neutral conductor.

1.46 Is green and white color coding applied ONLY to grounding and grounded conductors, respectively?

Green and white wiring must not be used for phase conductors as it is an industry accepted color coding convention for grounding and grounded conductors. Not following it could confuse maintainers, leading to hazards and accidents.

It should be noted that grounding conductors are permitted to be bare, covered, or insulated. "Covered" is not recognized by the code as electrical insulation (see article 100 definitions). Therefore, anyone wanting to "re-designate" a grounding conductor to as a phase conductor could be using a conductor that's effectively bare.

The NEC provides some exceptions where conductors can be redesignated at the terminations. This does not give license to wire shelters or other systems with power distribution wiring with all white wires that are redesignated at terminations. Damaged wire ends may require the wire to be cut and re-stripped, at which time the redesignating marking may be lost.

Power cables with pigtails must never have the colors redesignated. There have been cases where split-phase power cables (black, red, white and green conductors) were used to power three phase systems with the green wire redesignated for phase C. This is a violation of various safety standards. In addition, damage to the pigtail through repeated use will require the cable to be cut back and re-stripped, at which time the red-colored sleeve added over the green wire would be lost.

- **NFPA 70-05 -** Article 200.7 permits white color coding only for the grounded conductor, through there are some exceptions that permit re-identification of the white insulation at all visible and accessible locations at the time of installation. Thought the code has a specific subsection that addresses re-designation of a grounded conductor, there isn't such a subsection for the grounding conductor. Article 250.199 does not permit green colored insulation for any use other than grounding. This is supported by articles 400.23, 551.55, and 552.56. Articles 400.22 and 400.23 address flexible cords and cables.

  Though Article 200.7(C)(3) has an exception that permits the white conductor of a flexible cord to be connected to a phase conductor, it is strongly recommend that this practice be avoided where the cord is used as a power cable that terminates in pig-tail conductors that connect to generator terminals or shore power terminals. Damage to the pigtail through repeated use will require the cable to be cut back and re-stripped, at which time any sleeving added over the white wire to redesignate it would be lost.
- **UL 1950 -** par 3.1.6 states that the color combination green/yellow shall be used only to identify

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protective earth connections.

- **UL 60950 –** par 2.6.3.4 applies.
- **UL 891 –** par 49.5.3 states that a white or gray color is only to be used to indicate the neutral, and a continuous green color or a continuous green color with one or more yellow stripes is only to be used for grounding or bonding purposes.
- **MIL-STD-1857 -** par 3.2.8 states that green and white color coding applied only to grounding and grounded conductors, respectively.
- **MIL-STD-686 -** par 4.2 provides color coding requirements for electrical cords and states that white shall always be used for the neutral conductor. Green is to be used for grounding only.

1.47 Do power attachment plugs automatically ground equipment?

Using a plug and a separate grounding strap where the grounding strap provides the only grounding connection would violate this requirement. Use of a cheater plug to connect a typical 5-15 NEMA plug (with a ground pin) to a 1-15 NEMA, two-slot receptacle would also violate this requirement.

- **NFPA 70-05 -** article 250-114 identifies equipment connected by cord and plug that is required to be grounded.
- **UL 1950 -** par 3.2.4 requires that a protective earthing conductor shall be provided and interconnected between the earthing terminal of the equipment and the earthing contact of the plug.
- **UL 60950 –** par 2.6.5.3 applies.
- **MIL-HDBK-454A –** guideline 1, par 4.5.2.2 states equipment should have provisions for automatically grounding when the plug is mated with the receptacle.

1.48 When the grounded power plug is mated with the receptacle, does the ground pin contact make first/break last?

Personnel may be in contact with equipment as the plug is inserted into the receptacle. Therefore, it's important to establish a ground connection first in cases a fault may have been created during transportation or equipment setup.

- **NFPA 70-05 -** article 406.9(D) requires draw out equipment or attachment plugs and mating connectors and receptacles to provide for first-make, last-break of the equipment grounding conductor.
- **UL 1950 -** par 2.5.7 states that protective earthing connections shall make earlier and break later than the supply connections.
- **UL 60950 –** par 2.6.5.4 applies.
- **MIL-HDBK-454A –** guideline 1, par 4.5.2.2 states the ground pin of a receptacle shall make first, break last.

1.49 Are noncurrent-carrying metal parts, grounding wires, etc (except RF cable shields) not used to complete electrical circuits?

One of the purposes of grounding is to limit any potential differences between the equipment and ground.

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Current flowing through grounding conductors, metal raceways, and building steel can create potential differences between these exposed parts and ground.

- **NFPA 70-05 -** article 250.6 addresses objectionable currents over grounding conductors. The very definition of a grounding conductor (Article 100) is a conductor that is used to connect the **non-current-carrying** parts of equipment, raceways, etc. Furthermore, article 250.24 prohibits a grounding connection of a grounded circuit conductor on the load side of the service disconnecting means as this could cause objectionable current to flow over the grounding conductor.
- **UL 1950 –** by definition, the earthing conductors are to bond dead metal parts not intended to carry current. Par 5.2.2 covering leakage current requirements can also be applied.
- **UL 60950 –** par 5.1 addresses current limitations on the protective earthing conductor.
- **MIL-HDBK-454A –** guideline 1, par 4.4.2.2 states static and safety grounds shall not be used to complete electrical circuits. Except for coax cables, the shield shall not be depended upon for a current-carrying ground connection.

1.50 Is the grounding wire separate from electrical circuits, i.e., not tied to neutral other than at the power source?

One reason why the neutral conductor is not permitted to be tied to the grounding conductor other than at the power source is that should the neutral wire become disconnected, the grounding conductor will carry the total current, raising the voltage to ground of exposed metal parts not intended to carry current. This could result in arcing to other grounded parts (concealed pipes, building metal, etc). Maintainers who accidentally open the grounding path could be exposed to a severe shock hazard.

Close attention needs to be paid to systems that incorporate on-board power sources and that also use external power, since the on-board power source will have a ground-neutral bond connection. This connection point needs to be isolated from the external power source to prevent current from back flowing through the on-board power source onto the grounding conductor. Switching the neutral conductor along with the phase conductors when selecting between on-board or external power will avoid this problem. However, a switch is not to be provided in the grounding circuit.

- **NFPA 70-05 -** articles 250.6 and 250.24 apply as discussed in question 1.49 above. Note that for permanent structures, the ground/neutral are interconnected at the service entry location/circuit breaker box, where connection to a ground rod is also mandated. The bond at this location is considered to be reliable and permanent. In the cases of mobile shelters, a ground-neutral bond at the shelter entry could cause the enclosure to be energized if the ground wire to the power source were open or interconnected incorrectly. In light of this, article 550.16, requiring the separation of neutral and ground wires within mobile homes, also applies to mobile shelters.
- **UL 1950 -** par 1.6.3 applies as discussed in question 1.49 above.
- **UL 60950 –** par 1.6.4 applies.
- **UL 891 -** par 28.3.1 discusses separation of neutral and ground unless the panel board is designated for use as service equipment.
- **MIL-STD-1857 -** par 3.2.8 states all AC circuits must be floated to one location (power source) and each AC neutral shall be connected to frame or ground at no other point. The equipment grounding wire shall not be connected to the power return circuit (neutral) and the neutral wires are not to be used as equipment grounding wires.
- **MIL-STD-686 -** par 4.2 states that the white conductor shall always be used as the neutral conductor and shall be insulated from the equipment chassis/connector.

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1.51 If a neutral-ground bond point is provided at the equipment's secondary supply circuit, is it isolated from the primary power source neutral-ground bond point in order to prevent ground loops?

This requirement applies if the UPS incorporates a neutral-ground bond on the secondary, as opposed to relying on the primary source neutral-ground bond (refer to question 1.50 comments above). In order to maintain isolation between the neutral-ground point of the UPS secondary and the neutral-ground point at the primary supply location, any switching circuitry within the UPS must switch/interrupt both the line and neutral conductors

- **UL 1778 –** Par 2.6.101 and Annex EE specify when the UPS AC output needs to be grounded to avoid any back feed that could cause current to flow over the grounding conductor.
- **NFPA 70–05 -** article 250.30 addresses grounding of separately derived power sources (defined as having no direct electrical connection to supply conductors originating in another system). The requirements are intended to ensure adequate grounding of such systems while preventing objectionable current of the grounding system through ground loops.
- **UL 60950 –** par 1.6.4 states that the neutral conductor shall be insulated from earth and from the equipment body th4roughout the equipment as if it were a line conductor. However, Annex NAE (U.S. and Canadian regulatory requirements) notes that units having receptacles for the output of AC power which are generated from an internal separately derived source shall have the grounded circuit conductor bonded to earth. This latter requirement is not a violation of 1.6.4 since the secondary "separately derived" supply is entirely isolated from ground, and bonding one of the secondary lines will not lead to ground loops. Refer to the NFPA 70-05 NEC Handbook reference for additional details.

1.52 On transmitting equipment, is a grounding stud provided that permits attachment of a portable shorting rod?

Transmitting equipment having high voltage circuits or capacitors that could retain hazardous charge under a single fault condition (bleeder resistor fails) has to be able to be discharged. If a shorting rod is not provided with the equipment, a ground stud should be provided to which a maintainer can attached a portable shorting rod.

- **MIL-HDBK-454A -** Guideline 1, par 4.5.5.2 states that shorting rods should be provided with all transmitting equipment where voltages are in excess of 70V. Where size does not permit storage of a shorting rod, a grounding stud should be provided to permit attachment of a portable shorting rod.

1.53 Is a ground stud provided on equipment intended to be interconnected to remote systems via long lengths of signal cables?

Portable equipment interconnected to other system via long lengths of signal line may have large surges induced due to EMP or nearby lightning strikes. Typically, remote equipment will have no surge protection provided in the line other than that designed into the equipment itself. As a result, the equipment enclosure will become energized during an event. To prevent the operator from becoming the discharge path to ground for the surge, it is recommended to have the equipment bonded to a suitable ground. It is not the intent of this requirement to make the operator carry and install ground rods with all remote, portable equipment. Rather, if weather is threatening (lightning possible) and mission permits, the operator can interconnect the equipment (via the ground lug) to any grounding system that may be locally available (grounded shelter, water pipe, steel structure, etc), eliminating unnecessary hazard exposure.

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The grounding lug should be selected so that it can be used with typical grounding straps and grounding wires, etc.

- **NFPA 70-05 –** Article 800.100 discusses grounding requirements for shielded cables and surge protective devices used with communications circuits.
- **UL 1950 -** section 6.4 requires that systems interconnected with telecommunication lines withstand 10 impulses of a 2500 volt test surge with no resulting hazard to the operator. The test voltage is based on the assumption that the system will be installed on telecommunication lines where adequate transient surge protection has already been provided by the authorities (par 6.1, note 1). This, however, may not be the case for military applications. For most transportable military systems, a grounding system would have to be installed once the system is set up.

1.54 Has a test been conducted to verify that the equipment (as well as equipment systems) allows less than 5 Measurement Indication Units (MIU) of residual leakage current to flow to ground under the most adverse conditions of input voltage/frequency (3.5 MIU if the system can be powered from GFCI protected circuits)?

Leakage Current is the residual electrical current that passes over or through conductive parts and ground; parts that normally are not intended to carry current. All electrical equipment produces leakage current. When equipment is properly grounded, equipment LC is dissipated to ground and/or the power source and does not present a hazard to personnel. However, accessible equipment surfaces may become energized should the grounding path open.

Current levels as low as a few microamperes can be sensed under certain conditions. Various studies have determined that at 0.5 mA, most people can perceive the current, but are not likely to have a startle reaction. For cases where a startle reaction only results in an involuntary muscle reaction and does not lead to an accident or increased injury, then the next threshold of concern is the ability to let-go of an energized part (5.0 mA rms). Where products may be used in a wet or damp environment and therefore could be plugged into a GFCI, leakage current levels must be less than 3.5 mA to avoid nuisance tripping.

Frequency has an impact on the above identified current limits. As frequency increases, the human body becomes less sensitive to LC and hence, current thresholds for perception, startle reaction, and let-go also rise. Safety standards have established an upper threshold limit of 70 mA to prevent small touch-area burns. It's important to note that the 50/60 Hz region is the worst-case frequency range from a physiological response standpoint.

The LC test is carried out using a resistor/capacitor network that represents the body's impedance as well as the body's sensitivity to current frequency. Since this frequency sensitive network reduces the actual leakage current measurement at higher frequencies, the term Measurement Indication Units (MIU) is used. At 60 Hz, 0.5 mA of LC corresponds with 0.5 MIU. At 100 kHz however, a 70 mA sine wave will indicate 0.5 MIU on the LC test meter. Hence, the correct term to use is MIU when recording a measurement or specifying a requirement independent of frequency.

Leakage current measurements should be taken with the equipment power switch on and off and through all modes of operation. If it is possible that the equipment could be powered from a source with reverse polarity, measurements should also be taken under this condition.

Certain UL standards require a leakage current test only if measured voltages for accessible surfaces exceed 42.4 V peak. These standards cover products where leakage current is typically due to complex electronics located in a low voltage secondary circuit or power supply. For most products however, sources of leakage current are components located in the 120/240 V supply circuit (i.e. motors, filters, surge arrestors, transformers, heaters, and the like). For this reason, the LC requirement must be met independent of whatever the measured voltage of the accessible component is.

- **ANSI C101.1 –** The procedure for leakage current testing is specified in detail for typical household

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and similar appliances rated 20 A or less. However, a pass/fail criterion of 0.5 mA is specified for portable appliances (0.75 for stationary/fixed appliances).

- **UL 1950 –** section 5.2 outlines the procedure. Par 5.2.2 contains a 3.5 mA pass/fail criterion, as well as additional requirements if LC criteria are not met (see UL 60950 below).
- **UL 60950 –** section 5.1 addresses requirements for touch current and protective conductor current. Touch current is defined as the current through a human body when it touches accessible parts. Protective conductor current is the current flowing through the protective earthing conductor under normal operating conditions. Touch current is measured through an impedance network and shall not exceed 3.5 mA. However, equipment that's stationary and permanently wired or connected with an industrial plug (grounding connection has higher reliability), the leakage current can be up to 5% of rated equipment load current. The protective conductor current is measured using an ammeter without an impedance network.
- **UL 1795 -** The Standard for Hydromassage Bathtubs contains stringent electrical shock requirements since personnel are immersed in water; the individual has a huge surface contact to ground. Requirements do not specify a voltage, but rather state that the current between any two parts accessible to the tub occupant shall not exceed 0.5 mA as measured through a 500 ohm resistor.
- **MIL-HDBK-454A -** guideline 1, par 4.5.2.5 states the equipment leakage current should not exceed 3.5 mA.

1.55 Where equipment has excessive leakage current, are redundant EGCs provided?

Most product standards do not require a leakage current test for equipment that is stationary or hard-wired in place. For such systems, the grounding path is considered to be highly reliable and the possibility of shock due to a disconnected ground is far less. However, for cord-connected equipment where the hazard probability is greater, redundancy is necessary to prevent a shock hazard.

All attempts must be made to limit leakage current to less than 3.5 mA for transportable electronics equipment that may be used in outdoor, damp or unprotected environments. Soldiers would be more susceptible to shock risk in these environments, and the repetitive setup and teardown of equipment increases the risk of damage to the grounding path. Furthermore, products used in these environments will most likely be plugged into a GFCI, which would trip if leakage current levels exceed 3.5 mA.

- **UL 1950 –** Par 5.2.5 Leakage current is permitted to exceed 3.5 mA and up to 5% of total system input current if the equipment is stationary, and either permanently connected or connected via industrial plugs. Such grounding connections are considered to be extremely reliable, which justify loosening of the requirements.
- **UL 60950 –** Par. 5.1.7 permits equipment that's stationary and permanently wired or connected with an industrial plug (grounding connection has higher reliability) to have leakage current up to 5% of rated equipment load current. The protective conductor current is measured using an ammeter without an impedance network.
- **MIL-HDBK-454A -** guideline 1, par 4.5.2.5 states that when excessive leakage current is present, redundant grounding or double insulation methods should be incorporated.

1.56 Is a means provided so that power can be cut off while installing, replacing, or servicing a complete system or any Line Replaceable Unit (LRU)?

A disconnect that isolates the equipment from hazardous voltages is required to protect maintainers. Examples of acceptable disconnecting means are: 1) circuit breakers on a control panel (readily accessible),

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2) separable cord and attachment plug which is readily accessible, and 3) the main power switch on the equipment.

Not all switches are considered an acceptable means of disconnection. If an equipment main power switch is provided for this purpose, it must: 1) have a contact separation of at least 3 mm, 2) be connected as closely as possible to the incoming supply, 3) open all phase and neutral conductors (neutral disconnection not necessary if it is possible to rely on an identified, grounded neutral at the supply source), and 4) marked suitably. Main disconnect switches must be able to safely interrupt the short circuit current available from the supply (as much as thousands of amps). Many products provide "functional" (equipment on-off) switches that do not meet the above.

Note that if the equipment is provided with other suitable means of disconnection, the "functional" power switch does not have to comply with the above "main power "switch requirements.

If a power cord will be relied upon as the main disconnecting means, it must be accessible with the equipment installed.

- **NFPA 70-05 –** Articles 210.10, 225.31 (outside branch circuits), 230.70 (services) 422.30 (appliances), 430.74 (motors) and other articles apply. Also see article 110.9 regarding interrupting ratings. Article 422.33 notes that where a separable plug is used as the disconnecting means, it must be accessible.
- **UL 1950 -** Section 2.6 addresses various means of disconnection from primary power.
- **UL 60950 –** Section 3.4 applies.
- **UL 891 -** section 16 applies.
- **MIL-HDBK-454A -** Guideline 1, par 4.5.1 requires that a disconnecting means be provided so that the equipment can be deenergized during maintenance/replacement of components.

1.57 If a main power switch is provided, does it cut off all power to the complete system?

The main power switch often serves two safety-related functions: isolate the equipment during maintenance, and provide a means to deenergize the equipment in an emergency. In the latter case, it is important that the main power switch also deactivate any UPS provided output. System designers make take issue with this, stating the UPS must continue powering a system in the event the main circuit breaker (often the main switch) trips due to a power surge. As an alternative, a separate switch can be incorporated to readily deactivate UPS output power in an emergency (electric shock or fire). Where equipment has multiple power sources or switches, clear instructions must be provided that identify how to remove all power from the system.

The disconnect must cut off all power to the system. If it is possible that power polarity can be reversed (non polarized plugs used), then both the phase and grounded (neutral) conductors need to be disconnected.

Where equipment incorporates a backup power source (UPS) that provides over 750 VA, consideration should be given to incorporating a means for connection to a remote emergency power off circuit that disconnects the battery power source.

- **NFPA 70-05 –** Article 230.70 requires a means to disconnect all conductors in a building from service-entrance conductors. Article 240.20 requires circuit breakers to open all ungrounded conductors of the circuit (with certain exceptions). Article 422.30 requires a means of disconnection be provided for appliances. Article 550.11 addresses disconnecting means for mobile homes. Article 551.45(C) addresses mobile recreation vehicles. Article 645-10 addresses disconnecting means for equipment in an Information Technology Rooms. Article 645-11 further requires that the output power of an UPS that's installed in an information technology room also be interrupted when the main disconnect means is activated. This is not required if the UPS is integral to the electronics

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equipment (not powering wall receptacles - see article 645-15) and is limited to 750 VA output. The NEC does not consider this power level to be a fire hazard, and therefore, includes the exception. However, the possibility of electric shock must be considered where maintenance is conducted within shelters, where many accessible surfaces are grounded, where the UPS powers a number of equipments, where quarters are tight, and so forth. In such cases, the main disconnect should also interrupt the UPS output.

- **UL 60950 –** sections 3.4.6 and 3.4.7 address disconnect requirements for single and three phase equipment. Sections 3.4.10 and 3.4.11 address interconnected equipment and equipment powered by multiple power sources. Par 1.7.9 states where there is more than one connection supplying hazardous voltage or energy levels, a prominent marking shall describe how to deenergize the entire equipment and which switch controls which part.

  Annex NAE (U.S and Canadian regulatory requirements) clause 3.4.10 states that for computer room applications, batteries integral to equipment shall incorporate a means for battery disconnect and a means for connection to the remote emergency power off circuit that disconnects the battery power source where it exceeds 750 VA (with exceptions).

- **UL 1950 -** sections 2.6.6 and 2.6.7 address disconnect requirements for single and three phase equipment. Sections 2.6.11 and 2.6.12 address interconnected equipment and equipment powered by multiple power sources. Guidance includes a prominent marking near the disconnect that provides adequate instructions for removal of all power from the system (also covered in 1.7.9). Annex NAE, clause 2.6.11 contains guidance on internal backup power (see UL 60950 above).

- **UL 1778 –** Par. 2.1.103 states that a battery supply for an UPS provided with a marking indicating that it is suitable for use in a computer room shall incorporate a battery disconnect and a means for connection to the remote emergency power off circuit that disconnects the battery power source.

- **UL 891 -** section 16 applies.

- **MIL-HDBK-454A -** Guideline 1, par 4.5.1 states that if a main power switch is provided, it should cut off all power to the equipment. Equipment that uses an UPS should have provisions to isolate the supply from the equipment.

1.58 Is the switch located on the front panel and clearly identified?

The main power switch must be in a readily accessible location and clearly identified. For shelters, it is important to keep the main power switch near the exit/entry so that a person outside of the shelter could deactivate power during an emergency without having to enter the shelter. For cases where equipment has multiple power sources, clear instructions must be provided that identify how to remove all power from the system.

- **NFPA 70-05 –** Article 230.77 states the service disconnecting means shall plainly indicate whether it is in the open or closed position. Article 422, part III for Appliances requires a disconnecting means that is identified and accessible. This can be carried out through a main equipment power switch, breakers on a power panel or by unplugging an appliance. Product Safety Standards will provide more details and requirements. Article 550.11(A) covering mobile homes requires a single disconnecting means be provided that is plainly marked “Main”. Article 645.10 covering information technology equipment rooms requires the disconnecting means to be located at principle exit doors.

- **UL 1950 -** par 2.6.8 requires switches used as the disconnect to be marked. Though this paragraph does not specifically state that the power switch be located on the front panel, Section 1.7.2 addresses the need for the disconnecting means to be accessible once equipment is installed.

- **UL 60950 –** Paragraphs 3.4.2 and 3.4.8 apply. Section 1.7.2 addresses the need for the disconnecting means to be accessible once equipment is installed.

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- **MIL-HDBK-454A -** Guideline 1, par 4.5.1 states that if a main power switch is provided, is should be clearly labeled.

1.59 Are power and control switches selected and located to prevent accidental actuation or stopping of the equipment?

Such a requirement would apply in situations where unintentional actuation of a switch could cause an unacceptable hazard. Consider how the equipment may be installed: location in an egress path where it can be snagged or hit by a foot.

- **UL 73 –** par 33.4 states that if unintentional operation of a switch can result in a risk of injury to persons, the actuator of the switch shall be located or guarded so that operation is unlikely.
- **MIL-HDBK-454A –** Guideline 1, par 4.7.2 states that power switches should be selected and located so that accidental contact by personnel will not operate the switch.
- **29 CFR 1910 -** Subpart O contains sections such as 1910.217(b)(8) that require disconnect switches that can be locked in the Off position, as well as protection against accidental operation of the motor start button.

1.60 Are switches provided to deactivate mechanical drive units without disconnecting other parts of the equipment?

A means should be provided to permit deactivation of moving parts without having to deenergize the entire system. Otherwise, users may not deenergize the equipment and may expose themselves to potential hazards. For example, camouflage netting may have to be erected over a system having a moving antenna dish. If personnel need to stand near the dish during this process, the user should be able to deactivate the antenna drive & RF without having to take down and restart the whole system.

- **NFPA 70-05 -** Articles 430.87 and 430.102 provide some guidance for motor controllers and disconnecting means. Typically, each motor should be supplied through a separate controller/disconnect, with exceptions such as where a number of motors serve a single machine, etc.
- **MIL-HDBK-454A -** Guideline 1, par 4.5.4.3 recommends the use of switches that can deactivate mechanical drive units without disconnecting other parts of equipment.

1.61 Are power/maintenance switches provided at equipment which can be powered or controlled remotely?

Equipment having potentially hazardous conditions and capable of being operated remotely shall be provided with a reliable lockout means at the remoted equipment to prevent accidental remote operation during maintenance. Any energized parts to the supply side of the interlock that could be accessed during the maintenance procedure should be protected against accidental contact.

- **NFPA 70-05 -** For motors, 430.102 addresses disconnecting means, which have to be within sight of the motor (with exceptions). Many other products such as hydro-massage tubs, pools, HVAC systems, etc require disconnects at the remoted locations.
- **MIL-HDBK-454A -** Guideline 1, par 4.5.4.3 states that remotely located units shall have provisions for non-overrideble safety switches to allow independent disconnection.

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- **29 CFR 1910 -** subpart O requirements for machinery and machine guarding can be referenced and applied.

1.62 Can lockout/tagout devices be applied to switches that are relied upon to deactivate power during maintenance?

Certain 29 CFR 1910 requirements, such as subpart O for Machinery and Machine guarding require the use of lockout tagout devices. Local unit standard operating procedures may also require the use of devices that can clip over circuit breakers, etc. in accordance with 29 CFR 1910.333. In those cases, any rubber boots over circuit breakers would hinder the application of lockout/tagout devices.

- **NFPA 70-05 -** article 422.31(B), 430.102 exception and 525.21address cases where remoted disconnects need to be lockable in the open position.
- **29 CFR 1910.147 –** addresses lockout/tagout requirements for the servicing and maintenance of machines and equipment in which the unexpected energization or start-up of the machines or equipment, or release of stored energy could cause injury to employees. Subpart 1910.147(c)(2)(iii) states that lockable energy isolating devices shall be installed with new machines and equipment or during major renovation/modification.
- **UL 891 –** par. 23.4.5 discusses provisions for locking the disconnect device in an open position for motor control circuits.

1.63 Is protection provided against accidental contact with the supply side of the main power switch?

Refer to question 1.6 for additional guidance.

- **NFPA 70-05 -** the general "guarding of live parts" requirement detailed in article 110.27 can be applied. Article 408.3(A) requires barriers in service switchboards so that service terminals are protected from inadvertent contact by persons or maintenance equipment while servicing load terminations. Article 408.3(D) addresses location of load-side terminals so that it is not necessary to reach across an uninsulated line bus to make connections.
- **UL 1950 -** par 2.6.4 states that the supply side of a disconnect that can remain energized shall be guarded against accidental contact.
- **UL 60950 –** Par. 3.4.4 applies.
- **UL 891 -** par 25.4.5 addresses protection of parts on the line-side of a service disconnect against inadvertent contact.
- **MIL-HDBK-454A -** Guideline 1, par 4.5.3.5 states the input side of the main power switch should be given physical protection against accidental contact.

1.64 Are emergency controls readily accessible and clearly identified?

Where required, emergency controls shall be readily accessible and clearly identified.

- **29 CFR 1910 –** subpart 1910.269(v)(11)(xi) addresses emergency stop buttons for conveyor systems and requires the emergency stop devices to be easily identifiable. Other sections of 29CFR1910 may contain guidance regarding safety controls based on the system configuration and intended use.

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- **MIL-STD-1472F -** par 5.1.2.3.8 states that emergency controls shall be located where they can be seen and reached without delay.
- **UL 1950 –** par 1.7.8.1 states indicators, switches, and other controls affecting safety shall be identified or located so as to indicate clearly which functions they control.
- **UL 60950 –** par 1.7.8.1 applies.

1.65 Where safety interlocks are used, is the interlock actuator recessed or otherwise protected against contact?

Contact actuators must be protected not only from accidental contact, but so that it isn't easy for users/maintainers to bypass, such as by inserting a finger.

- **UL 1950 -** par 2.8.3 states that the safety interlock shall be designed so that inadvertent reactivation of the hazard cannot occur when covers, guards, doors, etc are not in the closed position, to include access by a test finger.
- **UL 60950 –** par 2.8.3 applies.
- **UL 73 –** par 33.6 states that the actuator of an interlock switch shall be located so that unintentional operation is unlikely.

1.66 Are safety interlock circuits designed to be fail-safe?

Safety critical interlocks must be designed so that a failure in any component will not create a hazard for which protection is required. Alternatively, the circuit would have to be reliable enough to avoid failure for the life of the product. We have seen interlock systems implemented where activation of an interlock would send power to a control relay that would trip and deenergize power to the system. This is unacceptable since a failure in the interlock switch, circuit wire, power source, etc. would effectively defeat the interlock system. Such a circuit should be designed so that activation of the interlock would drop power to the control relay causing it to trip. The reliability numbers for the control relay would have to be considered.

- **NFPA 70-05 –** Article 430.73 addresses motor control circuits and the need to design/protect them so that they cannot be accidentally bypassed due to a fault.
- **UL1950 -** Article 2.8.4 requires that either the interlock be designed so that any probable failure mode will not create a hazard for which protection is required, or that an assessment of the interlocking means concludes that failure is not likely to occur for the life of the equipment. The latter may require special assessments and cycling tests (10,000 operations).
- **UL 60950 –** par 2.8.4 applies.
- **UL 73 –** par 26.4 states that where a guard, release, interlock, or the like are required, their adequacy shall be determined from an investigation of the complete appliance, its operational characteristics, and the likelihood of a risk of injury to persons resulting from a cause other than gross negligence.
- **MIL-HDBK-454A –** par 4.2. states the design and development of military electronic equipment should provide fail-safe features for safety of personnel during installation, operation, maintenance, and repair or interchanging of a complete equipment assembly or component parts thereof.

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1.67 Are live parts of safety interlocks protected from contact?

The concept and requirements for protecting the live parts of safety interlocks against accidental contact is addressed in questions1.6 and 1.63.

1.68 Where bypassable safety interlocks are used, do they automatically reset once the cover or guard is replaced?

Bypassable interlocks must automatically reset or otherwise be of such a design that normal operation of the system is prevented.

- **UL 1950 -** par 2.8.5 permits interlocks that can be bypassed by service personnel provided the interlock 1) requires an intentional effort to operate; 2) reset automatically to normal operation when servicing is complete or prevent normal operation unless service personnel have carried out restoration; 3) require a tool for operation when in operator access areas; and 4) not bypass a safety interlock for an extreme hazard unless other safety protection provided.
- **UL 60950 –** par 2.8.6 applies.
- **MIL-STD-1472F -** par 5.13.7.1.12 states that any interlock override should automatically reset when the cover or case is replaced.
- **MIL-HDBK-454A -** Guideline 1, par 4.5.4.1.b states that the bypass device should be designed so that closing the associated door, cover, or plate will automatically open the bypass device and leave the interlock in position to function normally.

1.69 Are battle short interlocks provided with an indicator to show when active?

The battle short switch should be clearly identified and protected against accidental contact. A toggle switch with a red flip-up cover is often used with generators. A red pilot light or other visual indicator that is visible from the operator location and an audible alarm should be used.

- **MIL-HDBK-454A -** Guideline 1, par 4.5.4.2 states that equipment with battle short circuitry should have an audio (with manual silencing and auto reset) and visual warning system. However, catastrophic fault interlocks should not be bypassed.

1.70 Is equipment that is designed to have multiple-input power capabilities, or powered by a generator with multiple-voltage output capabilities, protected from damage when connected to incorrect input power/voltage levels?

Equipment that can be powered from different power sources must be protected from damage when connected to incorrect input voltage levels, frequency or polarity. This is especially critical with systems have power cables that terminate in pigtails, which rely on a human element for correct power hookup. In this case, the protective means should be automatic. Relying upon an individual to check the voltage reading in a shelter or on a piece of equipment is not automatic, and has led to system damage. Circuitry that monitors for a voltage range and that does not close a power relay until the proper voltage is applied would be an automatic means.

- **NFPA 70-05 -** articles 406.7 requires that different configuration plugs be used for different supply circuits. Article 551.20 addresses combination electrical systems for recreation vehicles, where wiring and equipment must be rated and installed in compliance with both “voltage system” requirements.

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- **UL 1950 -** par 3.2.1 covers requirements to protect equipment that is provided with more than one supply connection
- **UL 60950 –** Par 3.2.2 applies.

1.71 Are overcurrent and/or overload protective devices provided for primary circuits?

Overcurrent, as defined by the NEC, is any current in excess of equipment or conductor rated ampacity as a result of overload, short circuit, and/or ground fault. Overload (a type of overcurrent condition) is defined as operation of equipment/conductors in excess of rated ampacity that, when it persists for a sufficient length of time, would cause damage or dangerous overheating. This is typically associated with motor circuits where a heavy load may be causing a motor to draw more that it's rated current. Having too many products plugged into a receptacle can also overload the receptacle and branch circuit feeding it. A fault, such as a short circuit or ground fault, is not considered an overload.

The NEC addresses both overcurrent and overload protection. In some cases such as with motors, two separate protective devices may be required, whereas a receptacle can be adequately protected by a circuit breaker for both conditions.

Overcurrent protective devices are marked with both a load rating and an interrupt rating. The load rating (15, 20, 30 amps, etc) is the value at which the device will operate indefinitely. Once the current is increase above the load rating, the device will open within a certain time period (for circuit breakers rated less than 30 amps: at 135% of rating - within 1 hour, at 200% of rating - within 2 minutes).

The interrupt rating is the amount of current that the protective device can safely interrupt, and must therefore be greater than the short circuit current available from the power source. Otherwise, a protective device with an inadequate interrupt rating could rupture while attempting to clear a fault (for example, UL research has shown that for a typical residential outlet, up to 1000 Amps could instantly flow during a direct short. The circuit breaker would have to be able to interrupt such a current without sustaining damage). Use of special "Current Limiting Overcurrent Protective Devices" are required where the available supply short circuit current exceeds the interrupt rating of the protective device, or where it exceeds the short-circuit withstand rating (level before damage occurs in equipment/components) of the attached components (see NFPA 70-05 Handbook, articles 110.10 and 240.2). Listed "Molded-Case Circuit Breakers" have a minimum interrupt rating of 5000 amperes. General purpose or supplementary circuit breakers and fuses located within equipment typically do not have a suitable interrupt rating, and therefore require suitable branch circuit protection be provided on the supply side.

Motor overload protectors are provided with adjustable controls set to trip between 115% and 170% of the motor nameplate full load current rating (see NFPA 70-05, article 430, part III for specifics). Overload protective devices used for motors typically do not have an adequate interrupt rating against short circuits or ground faults, and therefore must also have overcurrent protection (fuses, circuit breakers) located ahead in the supply line.

Not all products require overcurrent or overload protection. Many products connected to 15 or 20 A receptacles rely upon the branch circuit breakers for protection. This is acceptable provided any single internal fault to the equipment will not cause excessive equipment damage or initiate a fire before the branch circuit breaker can open.

Note that a GFCI is not a form of overcurrent or overload device. GFCI's still require proper overload and overcurrent protection.

Circuit breakers and fusing must be adequately labeled at the power panel to identify which equipment they protect.

- **NFPA 70-05 -** articles 110.9 & 10 provide general requirements. Article 210.20 addresses requirements for branch circuits. Article 215.3 addresses requirements for feeders. Article 230 part

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VII addresses requirements for services. Article 240 provides general requirements for overcurrent and overload protection. Article 430 addresses overload and overcurrent protection requirements for motors. Article 408.4 requires a circuit directory on the face or inside of a panel board or at each switch on a switchboard.

- **UL 1950 -** section 2.7 provides general requirements for overcurrent protection.
- **UL 60950 –** section 2.7 applies.

1.72 If overcurrent protective devices are provided in series with any conductor grounded at the power source, does this device simultaneously open all other load conductors in the circuit?

Overcurrent protective devices are permitted to be installed in the grounded conductor (neutral) provided any fault will simultaneously open the neutral and all phase conductors. This is typically done through the use of multipole circuit breakers with the individual actuating members ganged together. Overcurrent protective devices shall not be placed in the grounding circuit.

- **NFPA 70-05 -** articles 240.22 applies as discussed above.
- **UL 1950 -** section 2.7.4 states that if a protective device interrupts the neutral conductor, it shall also interrupt all other supply conductors.
- **UL 60950 –** par 2.7.4 states that if a protective device interrupts the neutral conductor, it shall also interrupt all other supply conductors. Par 2.6.5.2 states protective earthing and bonding conductors shall not contain switches or overcurrent protective devices.

1.73 Are multi-pole circuit breakers provided for multi-phase circuitry which will open all phases during a fault in any one?

Maintainers need to be protected from the case where they may deenergize a breaker and not realize that the equipment is still energized through another breaker. This applied not only to equipment, but also receptacles or devices on the same yoke that could be powered by two separate circuits. For instance, duplex receptacles are designed so that each receptacle can be powered independently. In this case, the two breakers supplying the duplex receptacle would have to have a handle tie installed.

- **NFPA 70-05 -** article 210.4(B) & (C) requires that a multiwire branch circuit supplying more than one device or equipment on the same yoke be provided with a means to disconnect simultaneously all ungrounded conductors at the panelboard where the branch circuit originates. Article 240.20(B) requires multipole breakers or single pole breakers with approved handle ties for line-to-line loads and multiwire branch circuits.
- **UL 1950 -** par 2.7.4 applies.
- **UL 60950 –** par 2.7.4 applies.
- **MIL-HDBK-454A -** Guideline 8, par 4.1.3 states that multipole circuit breakers should be used for three-phase equipment and should disconnect all phases if an overload occurs in any one phase.

1.74 If circuit breakers are used to power up/down equipment, have they specifically been designed for this purpose?

This question originates from the MIL-HDBK-454A guidance. However, the NEC does permit use of a circuit breaker as a switch with certain provisions and limitations. The key is to ensure that the type of load that the

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switch controls (motor load, lighting ballast load, etc.) will not prematurely damage the circuit breaker contacts due to repetitive switching.

- **NFPA 70-05 -** Article 404.11 states that a hand-operable circuit breaker equipped with a lever or handle, or a power operated circuit breaker capable of being opened by hand in the event of a power failure, shall be permitted to serve as a switch if it has the required number of handles. Article 240.81 requires circuit breakers to clearly indicate whether they are in the open or closed position. Articles 240.83 states that if a circuit breaker is used as a switch for 120 V or 277 V fluorescent lighting circuits, it shall be listed and marked with SWD or HID.
- **MIL-HDBK-454A -** Guideline 8, par 4.1.3 states that circuit breakers should not be used as switches unless such circuit breakers have been specifically designed and tested for that type of service.

1.75 Do circuit breakers provide a visual indication when tripped?

- **MIL-HDBK-454A -** Guideline 8, par 4.1.3 states that circuit breakers should give a visual indication when tripped.
- **UL 489 –** Section 9.1 addresses markings for molded case circuit breakers.
- **MIL-STD-1472F –** Par 5.9.17.2.1 states a positive indication shall be provided to reveal that a fuse or circuit breaker has opened a circuit.

1.76 Can fuses be removed safely (no exposed live parts) and without the use of tools?

Refer to question 1.6 and 1.63 for additional guidance.

- **NFPA 70-05 -** article 110.27 guarding of live parts can be referenced. Article 240.40 requires a disconnecting means for fuses where accessible to other than qualified persons.
- **UL 891 -** par 8.2.20 states if a live part can be exposed to possible contact during fuse replacement, a barrier shall be provided to prevent such contact. 17.2.12 provides additional guidance.
- **UL 1950 -** par 2.1.4 states that hazardous voltages shall be protected or located so that unintentional contact is avoided while servicing other parts.
- **UL 60950 –** Par 2.1 applies.
- **MIL-HDBK-454A -** Guideline 8, par 4.1.2 states that panel-mounted fuse posts should be such as to permit renewal of fuses without use of tools.

1.77 Are fuse replacement types and ratings labeled?

Ensure any special fusing characteristics are also labeled, such as slow-blow, etc.

Where multiple fuses or circuit breakers are collocated such as at a power panel, the equipment/circuit they are protecting must also be identified.

- **NFPA 70-05 -** article 240.50 addresses marking requirements for plug fuses, fuseholders, and adapters. Article 408.4 requires a circuit directory on the face or inside of a panel board or at each switch on a switchboard.
- **UL 1950 -** par 1.7.6 states that markings shall be located on, or adjacent to, each fuseholder giving the fuse rated current, where fuses of different rated voltage value could be fitted, the voltage rating. Any special fusing characteristics such as time delay shall also be identified.

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- **UL 60950 –** par 1.7.6 applies.
- **MIL-HDBK-454A -** Guideline 67, par 4.6 states the current rating of fuses should be marked adjacent to the fuseholder.

1.78 Is surge protection incorporated to protect the user and the equipment?

- **NFPA 70-05 –** articles 280 and 285 addresses general requirements for the installation of surge protection, but do not actually require the use of these devices. Articles 800.30, 810.20, 810.57 and 830.30 address requirements for communications circuits.
- **UL 1950 –** section 6 addresses design and testing requirements to protect against surges coming across telecommunications lines.
- **UL 60950 –** Section 6 addresses design and testing requirements to protect against surges coming across telecommunications lines.

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♦ **ENCLOSURES AND GUARDS** ♦

2.1 Are equipment enclosures suitably designed to protect the equipment and personnel when considering the anticipated environment and rough handling.

Equipment must be rugged enough to withstand the worst-case environment that it could reasonably experience. Any damage to the enclosure must not expose hazardous parts. Panels must not bend so that they contact and short internal energized parts. Pay special attention to panel meters and glass or plastic parts that may serve as part of the enclosure. Consider how panels and frame members are fastened and whether they can loosen or break.

For equipment being evaluated as a standalone system (i.e. not installed in a shelter, vehicle, etc), consider the types of environments it may be reasonably exposed to. Will it be used in an office environment? Is it handheld and can it be dropped? Will it be exposed to the elements? This information can be obtained from the system Operational Requirements Document and other mission profile documentation, discussions with user representatives, or a review of similar equipment.

If the equipment is being evaluated as installed, consider how it can be damaged. Is equipment is mounted near the floor or in egress pathways where soldiers could step on it? Can the equipment be used as a handhold? Could duffle bags and other materials be stored near or on the equipment, leading to damage or overheating? Can heavy equipment be rolled into the enclosure?

Enclosures made of molded plastic materials can warp or distort with age and/or if exposed to heat, depending on the specific material used as well as the way it is molded. Analysis or accelerated aging tests may be required to ensure the enclosure won't crack or warp in a way that will expose hazardous parts.

- **NFPA 70-05 –** article 110.27(B) states that where equipment is likely to be exposed to physical damage, enclosures or guards shall be s arranged and of such strength as to prevent damage.
- **UL 1950 –** Par 4.2.1 states that enclosures shall have adequate mechanical strength and shall be so constructed as to withstand such rough handling as may be expected in normal use. Section 4.2 goes on to specify different types of test to verify this requirement, such as drop tests, enclosure force tests, etc.
- **UL 60950 –** Par 4.2 applies.
- **MIL-STD-1472F –** Par 4.9 states systems and equipment shall be sufficiently rugged to withstand handling in the field during operation, maintenance, supply, and transport within the environmental limits specified for those conditions in the applicable hardware or system specification.
- **UL 73 –** Par 7.1 states that an appliance shall be formed and assembled so that it will have the strength and rigidity necessary to resist the abuses to which it is likely to be subjected, without increasing the risk of fire, electric shock or injury to persons due to total or partial collapse with resulting reduction of spacings, loosening or displacement of parts, or other serious defects.

2.2 Are equipment openings and vents sized and located to prevent access to hazardous parts, as well as to prevent objects from falling inside and contacting hazardous parts?

Equipment openings must prevent access to hazardous parts. A test finger complying with UL and IEC standards can be used to verify compliance. Vents must also be designed and sized so that objects (tools, coins, paper clips) cannot fall inside of the product and contact hazardous parts. This is especially important for products that can be used/held in any orientation.

Where products are provided with keyhole slots, notches, etc. for hanging on a wall or other product, it shall be designed to protect the securing hardware (bolt, hook, etc) from contact with hazardous parts.

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- **UL 60950 –** Par. 4.6.1 addresses design of openings. Par 4.6 states that equipment that can be used in more than one orientation shall be evaluated in those orientations. Paragraph 4.6.4 addresses additional requirements for transportable equipment, defined as equipment that is routinely carried by a user. Such equipment must minimize risk of ignition caused by small metallic objects, such as paper clips, moving around inside.
- **UL 1950 –** Par 4.3.15 and 4.3.16 address opening designs to prevent operator access to hazardous parts and to prevent entry of a falling object into the equipment.
- **MIL-STD-1472F –** Par 5.9.8.3 states where covers require vent holes, the vent holes shall be small enough to prevent inadvertent insertion of objects that might touch high voltage sources or moving parts.
- **UL 73 –** Section 11 addresses access of uninsulated live parts, and specified the dimensions for openings as well as testing with an IEC finger probe. Par 7.14 states an opening in the appliance provided for hanging shall be located or guarded so that a nail, hook, or the like does not contact hazardous parts or displace a part that would create a risk of fire or shock.

2.3 Are fasteners and methods of securing doors and peripheral components sufficiently strong to prevent breakaway during normal use?

This applies to both to fasteners that keep the equipment together, as well as fasteners that mount the equipment to other surfaces. In the case of power distribution equipment, conduit and splice boxes must be properly secured at the required intervals. Fasteners that could be exposed to moisture or other chemicals should be able to resist corrosion that could lead to failure.

Adhesives may be used to secure parts but must be suitable for the environment, temperature, and able to withstand mechanical impact without breaking. Consider whether brittle materials such as certain epoxies may break when subjected to shock. Wire fasteners that are secured with double-sided adhesive tape have a history of failure and are not recommended.

- **NFPA 70-05 –** article 300.11 states raceways, cable assemblies, boxes, cabinets, and fittings shall be securely fastened in place. Articles covering specific equipment and applications contain additional guidance.
- **UL 60950 –** Par. 4.2.1 states that enclosures shall have adequate mechanical strength and shall be so constructed as to withstand such rough handling as may be expected in normal use. Par 4.2.10 states the mounting means of equipment intended for wall or ceiling mounting shall be adequate.
- **UL 1950 –** Par. 4.2.1 applies.
- **UL 73 –** Par 7.1 states that an appliance shall be formed and assembled so that it will have the strength and rigidity necessary to resist the abuses to which it is likely to be subjected. Chapter 8 addresses the used of adhesives to secure parts. Chapter 10 addresses protection against corrosion.

2.4 Are snag hazards due to exposed gears, cams, fans, belts, guy wires, and other moving parts avoided?

Personnel must be protected from sharp and moving parts. Consider whether an individual needs to interact with the moving part or may just be exposed to accidental contact. Can the moving part snag clothing? Emergency stop switches may be required where a person can be snagged and pulled into equipment.

Interlocks may be required where guards can be removed for maintenance and adjustment. If interlocks are provided, they must be able to eliminate the hazard within a couple of seconds. In the case of rotating parts, a braking system may be required.

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- **UL 60950 –** Par. 4.4.1 states hazardous moving parts of equipment shall be so arranged, enclosed, or guarded as to provide adequate protection against risk of personal injury. Par. 4.4.2 – 4.4.4 contain additional guidance for operator and maintainer protection.
- **UL 1950 –** Par 4.1.2 applies.
- **MIL-STD-1472F –** Par 5.13.7.2.1 states a guard will be placed on all moving parts of machinery and transmission equipment on which personnel may become injured or entangled.
- **MIL-HDBK-454A** – Guideline 1, par 4.7 states suitable protection should be provided to prevent contact with moving mechanical parts.
- **29 CFR 1910 –** Subpart O addresses machine guarding requirements. 1910.212 provides general requirements for protection against nip points, rotating parts, flying chips, etc.
- **UL 73 –** Par 28.1 states the rotor of a motor, a pulley, belt, etc shall be enclosed or provided with other means of reducing the likelihood of unintentional contact.

2.5 Does the equipment enclosure material and any enclosure openings limit fire propagation?

The enclosure material must be able to limit the spread of fire. Typically, stationary or permanent equipment have more stringent requirements since they cannot be readily removed from the area. Plastic materials must meet certain flame-spread requirements as specified in end product standards. Plastic materials are evaluated and classified IAW UL 94 Standard for Flammability of Plastic Materials.

Equipment openings and vents must also limit the spread of flame. Openings in the bottom of products are of greatest concern, and must not permit molten or flaming material to fall onto combustible surfaces.

- **UL 60950 –** Sections 4.6 & 4.7 address the reduction of risk of ignition and spread of flame. Par 4.6.2 addresses design considerations to prevent material that could be emitted under fault conditions and that could ignite supporting surfaces.
- **UL 1950 –** Par 4.1.2 applies.
- **MIL-HDBK-454A** – Guideline 3, par 4.1 states materials used in military equipment should, in the end item configuration, be noncombustible or fire retardant in the most hazardous conditions of atmosphere, pressure, and temperature to be expected in the application.
- **UL 73 –** Par 7.7 provides guidance on design of equipment to prevent molten or burning material from falling onto combustible surfaces.

2.6 Are switches and other electrical components adequately protected against water entry due to rain or equipment washdown?

The NEC identifies three location categories: dry, damp, and wet. Dry locations are those not normally subject to dampness or wetness. Damp locations are those that are partially protected such as porches, basements, etc. Wet locations are those that are exposed to the elements or saturation. NEMA standard 250 further defines enclosure type designation for various levels of protection ranging from indoor installations to protection against windblown rain.

Consider how the product will be exposure to water: light moisture, wind swept rain, washdown, immersion, etc. Wiring and insulation must not get wet. Consider accumulation of water if drain holes not provided. Application of any rubber boots over circuit breakers or switch handles must not interfere with the ability to apply lock-out devices to designated disconnects (see question 1.62).

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- **NFPA 70-05 –** article 110.11 states no conductors or equipment shall be located in damp or wet locations unless identified for use in such environments. Article 225.22 states raceways in exterior surfaces of buildings shall be raintight and arranged to drain (i.e. prevent water accumulation at low points). Article 312.2 states that in damp or wet locations, surface type enclosures shall prevent water from entering and accumulating within the enclosure.
  Article 406.8(B) requires 15 and 20 amp outdoor receptacles installed in a wet location shall have an enclosure that is weatherproof whether or not an attachment plug cap is inserted.
- **UL 60950 –** Annex T addresses guidance on protection against ingress of water. Water should not contact insulation that is not designed to operate when wet. If the equipment has no drain holes, account should be taken of the possibility of build-up of water. Equipment with drain holes must be designed so any water that enters will not accumulate. Additional guidance and testing requirements are listed.
- **UL 1950 –** Annex T applies.
- **UL 891 –** Par 8.7 addresses requirements for Type 3R (rainproof) enclosures to prevent water entry. A spray test for the assembled product is specified in par 35.1 – 35.6. Par 8.7.1 states that a switch, circuit breaker, receptacle (complete with its associated attachment plug), fuseholder, or similar device, as well as any opening associated with an operating handle, shall be shielded from rain.

2.7 Is the equipment designed to provide personnel adequate and safe access (free of obstructions) during installation, operation, and maintenance?

Personnel must have adequate working space to permit safe equipment operation and maintenance. Where more than one person is required to remove or install equipment, adequate space must be provided for the required number of persons.

- **NFPA 70-05 -** article 110.26 discusses requirements to ensure that sufficient access and working space is provided for safe equipment operation and maintenance.
- **UL 60950 -** par 2.1.2 states that hazardous voltages shall be protected or located so that unintentional contact is avoided while servicing other parts. In deciding whether a hazardous part can be unintentionally contacted, account has to be taken of how service personnel gain access past or near the part, the service procedure that's carried out, and tools involved.
- **UL 1950 –** par 2.1.4 applies.
- **MIL-STD-1472F –** Par 5.9.1.8 states equipment design shall provide the maintainer with complete visual and physical access during maintenance, insofar as possible. Par 5.13.5.2 states equipment items shall be so located and mounted that access to them can be achieved without danger to personnel from electrical, thermal, mechanical, chemical, radiological, or other hazards.
- **MIL-HDBK-454A** – Guideline 1, par 4.7 states the design of equipment should provide personnel maximum access and safety while installing, operating, and maintaining the equipment. Guideline 36, par 4.4 provides additional guidance.

2.8 Are "no step" markings provided at necessary locations to prevent injury and equipment damage?

Consider surfaces that could be stepped on outside of the typical system setup. For instance, a soldier may not need to climb on top of a generator during setup, but may stand on top of it while setting up camouflage netting or attaching a lift sling.

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- **MIL-STD-1472F –** Par 5.13.2.5 states NO-STEP marking shall be provided when necessary to prevent injury to personnel or damage to equipment.

♦ **STOPS, LIMITS AND INTERLOCKS** ♦

2.9 Are self-locking or other fail-safe devices incorporated into expandable and collapsible structures, such as shelters, jacks, masts, and tripods, to prevent accidental or inadvertent collapsing or falling?

Jacks and winches should have release mechanisms that release/lower the supported item in controlled increments. Release mechanisms should not result in "free-wheeling" or collapse where it could lead to injury or damage. A safe method of adjusting leveling devices must also exist where equipment could shift or sink in sand, mud, etc.

- **MIL-STD-1472F** - Par 5.9.12.7 states limit stops shall be provided on racks and drawers that are required to be pulled out of their installed positions. Rollout racks and drawers shall be self-locking in the retracted and extended positions. The limit stop design shall permit convenient overriding of stops for rack or drawer removal.

2.10 Are reliable stops/limits integrated to protect moving parts from damage due to over-extension or by being driven into fixed parts?

Jacks, winches, etc should have integrated limits to prevent failure or damage to equipment. In one case, a jack used to manually lower and stow an antenna incorporated no limit devices and resulted in system frame damage due to repetitive over-tightening. Limiting devices should also be incorporated where doors could open into equipment and cause damage. Consider how moving parts may interact with maintenance or storage doors in various positions. For instance, can a moving antenna dish tracking at a particular angle come in contact with transit case doors left in an open position?

- **MIL-STD-1472F –** Par 5.9.7.4 states guides, tracks, and stops shall be provided as necessary to facilitate handling and prevent damage to equipment or injury to personnel. Par 5.9.12.7 also states limit stops shall be provided on racks and drawers that are required to be pulled out of their installed positions.
- **MIL-HDBK-454A –** Par 4.7 states equipment design should include provisions to prevent accidental pulling out of drawers or rack mounted equipment. Doors or hinged covers shall be provided with stops to hold them open.

2.11 Where pins or latches are applied during equipment stowage, transportation or maintenance to secure moveable components (i.e. motorized antenna dish, etc.), is damage prevented if the pins are left in and the drive mechanism activated?

Maintenance lockout devices or pins may be recommended for use to prevent equipment motion. In there cases, operation of the equipment should not lead to system damage if the lockouts are accidentally left in place.

- **MIL-STD-1472F –** Par 4.5 states a fail safe design shall be provided in those areas where failure can cause catastrophe through damage to equipment, injury to personnel, or inadvertent operation of critical equipment.

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2.12 Are doors and drawers and associated hinges, supports, slides, and stops positively locked or otherwise secured to prevent unintended movement when in the open or closed position?

Rack mounted equipment installed on roller tracks should not pull out completely without a secondary action.

- **MIL-STD-1472F –** Par 5.9.9.2 states hinged access covers that are not completely removable shall be self-supporting in the open position.
- **MIL-HDBK-454A –** Guideline 1, par 4.7 states equipment should include provisions to prevent accidental pulling out of drawers or rack mounted equipment components.

♦ **PINCH POINTS AND SHARP EDGES** ♦

2.13 Are telescoping ladders and assemblies provided with adequate clearance between rungs/parts to prevent pinch points?

The key is to watch for potential pinch points that could occur during system setup or operation. Typical handhold locations should be considered when equipment is handled. In one case, a heavy table mounted on rollers posed a serious finger hazard due to the location that personnel placed their hands when lifting and pushing the table into the stowage position.

- **MIL-STD-1472F –** Par 5.13.7.2.2 states adequate finger clearance shall be provided between rungs of telescoping ladders.

2.14 Are hinged brackets and such devices designed and located so that fingers are not exposed to pinch points during adjustment?

Watch for potential pinch points that could occur during system setup or operation. Typical handhold locations should be considered when equipment is handled. Fold-out hinges used to limit equipment adjustment can act as scissors if improperly placed.

- **MIL-STD-1472F –** Par 5.9.10.5 addressing latches and catches can be referenced, which states the spring action or snap-down force shall not be strong that it could injure a maintainer. In addition, par 5.13.7.2.1 and 2 can be referenced.
- **UL 60950 -** par 4.4.2 states that protection will be provided by a suitable construction reducing the likelihood of access to hazardous moving parts. Though this paragraph is usually applied to hazards such as moving belts, gears, and cutters, other potential pinch points would also apply.

2.15 Are sharp corners, edges, and projections avoided?

When evaluating corner and edge sharpness, consider location of the part relative to setup, use, teardown, and maintenance. Evaluate egress paths for snag points. Most critical are edges and corners located at head and eye level. Greater injury can be sustained if physical exertion is required near the part in question (cranking a leaver near a support bar could be a "knuckle-buster"). Where systems must be operated in a NBC environment, ensure that sharp edges and snag point cannot pierce or tear MOPP gear.

- **UL 60950 –** Par 4.3.1 states edges or corners, except those required for proper equipment functioning, shall be rounded or smoothed when they could otherwise be hazardous to operators because of location or application in the equipment.
- **UL 1439** – This standard addresses a method for testing the sharpness of edges. A device is described which contains a spring loaded probe covered with three layers of special tape. The

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probe is moved across the edge to be tested, and then examined to determine of any penetration has occurred through the twp outer layers.

- **MIL-STD-1472F –** Par 5.13.5.4 states all exposed edges and corners shall be rounded. Dimensions for corners and edges are specified. Par 5.7.1.2 states handles on cabinets and consoldes should be recessed to eliminate projections on the surface, or otherwise configured and located to preclude injuring personnel or entangling their clothing or equipment.
- **MIL-HDBK-454A** – Guideline 1, par 4.7 states sharp projections on cabinets, doors, and similar parts should be avoided. Doors or hinged covers should be rounded at the corners and provided with stops to hold them open.

2.16 Is hand-held equipment designed without sharp edges or protrusions that could cause injury if hit or felled upon while carried in a pocket?

Hand-held equipment that may be carried in a pocket must have rounded and smooth surfaces without any significant projections. Otherwise, a soldier falling on top of the equipment may be injured by projecting knobs or connectors.

- **UL 60950 –** Par 4.3.1 states edges or corners, shall be rounded or smoothed when they could otherwise be hazardous to operators because of location.
- **MIL-STD-1472F –** Par 5.13.5.4 states all exposed edges and corners shall be rounded.
- **MIL-HDBK-454A -** Guideline 1, par 4.7 applies.

2.17 Is the installed equipment free of overhanging edges and corners that may cause injuries?

Consider for both operator and maintainer positions, as well as egress paths. Most critical are edges and corners located at head and eye level.

- **UL 60950 –** Par 4.3.1 states edges or corners, shall be rounded or smoothed when they could otherwise be hazardous to operators because of location.
- **UL 1950 –** Par 4.1.4 applies.
- **MIL-STD-1472F –** Par 5.13.5.4 states all exposed edges and corners shall be rounded.
- **MIL-HDBK-454A -** Guideline 1, par 4.7 applies.

2.18 Are door and cover edges not at eye level when in an open position?

Doors, especially those that swing open and are retained in an upward position, may not be as visible when open and could lead to significant injury.

- **UL 60950 –** Par 4.3.1 states edges or corners, shall be rounded or smoothed when they could otherwise be hazardous to operators because of location.
- **UL 1950 –** Par 4.1.4 applies.

♦ **HANDLING** ♦

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2.19 Is the equipment weight limited to permit safe handling by the anticipated user/maintainer crew size per the criteria below?

# Soldiers	Weight (lbs)
1	37
2	74
3	102
4	130

The above values are taken out of MIL-STD-1472 and are based on a 5 ft/shoulder height lift. Weight limits are doubled for two person lifting, and 75% of the one person lift limit is added for each person thereafter. If the most likely lift height will be a 3-ft/bench height lift (HMMWV cargo area), then 44 lbs may be used as the single person lift limit. Lift limits are also specified for Male-only populations where applicable.

MIL-STD-1472, par 1.4 provides the following exception: "if an item is to be used by an already established military occupational specialty (MOS), any discrepancy between the force criteria of this standard and the (MOS) physical qualification requirements will be resolved in favor of the latter. The least stringent physical qualification requirement of all specialties which may operate, maintain, transport, supply, move, lift or otherwise manipulate the item in the manner being considered, will be used as a maximum design force limit." Although many of the electronics maintenance MOS specify physical qualification requirements, some of these requirements have been relaxed. In addition, it is often not possible to ensure that only a particular MOS will transport, setup, carry, etc the equipment. For this reason, it is recommended to strive to comply to the criteria specified within MIL-STD-1472

- **MIL-STD-1472F –** Section 5.9.11.3 addresses lifting and carrying requirements. Details are also provided regarding handles, load size, load uniformity, carrying distances, etc.
- **MIL-HDBK-454A -** Guideline 36, par 4.1 states sizes and weights of replaceable assemblies should conform to MIL-STD-1472.
- **DHHS (NIOSH) 94-110 –** The NIOSH Applications Manual for the revised NIOSH Lifting Equation provides a method of identifying tasks that could lead to lower back injuries in workers. The lift equation takes into account the object's size, weight, the height of lift, the proximity to body, vertical distance moved, number of lifts, and other variables.

2.20 Is a caution label specifying weight and lifting requirements affixed to equipment exceeding the single soldier handling criteria?

Soldiers need to be warned of the potentially heavy equipment before trying to unload it by themselves. Where equipment weight requires a lift of other mechanical means of movement, weight should still be identified so that a properly rated lift device is selected.

- **MIL-STD-1472F –** Par 5.9.11.3.9 states that equipment exceeding the one person lift limit will be labeled with the equipment weight and the lift limitation (two-person lift, etc).

2.21 Are suitable carrying handles or hand grasp areas provided?

Handles must be durable enough so that they cannot break. Ensure adequate room is provided for hands wearing gloves.

- **UL 60950 –** Par 4.3.2 provides guidance on handles. A handle that supports more than 19 lbs must

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be capable of supporting more than 4 times the weight of the product without breakage.

- **UL 1950 –** Par 4.1.7 applies.
- **MIL-STD-1472F –** Par 5.9.11.5 addresses handle and grasp areas.

2.22 Does the equipment's size and weight distribution allow for easy handling, moving, and positioning?

Lifting requirements specified in question 2.19 assumes an evenly distributed load. Refer to MIL-STD-1472 for additional guidance.

- **MIL-STD-1472F –** Par 5.9.11.3 addresses various requirements for equipment size, weight distribution, lift and carrying limits, etc.
- **MIL-HDBK-454A -** Guideline 36, par 4.1 states sizes and weights of replaceable assemblies should conform to MIL-STD-1472.

2.23 Is the temperature of all exposed parts subject to momentary contact less than 60°C (140°F) for metal, 68°C (155°F) for glass, or 85°C (185°F) for plastic/wood at an ambient temperature of 25°C (77°F), regardless of the condition of operation?

These requirements are based on momentary contact values. Where extended contact is required such as handles, lower values specified in Questions 2.25 should be followed. Solar loading is often not considered for this requirement.

- **UL 60950 –** Par. 4.5.1, table "Part 2"provides maximum temperature rises that depend on the material of the part and its purpose. The criteria in this standard varies slightly from the values specified above. Separate requirements are identified for handles held continuously or for short periods, and requirements are specified for parts inside of equipment that may b e accessed. Ambient is assumed to be 25 deg C.
- **UL 1950 –** Table 16, part 2 applies.
- **MIL-STD-1472F –** Par 5.13.4.6 applies and specifies these temperatures.
- **MIL-HDBK-454A –** Guideline 1, par 4.4 provides some general guidance on surface temperatures.

2.24 If the answer to question 2.23 is NO, are the hot surfaces adequately labeled and protected against accidental contact?

Labeling alone is often inadequate unless the hot surfaces are normally not accessible. For instance, can duffle bags be thrown against the hot surface and catch fire?

- **UL 60950 –** Par. 4.5.1 provides some exceptions depending on the how the hot surface is labeled, accessed, it's size, etc.
- **UL 1950 –** Par. 5.1 applies.
- **MIL-STD-1472F –** Par 5.13.4.6 applies.

2.25 Where prolonged contact is required (handles, controls, etc.), are surface temperatures less than 49°C (120°F) for metal, 59°C (138°F) for glass, or 69°C (156°F) for plastic/wood at an ambient temperature of 25°C (77°F), regardless of the condition of operation?

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When comparing standards, note that some specify maximum temperature limits whereas others specify temperature rises.

- **UL 60950 –** Par. 4.5.1, table "Part 2"provides maximum temperature rises that depend on the material of the part and it's purpose. Ambient is assumed to be 25 deg C.
- **UL 1950 –** Par. 5.1 applies.
- **MIL-STD-1472F –** Par 5.13.4.6 applies and specifies these temperatures.
- **MIL-HDBK-454A -** Guideline 1, par 4.4 provides some general guidance on surface temperatures.

♦ **MISCELANEOUS** ♦

2.26 Is the equipment likely to remain upright under normal use and in strong wind, considering its means of support, center of gravity, and slope?

Consider stability of the system with any moving parts in the worst-case position. If equipment requires disassembly to avoid damage during high wind conditions (antenna dish, etc), ensure controls are in place to avoid disassembly during high winds.

- **NFPA 70-05 –** Article 110.13 addresses mounting of equipment and can be referenced. Article 110.12 also states that electrical equipment shall be installed in a neat and workmanlike manner.
- **UL 60950 –** Par 4.1 states under conditions of normal use, equipment shall not become unstable.
- **UL 1950 –** Par. 4.1.1 applies.
- **MIL-STD-1472F –** Par 5.13.6.4 states equipment that may tip over and injure personnel due to a high center of gravity should have anchors or outriggers for stability and shall display an appropriate warning.
- **MIL-HDBK-454A –** Guideline 1, par 5.3 states the design of rack-mounted equipment should maintain the center of gravity as low as possible to minimize tipping over.

2.27 Is the weight bearing capacity of hoists, jacks, and other such equipment suitable for the expected loading conditions and is the load capacity labeled?

Ensure that the proper safety factor is designed into the lift device; they vary depending on the device. In addition, maintenance procedures may require regular inspections and testing of the lift device.

- **MIL-STD-1472F –** Par 5.13.2.3 states the weight capacity shall be indicated on stands, hoists, lifts, jacks, vehicles, and similar weight-bearing equipment, so as to prevent overloading.
- **29 CFR 1910 –** Subpart N addresses various lifting devices and requirements for load capacity labeling.
- **TB 43-0142** – This technical bulletin addresses various lifting devices and requirements for load capacity labeling, maintenance, testing, etc.

2.28 Are pressurized systems or components provided with relief valves that will vent in a safe direction and manner?

Transit cases should have relief valves to equalize pressure. Battery boxes should be able to vent any battery off-gassing. Relief valves must vent away from the operator. Relief valves handles should be

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labeled to show the proper open and closed positions.

- **UL 60950 –** Par 4.3.11 states equipment that contains liquids or gases shall incorporate safeguards against build-up of excessive pressure.
- **UL 1950 –** Par. 4.3.4 applies.

2.29 Are positive means provided to prevent mismating of fittings; couplings; fuel, oil, hydraulic, and pneumatic lines; and mechanical linkages?

Consider mismating of different systems as well as preventing the connection of devices or hoses that are not rated for the pressures involved.

- **MIL-STD-1472F –** Par 5.13.7.3.1 states each connector used in handling or controlling hazardous fluids shall be incompatible with other connectors within the access area of that connector.
- **MIL-HDBK-454A –** Guideline 1, par 4.7.1 states the design should provide positive means to prevent the inadvertent reversing or mismating of fittings; couplings; fuel, oil, hydraulic, and pneumatic lines' and mechanical linkage.

2.30 Are there provisions to prevent injury from the implosion of cathode ray tubes?

Cathode Ray Tubes need to be designed so that large pieces are not dispersed far IAW IEC 60065 for mechanical strength and protection against the effects of implosion.

- **UL 60950 –** Par. 4.2.8 applies.
- **UL 1950 –** Par. 4.2.9 applies.
- **MIL-HDBK-454A –** Guideline 1, par 4.7.3 applies.

2.31 Is all glass of the non-shatterable type?

Glass and ceramic surfaces should be durable enough to prevent breakage leading to personnel injury or access to sharp parts.

- **UL 1795 Hydromassage Bathtubs –** 29.3 requires tempered glass for fixture lenses

PART 3: OTHER SAFETY

Section 3: Other Safety

3.1 Is the system designed to preclude injury or equipment damage due to operator induced error?

The system should be designed so that if the operator does accidentally or inadvertently touch the wrong control or perform a wrong function it will not cause injury to the operator or damage to the equipment.

- **MIL-HDBK-759C** – Para 5.9.16.1.2.j, Equipment should be designed either to prevent the operator from making errors or to warn the operators of errors. Para 5.9.16.1.2.r, Safeguards against equipment damage from inadvertent human error should be provided. Para 5.9.16.1.2.v, Controls should be designed to prevent equipment damage if it is operated at the wrong time or in the wrong manner.
- **MIL-STD-1472F –** Par 5.4.1.8.1. Location and design. Controls shall be designed and located so that they are not susceptible to being moved accidentally or inadvertently, particularly critical controls where such operation might cause equipment damage, personnel injury, or system performance degradation.

3.2 Is equipment designed to prevent accidental ignition when used in hazardous atmospheres? (Applicable to equipment that is intended for use in atmospheres of explosive gas or vapors, combustible dusts, or ignitable fibers and flyings.)

The materials used in the equipment should be specifically approved for the hazardous atmosphere of explosive gas or vapor, combustible dusts, or ignitable fibers and flyings so that it doesn't cause accidental ignition.

Tools and equipment used in an explosive atmosphere should be non-sparking and explosion-safe.

- **NFPA 70-05 –** Article 517.61 (3) Equipment Operating at More Than 10 Volts. In hazardous (classified) locations referred to in 517.60, all fixed wiring and equipment and all portable equipment, including lamps and other utilization equipment, operating at more than 10 volts between conductors shall comply with the requirements of 501.1 through 501.25, and 501.100 through 501.150, and 501.30(A) and 501.30(B) for Class I, Division 1 locations. All such equipment shall be specifically approved for the hazardous atmospheres involved.
- **MIL-HDBK-759C** – para 5.13.7.8 Safety checklist, Table 38, question 22, When tools and equipment are used in an explosive atmosphere, are they non-speaking and explosion-safe?
- **MIL-STD-810 –** Method 511.4 covers explosive atmosphere testing performed to demonstrate the ability of materiel to operate in fuel-air explosive atmospheres without causing ignition.

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3.3 Are emergency controls readily accessible and clearly identified?

Operators should not have to search for emergency controls. Emergency controls should be color coded red so it stands out. Emergency controls should be placed in an area that everyone can get to and is clearly labeled. Emergency controls should have just the emergency functions.

- **NFPA 70-05** – Article 514.11 Circuit Disconnects.
  A. General. Each circuit leading to or through dispensing equipment, including equipment for remote pumping systems, shall be provided with a clearly identified and readily accessible switch or other acceptable means, located remote from the dispensing devices, to disconnect simultaneously from the source of supply, all conductors of the circuits, including the grounded conductor, if any. Single-pole breakers utilizing handle ties shall not be permitted. **B. Attended Self-Service Motor Fuel Dispensing Facilities.** Emergency controls as specified in 514.11(A) shall be installed at a location acceptable to the authority having jurisdiction, but controls shall not be more than 30 m (100 ft) from dispensers. [NFPA 30A, 6.7.1]
  C. Unattended Self-Service Motor Fuel Dispensing Facilities. Emergency controls as specified in 514.11(A) shall be installed at a location acceptable to the authority having jurisdiction, but the control shall be more than 6 m (20 ft) but less than 30 m (100 ft) from the dispensers. Additional emergency controls shall be installed on each group of dispensers or the outdoor equipment used to control the dispensers. Emergency controls shall shut off all power to all dispensing equipment at the station. Controls shall be manually reset only in a manner approved by the authority having jurisdiction. [NFPA 30A, 6.7.2] FPN: For additional information, see 6.7.1 and 6.7.2 of NFPA 30A-2000, Code For Motor Fuel Dispensing Facilities and Repair Garages.
- **MIL-HDBK-759C** - Par 5.4.1.4.5.1 Emergency controls. All emergency controls should be coded red. To give these emergency controls the visual emphasis they demand, only a bare minimum of other, less important controls should be color coded. Colors used to code critical controls should contrast sharply with those used for non-critical controls.
- **MIL-STD-1472F –** Par 5.4.1.9.2 Consistency of use. A control used for a critical/emergency use function shall be dedicated to that function only. Par 5.4.1.8.3. Rapid operation. Any method of protecting a control from inadvertent operation shall not preclude operation within the time required.

3.4 Are switches, indicators, panel instruments, and control devices adequately labeled to prevent confusion that could lead to a hazard?

Switches, indicators, panel instruments, and control devices should be located so that it is visible to everyone and clearly labeled. Labels should be on, adjacent or elsewhere provided it is obvious to which switch, indicator, panel instruments, or control devices label is for. Universal symbols and standard writings should be use.

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- **NFPA 70-05 –** Article **110.16 Flash Protection.** Switchboards, panel boards, industrial control panels, and motor control centers that are in other than dwelling occupancies and are likely to require examination, adjustment, servicing, or maintenance while energized shall be field marked to warn qualified persons of potential electric arc flash hazards. The marking shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment. FPN No. 1: NFPA 70E-2004, *Electrical Safety Requirements for Employee Workplaces*, provides assistance in determining severity of potential exposure, planning safe work practices, and selecting personal protective equipment. FPN No. 2: ANSI Z535.4-1998, *Product Safety Signs and Labels*, provides guidelines for the design of safety signs and labels for application to products.

- **UL 60950 –** Par **1.7.8.1 Identification, location and marking.** Unless it is obviously unnecessary, indicators, switches and other controls affecting safety shall be identified or located so as to indicate clearly which function they control. Markings and indications for switches and other controls shall be located either:
  - on or adjacent to the switch or control, or
  - elsewhere, provided that it is obvious to which switch or control the marking applies.

  Indications used for this purpose shall, wherever practicable, be comprehensible without knowledge of languages, national standards, etc.

- **MIL-HDBK-759C –** Para 5.4.1.5 Labeling of controls. Controls should have labels (on panel or control) that identify what they control and show how to operate the control. Some equipment manufacturers are developing uniform symbols for use with controls. Uniform symbols, which have been standardized and accepted, may be used in lieu of labels.

3.5 Is an audible/visual warning device provided to warn personnel of impending danger, or to indicate malfunction that could cause injury or equipment damage?

An audible/visible warning device is needed to warn personnel of impending danger, or to indicate a malfunction that can cause injury or equipment damage.

- **MIL-HDBK-759C –** Par 5.9.11.2.2.2 Boom indicators and controls. The main boom angle-indicator display should be easily visible to the operator and coded to alert the operator when there is danger of exceeding the maximum load angle. Load capacity, in kg, should be indicated on the equipment and audible warning devices should be provided when load is exceeded. Boom controls should have labels indicating their functions and direction of motion and be placed in the most accessible area for the 5th through 95th percentile operator when wearing cold weather clothing. These controls should be spring-loaded so they return to the stop position when released. Latches on control levers should not cause delay in operation. Also see para 5.13.7.8 Safety checklist, Table 38, question 7, Are audible signals distinctively recognizable and unlikely to be masked by other noises.

- **MIL-STD-1472F –** Par 5.4.1.9.1 Interlocks and alarms. Where practical, the critical

Section 3: Other Safety

position of a control that initiates hazardous operations (e.g. ignition, crane movement) shall activate visible and audible warning signals in the affected work area.

3.6 Is proper color coding provided for safety critical indicators (green: power on, ready; amber: caution; red: danger; white: info)?

The safety requirement for proper color coding is only necessary for the colors of red and yellow. Safety critical indicators/controls must have red standing for danger and yellow standing for caution. The use of any color for functional controls are permitted as long as safety is not involved.

- **UL 60950 –** Par 1.7.8.2 **Colours** Where safety is involved, colours of controls and indicators shall comply with IEC 60073. Where colours are used for functional controls or indicators, any colour, including red, is permitted provided that it is clear that safety is not involved.
- **29 CFR 1910.144** – Discusses safety color codes. **NOTE:** THE NEW COMMERICAL VERSION OF THE SAFETY SPEC ONLY REQUIRES THAT SAFETY CRITICAL CONTROLS/INDICATORS BE YELLOW FOR CAUTION, AND RED FOR DANGER. USE OF ANY COLOR IS OKAY FOR FUNCTIONAL CONTROLS PROVIDED IT IS CLEAR THAT SAFETY IS NOT INVOLVED. SUCH A REQUIREMENT IS MORE IN LINE WITH INDUSTRY.

3.7 Is adequate separation provided between critical warning lights and other lights?

There should be adequate separate between critical warning lights and other lights so that the operator does not accidental mistaken them for each other.

- **MIL-STD-1472F –** Par 5.2.6.7.10 Location of red alphanumeric LEDs/segmented displays. Red LEDs/segmented displays shall not be grouped with or located adjacent to red warning lights.
- **MIL-HDBK-759C** - para 5.13.7.8 Safety checklist, Table 38, question 9, Are the most critical warning lights grouped together within the operator's normal field of view and separated from other, less important lights?

3.8 Are audible warning signals distinguishable from other sounds under normal operating conditions?

Audible warning signals should be distinguishable and heard from routine signals or other signals under normal operating conditions. Audible warning signals should be in the operator's headset as well as in the work area.

- **MIL-HDBK-759C** – Para 5.3.3.4 Compatibility with other critical signals. No warning signals should be of such a character as to preclude hearing any other warning signal or reception of vital voice communication. Para

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5.3.13.4.1 Warning signals. Auditory warning signals should be presented through the operator's headset as well as to the work area when ambient noise level will exceed 85 dBA or when the operator will ordinarily wear earphones covering both ears during normal equipment operation. Para 5.13.7.8 Safety checklist, Table 38, question 7, Are audible signals distinctively recognizable and unlikely to be masked by other noises.

- **MIL-STD-1472F –** Par 5.3.4.3.5. Differentiation from routine signals. Audio alarms intended to bring the operator's attention to a malfunction or failure shall be differentiated from routine signals, such as bells, buzzers, and normal operation noises.

3.9 Is the display lighting of aircraft electronics (avionics) compatible to the use of night vision goggles?

The display lighting of aircraft electronics should be compatible to night vision goggles when it is used. When there is a requirement for night vision goggles then color lights should not be used. The spectral output of all light emitting from or illuminating a display should not be greater than 600 nm in wavelength. The lighting should be continuously variable to the full OFF position so that no current shall flow through the lamps. If night vision goggles are used then additional aids should include having the lettering be block-type white letters on a black background, all controls (knobs, switches) be painted white.

- **MIL-STD-3009** – Para 1.1. Scope**,** This standard establishes requirements for the emission characteristics of aircraft lighting and display equipment that is intended for use with night vision imaging systems (NVIS). It is applicable to all systems, subsystems, component equipment, and hardware that provide the lighting environment on aircraft where NVIS are employed.
- **MIL-STD-1472F –** Par 5.2.1.2.1.2, Night vision device compatibility. Where night vision device compatibility is required, the spectral output of all light emitting from or illuminating a display should be not greater than 600 nm in wavelength. The lighting shall be continuously variable to the full OFF position. In the OFF position, no current shall flow through the lamps. Par 5.8.2.1.2 Colored ambient illumination. Except where required for dark adaptation or night vision goggle compatibility, colored ambient illumination should not be used.
  Para 5.11.3.11.6 Night vision goggle (NVG) accommodation. If potential operator conditions include NVG use, spectral output wavelength should be not greater than 600 nm.
- **MIL-HDBK 759C** - Para 5.2.1.j. The display should be illuminated with white light when dark adaptation is not essential. Red illumination should be used when dark adaptation is required. Other colors may be necessary when night vision goggle compatibility is required. Para 5.8.2.7.4 Additional aids. The additional aids to night vision listed below should be incorporated. Lettering that must be read at low light intensities should be block-type white letters on a black background. All controls (knobs, switches) should be painted white. Instrument panels should be designed and located for both day and night use. Maps designed for used under red illumination should be used.

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3.10 Have all equipment related mechanical, electrical, chemical, and health hazards been suitably addressed through warning labels?

All equipment with mechanical, electrical, chemical, and health hazards should have the appropriate warning labels to warn user against the hazard, state the appropriate precautions, and consequences of not complying with the stated warning.

- **UL 60950** – Para 0.2 Hazards. Para 0.2.4 Heat related hazards….. measurements to reduce such hazards include:…-provision of markings to warn users where access to hot parts is unavoidable…..Para 0.2.5 Mechanical hazards…..measures to reduce such hazards to include…-provision of markings to warn users where access is unavoidable…. Para 0.2.6 Radiation…..-provisionof markings to warn users where exposure to the radiation hazard is unavoidable….Para 0.2.7 Chemical hazards….-provision of markings to warn users about the hazards.
- **MIL-HDBK-759C** – Para 5.5.7.5 Hazard signing and marking. Appropriate signing and marking of all potential hazards to personnel should be provided. The following signing and marking should be considered. a. Fixed physical obstructions (low overheads, open hatches or manholes, posts, and guardrails). b. Moving hazards (convey belts, chains, gears, loaders, cranes, and booms). c. Equipment contact hazards (high-voltage and high-temperature). d. Radiation hazards (electromagnetic and nuclear). e. Laser beams. f. Toxic contaminants (substances and gases). g. Flash or high intensity light. h. Requirements for safety glasses. i. High noise or blast. j. Criteria for hard hats. k. Explosives. l. High-pressure containers and hoses. m. Slipping and falling hazards. n. Other (fire, first aid and rescue).
- **MIL-STD-1472F –** Par 5.13.2.1 General. Conspicuous labels shall be placed on, or adjacent to, any equipment that presents a hazard to personnel (e.g. high voltage, heat, toxic vapors, explosion, or radiation). These labels or placards shall describe the hazard and state appropriate precautions. Labels and placards should also describe the consequences of not complying with the stated warning.

3.11 Are guards, covers, and barriers marked to indicate the hazard that may be present upon removal of such devices?

Labels should be on top of guards, covers, and barriers to let users know there is a hazard present when the guards, covers, and barriers are removed. Labels should be located so that it is not removed when the barrier is removed. If access areas must be located over dangerous mechanical or electrical components, the access door or cover should be designed so that an internal light is turned on when it is open.

- **MIL-HDBK-759C** – Par 5.5.4.6 Labels should be placed on the outside of equipment covers to identify control, display, or other functions located within a covered compartment.
- **MIL-STD-1472F –** Par 5.13.5.3 Hazardous access. Where access areas must be located over dangerous mechanical or electrical components, the access door or cover shall be designed to turn on an internal light when opened. A highly visible warning label shall be provided on the outside of the door or cover.

Section 3: Other Safety

- **MIL-HDBK-454A –** Par 4.8 Equipment safety markings…..Guards, barriers, and access doors, covers or plates should be marked to indicate the hazard which may be present upon removal of such devices. When possible, marking should be located such that it is not removed when the barrier or access door is removed.

3.12 Are labels sized and placed so that the associated hazard is identified before the user is exposed to the hazard?

The labels used to identify a hazard should be readable from an operational distance and placed on or near the hazard so that there is no question about where the hazard is.

- **MIL-HDBK-759C** – Para 5.5….g. Labels should be placed where they can be seen easily, not where other units in the assembly will cover or obscure them….h. Labels should be made large enough that the operators can read them easily at normal distance…..k. Labels should be placed on, or very near, the item they identify; any confusion with other items and labels should be eliminated.
- **MIL-STD-1472F –** Par 5.5.4.3 Visibility and legibility. Labels and placards shall be easy to read accurately from the operational reading distances and in the anticipated vibration, motion, and illumination environments…..Para 5.5.6.1.1 General Requirements. Each unit, assembly, subassembly and part shall be labeled with a clearly visible, legible, and meaningful name, number, code, mark or symbol. Par 5.5.6.2.4.
- **MIL-HDBK-454A –** Par 4.8.….Guards, barriers, and access doors, covers or plates should be marked to indicate the hazard which may be present upon removal of such devices. When possible, marking should be located such that it is not removed when the barrier or access door is removed. Additionally, hazards internal to a unit should be marked adjacent to hazards if they are significantly different from those of surrounding items. Such a case would be a high voltage terminal in a group of low voltage devices.

3.13 When possible, are labels located such that they are not removed when the barrier or access door is removed?

Labels should NOT be located on removable barriers or access doors, if at all possible, because when they are removed the user does not know there exists a hazard behind them. Labels should be attached as close to the hazard on the equipment as possible and user should be able to see it before they come in contact with the hazards.

- **NFPA 70-05 –** Article 665.23 Warning Labels or Signs. Warning labels or signs that read “DANGER – HIGH VOLTAGE – KEEP OUT” shall be attached to the equipment and shall be plainly visible where persons might come in contact with energized parts when doors are open or closed or when panels are removed from components over 150 volts ac or dc.
- **MIL-HDBK-454A –** Par 4.8 Equipment safety markings…….When possible, marking should be located such that it such that it is not removed when the barrier or access door is removed.

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3.14 Do warning labels comply with the marking, design, and color requirements detailed in the system specification?

Marking, design and color requirements of warning labels should comply with what is in the system specification. If no requirements are given in the system specification then use the commercial standards.

3.15 Are warning labels capable of lasting for the normal life expectancy and operational environments of the equipment to which they are affixed?

Warning labels should be as permanent as normal life expectancy of the equipment on which they are on.

- **MIL-HDB-454** – Para 4.8 Equipment Safety Markings…..The signs, label, tags, and markings should be as permanent as the normal life expectancy of the equipment on which they are affixed….
- **MIL-STD-1472F** – Par 5.5.4.5 Label mounting. Labels that are not part of the equipment or unit shall be securely attached to prevent its loss, damage, slippage, or accidental or unauthorized removal. They shall be attached to a structural member that is not removed during equipment servicing or routine maintenance. Labels shall be mounted so as to minimize wear or obscuration by grease, grime, or dirt, and shall remain legible for the overhaul interval of the labeled equipment. An alternative would be etching directly on the equipment.

3.16 Is PMCS established for safety critical circuits such as safety interlocks, voltage dividers, capacitor discharge circuits, etc.?

It is good safety engineering practice to establish Preventative Maintenance Checks and Services (PMCS) on safety critical circuits such as safety interlocks, voltage dividers, capacitor discharge circuits, etc. Periodic maintenance will maintain safe operations and production by reducing or eliminating system interruptions and equipment breakdowns.

- **NFPA 70B** – Para 3.3.6 Electrical Preventive Maintenance (EPM). A managed program of inspecting, testing, analyzing, and servicing electrical systems and equipment. Its purpose is to maintain safe operations and production by reducing or eliminating system interruptions and equipment breakdowns. EPM relies on the knowledge of the electrical systems and equipment being maintained, and on knowing the operating experience, loss exposures, potential for injury, and maintenance resources…….Para 22.2.1 Electrical equipment designed for use in hazardous (classified) locations should be maintained through periodic inspections, tests, and servicing as recommended by the manufacturer. Electrical preventive maintenance documentation should define the classified area (the class, group, and division specification, and the extent of the classified area) and the equipment maintenance required. Electrical preventive maintenance documentation should identify who is authorized to work on this equipment, where this maintenance is to be performed, and what precautions are necessary. Although repairs to certain equipment should be done by the manufacturer or authorized representatives,

Section 3: Other Safety

inspection and servicing that can be performed in-house should be clearly identified…….. Para 5.3 Main Parts of an EPM Program….should consist of the following essential ingredients:…..(2) Survey and analysis of electrical equipment and systems to determine maintenance requirements and priorities. (3) Programmed routine inspections and suitable tests….(5) Performance of necessary work.

3.17 Are all maintenance procedures within the qualifications of the designated Military Occupational Specialty (MOS)?

The maintenance procedures should be written within the qualification of the designated Military Occupational Specialty (MOS) for the maintenance tasks.

- **NFPA 70B** – Para 5.3 Main Parts of an EPM Program. An EPM program should consist of the following essential ingredients….. (1) Responsible and qualified personnel….Para 6.7.2 Maintenance should be performed only by qualified personnel who are trained in safe maintenance practices and the special considerations necessary to maintain electrical equipment for use in hazardous (classified) locations. These individuals should be familiar with requirements for obtaining safe electrical installations. They should be trained to evaluate and eliminate ignition sources, including high surface temperatures, stored electrical energy, and the buildup of static charges, and to identify the need for special tools, equipment, tests, and protective clothing.
- **AR 611-1,** Military Occupational Classification Structure Development & Implementation
- **DA Pam 611-21 Part III,** Military Occupational Classification and Structure

SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST HANDBOOK
PART 4: HEALTH HAZARDS

Section 4: Health hazards
•
This section to be addressed in the future

SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST HANDBOOK

PART 5: ENVIRONMENTAL IMPACT

5.1 Is the item or component free of hazardous or potential hazardous materials as defined by the Federal Standard 313, EPA (40 CFR), DOT (49 CFR), OSHA ACGIH or other federal laws, regulation or standard?

FED-STD-313 includes in its definition of hazardous materials any item or chemical is a health hazard or physical hazard as defined by OSHA 29 CFR1910.1200, is reportable or potentially reportable or noticeable as inventory under the reporting requirements of the Hazardous Chemical Reporting (40 CFR 302) or as an environmental release under the reporting requirements of the Toxic Chemical Release Reporting: Community Right to Know (40CFR 372); when being transported or moved is a risk to public safety or an environmental hazard; and is a special nuclear source, or byproduct material as defined in 10 CFR 40 or is registered or referred to as radioactive.

Hazardous and toxic substances can be defined as those chemicals present in the workplace that are capable of causing harm. In this definition, the term chemicals include dusts, mixtures, and common materials such as paints, fuels, and solvents. OSHA (29 CFR 191 -Subpart H - Hazardous materials and 29 CFR 1910 Subpart Z – Toxic and Hazardous substances) currently regulates exposure to approximately 400 substances. The OSHA Chemical Sampling Information file contains listing for approximately 1500 substances.

The Department of Transportation (DOT) regulates transportation on public roads in the 49 Code of Federal Regulations (49 CFR). Hazardous materials are defined in 49 CFR 171.8 as a substance or material capable of posing an unreasonable risk to health, safety, and property when transported in commerce. Hazardous wastes (40 CFR 261) are classified as DOT hazardous materials (49 CFR 171.8).

It is the national policy of the United States that pollution should be prevented or reduced at the source whenever feasible; pollution that cannot be prevented should be recycled in an environmental safe manner, whenever feasible; pollution that cannot be prevented or recycles should be treated in an environmentally safe manner whenever feasible; and disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner (Public Law 101-508, Pollution Prevention Act of 1990).

5.2 Is the item or component free of reactive or flammable chemicals such as solvents, thinners or diluents?

A liquid which having a flashpoint below 100° F (37.8° C), except any mixture having components with flashpoints of 100° F (37.8° C) or higher, the total of which make up 99 percent or more of the total volume of the mixture, is considered flammable (29 CFR 1910.106). NFPA defines the flashpoint of a liquid is the minimum temperature at which the liquid gives off sufficient vapor to form an ignitable mixture with air near the surface of the liquid. By "ignitable" mixture is meant a mixture that is within the flammable range and, thus, is capable of propagation of the flame away from the source of ignition.

FED-STD 313 states that any material or chemical when being transported or moved is a risk to the public safety or an environmental hazard is a hazardous material. Both reactive and flammable chemicals meet this definition well.
A liquid that is in the pure state or as commercially produced or transported will vigorously polymerize, decompose, condense, or will self-reactive under conditions of shocks, pressure, or temperature is considered reactive (29 CFR 1910.106).

OSHA (29 CFR 191 -Subpart H - Hazardous materials and 29 CFR 1910 Subpart Z – Toxic and Hazardous substances) currently regulates exposure to approximately 400 substances that are either toxic or carcinogenic.

5.3 Is the item or components free of toxins and carcinogens (e.g., polychlorinated biphenyl's, elemental mercury, beryllium oxide, asbestos, etc.)?

Certain chemicals are classified as persistent, bioaccumulative and toxic chemicals (i.e., mercury, PCBs) by EPA under section 313 of Emergency Planning and Community Right-to-Know Act (EPCRA). OSHA (29 CFR 191 -Subpart H - Hazardous materials and 29 CFR 1910 Subpart Z – Toxic and Hazardous substances) currently regulates exposure to approximately 400 substances that are either toxic or carcinogenic.

5.4 Is it free of ozone depleting chemicals (ODC, i.e., ozone depleting substances (ODS)) refrigerant gases, chlorofluorocarbons, etc?

As the result of actions taken by parties to the Montreal Protocol, the 1990 Amendments to the Clean Air Acts, and the Orders from the Executive Branch, Halons and other ozone-depleting chemicals have to be phased out. Clear Air Act (42 U.S.C. 7671a(a)) provided the following milestones: Halons out by 1 January 1994, CFCs (chlorofluorocarbons), carbon tetrachloride and Methyl chloroform (1,1,1-trichloroethane) out by 1 January 1996, Methyl bromide out by 1 January 2001, HCFCs (hydro CFCs) out by 1 January 2003.

5.5 Are electrical and electronic components free of lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE) (batteries excepted)?

The IEEE 1680 standard provides environmental guidelines for institutional purchasing decisions involving desktop and laptop computers and monitors. It offers criteria for materials selection, environmentally sensitive materials, design for end of life, end-of-life management, energy conservation, product longevity and life-cycle extension, packaging, and corporate performance.

The Federal Electronics Challenge and Electronic Product Environmental Assessment Tool (EPEAT) programs encourage the recycling of electronic hardware.

EU has the Restriction of Hazardous Substances (RoHS) Directive that affects the use of selected hazardous materials in electrical and electronic equipment. EU also has the Waste Electrical and Electronic Equipment (WEEE) Directive which requests member States to require manufacturers to develop an infrastructure to take back and dispose or recycle electrical and electronic equipment.

5.6 If the answer to any of questions 5.1 through 5.5 is "no", has every effort been made to substitute nonhazardous materials?

Public Law 101-508, POLLUTION PREVENTION ACT OF 1990, requires that pollution should be prevented or reduced at the source whenever feasible; pollution that cannot be prevented should be recycled in an environmentally safe manner, whenever feasible; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible; and disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner.

5.7 Have Safety Data Sheets for all hazardous materials been completed and submitted to the government?

FED-STD-313 imposes the requirement that federal contracts require the delivery of hazardous

materials by making sure the government has notice of hazardous materials and receives Safety Data Sheets (SDS) necessary for employee safety and health programs and the information necessary for the safe handling, storage, use, transportation and environmentally acceptable disposal of hazardous materials. Acquisition of SDS is also prescribed by OSHA regulations 29 CFR 1910 and paragraph 1-602(c) of EO 12191, Occupational Safety and Health Program for Federal Employees, dated February 26, 1980. FAR Subpart 23.3 and 52.223-3 implement the requirement the requirement of FED-STD-313.

5.8 Does the equipment avoid the use of batteries? If NO, complete section 8, Battery Safety.

There are two kinds of batteries available: Primary and secondary batteries. Primary batteries are those disposable ones and can be alkaline, carbon-zinc, lithium-manganese dioxide, lithium-sulfur dioxide, lithium-thionyl chloride, magnesium or mercury batteries. Secondary batteries are rechargeable and can be lead-acid, nickel-cadmium, nickel metal hydride and lithium ion batteries. Some batteries will require special handling (i.e., lithium sulfur dioxide battery will need special attention to prevent explosion due to excessive gas discharge). Other batteries will require special handling and disposal due to their hazardous/toxic contents (i.e., mercury, lead, acid, cadmium, lithium).

5.9 Is the system free of ionizing radiation sources (radioactive isotopes, etc.)? If NO, complete section 6, Radiation Safety. All radioactive isotopes, regardless of quantity, must be reported to Department of the Army.

Effects of over exposure to ionizing radiation (i.e., x-ray, gama-ray), depending on the mode of exposure (whole body or local exposure, acute or chronic), can be blood change, vomiting, central nervous system shuts down, carcinogenic effects, genetic effective and in-utero effects. The human organs most commonly affected by large acute exposures are the central nervous system, the skeleton, skin eyes and reproductive.

It is essential that adequate measures be taken to protect person who works with or one near radiation sources, as well as the general public, against excessive to radiations.
20 CFR 20, Standards for Protection Against Radiation, establish standards for protection against ionizing radiation and control the receipt, possession, use, transfer and disposal of radiation source.

5.10 Is the system free of Nonionizing radiation sources (radiofrequency, laser, etc.)? If NO, complete Section 6, Radiation Safety.

Laser and equipment generating high intensity optical radiation can present a hazard to personnel. The type of hazard presented depends on the intensity and the wavelength of the light. Skin damage can occurs at wavelength between 315 nm and 1 mm. Dependent on the intensity of exposure, anything from skin reddening to blistering and charring can occur. The most vulnerable organ to injury is the eye. Once again, the kind of potential damages depend on the wavelength and the intensity of the radiation. Because lasers can concentrate light into a very narrow beam of radiation, the potential for injury from them is potentially greater than that from a high intensity optical radiation source of the same output.

Radio wave and microwaves are forms of electromagnetic energy that are collectively described by the term "radiofrequency" or "RF." Tissue damage in humans could occur during exposure to high RF levels because of the body's inability to cope with or dissipate the excessive heat that could be generated. Two areas of the body, the eyes and the testes, are known to be particularly vulnerable to heating by RF energy because of the relative lack of available blood flow to dissipate excessive

heat load (blood circulation is one of the body's major mechanisms for coping with excessive heat).

At the present time (Nov 2006) there is no federally mandated radio frequency (RF) exposure standard. However, several non-government organizations, such as the American National Standards Institute (ANSI), the Institute of Electrical and Electronics Engineers, Inc. (IEEE), and the National Council on Radiation Protection and Measurements (NCRP) have issued recommendations for human exposure to RF electromagnetic fields. DODI 6055.11, IEEE C95.1-2019 and C95.1-2345-2014 provide specific RF exposure limit details.

5.11 Have all components that are routinely replaced in the course of maintenance been selected so as not to require special handling or disposal?

By avoiding the use of hazardous or toxic materials in the system, the need for costly disposal of hazardous/toxic waste generated can be eliminated and potential of future environmental damage can be avoided. The best control of pollution is to eliminate the pollutants at the source.

5.12 Have electrical and electronic components been designed to facilitate the economic recovery, reclamation and/or disposal of components?

Public Law 94-580, Resource Conservation and Recovery Act, amends the Solid Waste Disposal Act and establishes the objective of establishing a cooperative effort to recover potential energy sources and other valuable materials from discarded material.

The IEEE 1680 standard provides environmental guidelines for institutional purchasing decisions involving desktop and laptop computers and monitors. It offers criteria for materials selection, environmentally sensitive materials, design for end of life, end-of-life management, energy conservation, product longevity and life-cycle extension, packaging, and corporate performance.

The Federal Electronics Challenge and Electronic Product Environmental Assessment Tool (EPEAT) programs encourage the recycling of electronic hardware.

EU has the Restriction of Hazardous Substances (RoHS) Directive that affects the use of selected hazardous materials in electrical and electronic equipment. EU also has the Waste Electrical and Electronic Equipment (WEEE) Directive which requests member States to require manufacturers to develop an infrastructure to take back and dispose or recycle electrical and electronic equipment.

5.13 Have all materials that have the potential for the evolution or release of hazardous gases, vapors of fumes in violation of federal, state or local regulations been eliminated?

The 1990 Clean Air Act Amendments identified 189 (now 188) hazardous air pollutants that are carcinogens, mutagens, or reproductive toxins.

5.14 Has the system been designed so as not to release combustion products, emit objectionable odors, or create airborne particulates?

40 CFR 86, Control of Emissions From New and In-Use Highway Vehicles and Engines and 40 CFR 89 Control of Emissions from New and In-Use Nonroad Compression-Ignition Engines, set the limits of emission standards and certification provisions for combustion engines. Excessive emission of objectionable odors from the system may cause aesthetic problem and become unacceptable.

5.15 Has the potential for the release of toxic or hazardous substances onto the

soil, or to the surface or subsurface water been eliminated?

Toxic Substances Control Act (TSCA) controls chemical hazards through the regulation of listed chemicals in commerce, including manufacture, import, processing, distribution, use, and disposal.

FED-STD 313 states that any material or chemical when being transported or moved is a risk to the public safety or an environmental hazard is a hazardous material. Therefore, their releases to the soil, surface or subsurface water, or air must be controlled.

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6.1 Are warning labels provided that indicates the hazardous range of microwave emissions for components that produce a power density in excess of the following limits?

Replace with: Have electromagnetic radiation (EMR) warning signs been provided for electromagnetic emissions that exceed either the exposure reference levels (ERLs) or the dosimetric reference levels (DRLs) of **IEEE Standard C95.1-2345, Section 4**? **IEEE Standard C95.2** specifies the design symbols denoting the incidence of radio-frequency (RF) electromagnetic energy and is consistent with the ANSI/NEMA Z5353 series of standards. This standard is intended for all personnel of the presence of any potentially adverse effects levels from electromagnetic radiation (EMR) including EMR shock and/or burns.

ANSI power and frequency table deleted (copyrighted). ANSI and ACGIH statements updated to a single IEEE C95 statement as listed below.

IEEE Standard C95.1-1234- Section 4: The ERLs and DRLs are requirements derived from this reference and are to be used to determine the safe limits for whole-body to non-ionizing radiation in controlled/restricted environments. The ERLs and DRLs can be relaxed for partial body exposure assessments.

[MIL-HDBK-454**B** - Par 4.8] *Microwave or RF radiation warning signs, labels or tags should be provided on all radiation shields to warn personnel of the radiation hazards involved upon removal thereof. Any item, which can emit radiation levels in excess of the specified limits, should be labeled. Minimum safe clearance distances should be clearly marked.*

[DODI 6055.11 – Par E5.1.3] *RF warning signs are required at all access points in which these levels are exceeded in the controlled environment. Where the RF levels exceed the uncontrolled environment limits RF warning signs should be posted in applicable locations. In areas where access to levels greater than 10 times the controlled environment limits may exist, warning signs alone do not provide adequate protection. Other warning devices, such as flashing lights, audible signals, barriers, or interlocks, are required depending on the potential risk of exposure.*

6.2 For transmitting equipment, where antennas can develop RF currents through an impedance equivalent to the human body, are grasping and/or touching contact

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current limits on nearby dead metal objects below the exposure reference levels (ERLs) in IEEE Standard C95.1-2345TM?

[IEEE Standard C95.1-2345TM] The ERLs and DRLs are requirements derived from this reference and are to be used to determine the safe limits for whole-body and non-ionizing radiation in controlled/restricted environments. These requirements are for controlled environments and would not be reduced for uncontrolled environments as shown in Section 4 of this standard.

[MIL-STD-454N, req 1, par 4.4.3.4] *The hazard severity is dependent on the amount and frequency of the current that will pass through an individual contacting the RF source. Frequency is a factor since as it increases, the current tends to flow more at the surface of the body rather than through the body. IEEE C95.1-1991, sec 4.1.1(a)(ii) details the maximum RF current permissible as a function of frequency. Therefore, voltages higher than 70 V may be permitted depending on the frequency and anticipated current levels. Also refer to section 3.2 of this document.* **MIL-STD-454N was canceled and replaced by MIL-HDBK-454B, para 4.8.**

ACGIH TLV Guide – table 1]. *Part B of table 1 provides the maximum induced currents limits. Evaluation of the magnitude of the induced currents normally requires a direct measurement.* **ACGIH is no longer referenced for EMR policy, suggest deleting.**

6.3 Have all devices that exceed 10,000 volts been evaluated for X radiation?

[ACGIH TLV Guide – Ionizing Radiation, Table 1] *Dose limits for exposure to X-radiation are provided in this table.*

6.4 Are X-ray producing devices shielded to reduce personnel exposure to < 2.0 mR/hour and no more than 500 mR/year?

[UL 60950 **–** Par 4.3.13] *Equipment that can generate ionizing radiation shall be so designed that harmful effects to persons and damage to materials affecting safety are prevented.*

[MIL-STD-1472F – 5.13.7.5] *Ionizing radiation exposure rates produced by any device shall not exceed 0.5 milliroentgens/hr at a distance of 5 cm (2 in) from any point on the external surface.*

[MIL-HDBK-454B – Par 4.6.2] *Shielding guidelines should be maintained at all times which limit radiation levels to not greater than 2 milliroentgens (mr) in any one hour and 100 mr in any 7 consecutive days at the operator position or within 5cm from the equipment (whichever is closer) in any unrestricted area accessible to personnel. In addition, these levels should be reduced whenever necessary to ensure that exposed personnel never receive an absorbed dose to the whole body or any critical organ in excess of 125 millirem per calendar quarter or 500 millirem per year.*

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6.5 Are X-ray producing devices and the components in which they are located labeled with an X-radiation hazard-warning symbol?

[UL 60950 **–** Par 4.3.13] *Equipment that produces x-radiation shall be marked where readily visible during servicing to indicate the presence of radiation. Service conditions include the removal of shields, windows, cages and covers, with or without the chassis removed from its enclosure. CAUTION: Servicing this unit with circuits energized may involve exposure to x-radiation. Refer to service manual for radiation protection procedure.*

[MIL-STD-1472F – Par 5.13.2.1] *Conspicuous labels or placards shall be placed on, or adjacent to, any equipment that presents a radiation hazard to personnel. These labels or placards shall describe the hazard and state appropriate precautions. Labels and placards should also describe the consequences of not complying with the stated warning.*

[10 CFR 20 – Par 20.1901] *The Standard three-bladed radiation symbol using the colors magenta, or purple, or black (hatched pattern) on yellow background shall be used. Additional information, as appropriate can be used to further make individuals aware of potential radiation exposures and to minimize the exposures.*

[MIL-HDBK-454A – Par 4.8] *Shields, which protect personnel from X radiation, should be labeled in accordance with 10 CFR 20.*

6.6 Has the use of any amount of radioactive material in the design and manufacture of any part or component been avoided?

[MIL-STD-1472F – Par 5.13.7.5] *If radiation-emitting systems and equipment are used, their design shall minimize hazards to operators and maintenance personnel. If internal ionizing radiation hazards (e.g., breakage of a tritium-illuminated source in a fire-control device or rifle sight presents potential tritium ingestion by individuals in the area) cannot be eliminated, they shall be minimized through engineering design.*

[UL 60950 **–** Par 4.3.13] *Equipment that can generate ionizing radiation shall be so designed that harmful effects to persons and damage to materials affecting safety are prevented.*

6.7 If the answer to question 6.6 is NO, has the manufacturer identified the physical form, isotope, and quantity of ANY radioactive material utilized in each component / system?

[MIL-STD-1472F – Par 5.13.7.5] *Definitive and specific data should be obtained from the contractor or service agency responsible for control of personnel exposure to radiation.*

[UL 60950 – Annex H] *At any point 5 cm from the surface of the OPERATOR ACCESS AREA the dose-rate shall not exceed 36 pA/kg (0,5 mR/h). Account is taken of the background level.*

6.8 If the answer to question 6.6 is NO, does the manufacturer have the appropriate authorization (NRC License or CECOM Authorization) for radioactive material?

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(Commentary)
6.9 Are optical products (lenses, mirrors, windows, fiber optics, etc.) free of ANY amounts of radioactive material? *(Commentary)*
6.10 Are radiation markings and labels affixed to all parts or components containing radioactive material? [UL 60950 – Par 0.2.6] *Markings to warn USERS where exposure to the radiation hazard is unavoidable are intended to reduce radiation hazards.* [MIL-STD-1472F – Par 5.13.2.1] *Conspicuous labels or placards shall be placed on, or adjacent to, any equipment that presents a radiation hazard to personnel. These labels or placards shall describe the hazard and state appropriate precautions. Labels and placards should also describe the consequences of not complying with the stated warning.* [MIL-HDBK-454A – Par 4.8] *The marking or labeling of commodities containing radioactive materials should be in accordance with 10 CFR 20.*
6.11 Are filters, goggles, or other protective devices identified and/or provided, and are warning signs posted, for all sources of radio frequency, ultraviolet, infrared, high-energy visible, laser, and any other type of hazardous radiant energy? [MIL-STD-1425A – Par B.2.3] *Laser protective eyewear is presently available commercially in a variety of designs for most laser wavelengths. The eye protection generally consists of a filter plate or stack of filter plates, or two filter lenses, which selectively attenuate at specific laser wavelengths, but transmit as much visible radiation as possible. Eyewear is available in several designs. Suitable eyewear to be worn includes coverall spectacles with opaque side-shields, coverall spectacles with somewhat transparent side-shields, and laboratory style coverall goggles with flat glass or plastic absorbers.* [AR 385-63 - Par 1-f(2)], [DA PAM 385-63 - Par 3-3] [ANSI Z136.1-2014 Section 4.4.4.1] When other control measures are not practicable, PPE should be used to provide protection against laser radiation. Laser eye protection (LEP) shall be used for Class 3B and Class 4 lasers and laser systems. Clothing and gloves that have been specifically selected for suitable protection against laser radiation should be considered for Class 3B and 4 lasers and laser systems.
6.12 If lasers are used, has output power been limited to the lowest power density that could meet the performance requirements? **[ANSI Z136.1-2014 Table 5]**

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[International Electrotechnical Commission (IEC) 60825-1, Laser Safety Standards, Tables 3-8]

[MIL-STD-1425A – Par 1.4] *Military lasers shall be designed to the lowest hazard classification consistent with reliable mission accomplishment. Eye safe emissions are a goal for all lasers used in a training environment. Laser systems and their support equipment shall be designed to minimize accessibility to hazardous emissions during maintenance activities.*

6.13 Are warning labels affixed near the beam exit port and the laser fire button (as applicable) for all Class 3b and 4 lasers?

[MIL-STD-1425A – Par4.4.1] *Class 3b and Class 4 lasers shall be provided with a permanently affixed and legible label (or inscribed) and be easily viewed. The label shall be affixed to the laser system housing near the fire button and exit port when the port is remote from the operator in such a manner that viewing the label does not require personnel exposure to laser radiation. The label shall use the word "DANGER" and include the type of laser and the word "VISIBLE" or "INVISIBLE" as appropriate shall precede the word "RADIATION." The label shall also contain a safety statement for the operator or bystander as applicable. Refer to the document for recommended wording.*

[ANSI Z136.1-2014, Par 4.6.6] *Lasers or laser systems in most cases are required to be designated for a specific class by the manufacturer in accordance with the FLLPS or IEC 60825-1. These will bear appropriate laser equipment labels.*

6.14 Do lasers conform to the Code of Federal Regulations requirements as detailed in the system specification? If the answer is NO, answer questions 6.15 – 6.17.

[MIL-HDBK-454B – Par 4.6.3] *Laser equipment and system design, installation, and operational and maintenance procedures should conform to 21 CFR 1040 and ANSI Z136.1. If these cannot be met because of operational requirements, an exemption should be requested from the FDA through the procuring activity, and applicable military laser safety requirements in MIL-STD-1425 must be considered.*

[MIL-STD-1425A – Par 4.3.1*] Lasers classified as ANSI Class 1, Class 2, Class 2a, or Class 3a will meet the design (performance) requirements of 21 CFR Class I, Class II, Class IIa or Class IIIa respectively except where such requirements restrict operational capability or security.*

[21 CFR 1040 – Par Sec. 1040.10] *Provisions of this regulation are applicable as specified to all new laser products except when integrated by a manufacturer or sold as a replacement part for an electronic product and is not a removable product. Also, the manufacturer must register laser product and provide details including product name, model number and laser medium or emitted wavelength(s), and the name*

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and address of the manufacturer.
6.15 Has a military exemption been approved through the contracting office? [MIL-HDBK-454B – Par 4.6.3] *Laser equipment and system design, installation, and operational and maintenance procedures should conform to 21 CFR 1040 and ANSI Z136.1. If these cannot be met because of operational requirements, an exemption should be requested from the FDA through the procuring activity, and applicable military laser safety requirements in MIL-STD-1425 must be considered.* [MIL-STD-1425A – Par 1.2] *This MIL-STD provides requirements for the safe design of military laser products. Laser products normally must comply with the Radiation Safety Performance Standards issued by the Food and Drug Administration (FDA), in Title 21, Code of Federal Regulations, Subchapter (also referred to as the FDA Standard). The FDA Commissioner has exempted military laser products from those provisions of the FDA Standard where compliance would hinder mission fulfillment during actual combat or combat training operations or when the laser product is classified in the interest of national security (FDA Exemption No. 76 EL-01 DOD).*
6.16 Do exempt laser systems comply with MIL-STD-1425A? [MIL-HDBK-454B – Par 4.6.3] *If the laser equipment is not required to confirm to 21 CFR 1040 and ANSI Z136 due to operational requirements (and applicable waivers obtained) then safety requirements in MIL-STD-1425 must be considered.* [MIL-STD-1425A – Par 6.1] *This standard is used in lieu of the federal standard on lasers (21 CFR 1040.10) when the military exemption is used.*
6.17 Are exempt laser systems provided with a permanent caution label notifying of such? [MIL-HDBK-454B – Par 4.8] *A permanent label must be affixed on all military laser systems that have been certified exempt from 21 CFR 1040 (Performance Standards for Light-Emitting Products). The label should be in accordance with ANSI Z535.3, ANSI Z535.4, or ANSI Z535.5, and must use the single word caution, and read: CAUTION This electronic product has been exempted from FDA radiation safety performance standards, prescribed in the Code of Federal Regulations, title 21, chapter I, subchapter J, pursuant to exemption no. 76 EL-01 DOD issued on 26 July 1976. This product should not be used without adequate protective devices or procedures.* [MIL-STD-1425A – Par 4.2.2] *This MIL-STD requires the same caution label as specified in MIL-HDBK-454A for use on every exempt laser product. The label shall be permanently affixed to the device and be easily viewed.*

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[21 CFR 1040 – Par 1040.10] *Each Class IIa laser product shall have affixed a label bearing the following wording: ``Class IIa Laser Product--Avoid Long-Term Viewing of Direct Laser Radiation. “”Each Class II laser product shall have affixed a label with the following wording: “LASER RADIATION--DO NOT STARE INTO BEAM”; and “CLASS II LASER PRODUCT”. Each Class IIIa laser product with an irradiance less than or equal to $2.5x10^{-3}$ W cm^{2-} shall have affixed a label with the following wording: “LASER RADIATION--DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS”; and, “CLASS IIIa LASER PRODUCT”. Each Class IIIa laser product with an irradiance greater than $2.5x10^{-3}$ W cm^{-2} shall have affixed a label with the following wording: “LASER RADIATION--AVOID DIRECT EYE EXPOSURE”; and, ”CLASS IIIa LASER PRODUCT”. Each Class IIIb laser product shall have affixed a label with the following wording: “LASER RADIATION--AVOID DIRECT EXPOSURE TO BEAM”; and,”CLASS IIIb LASER PRODUCT”. Each Class IV laser product shall have affixed a label with the following wording: “LASER RADIATION--AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION”; and, “CLASS IV LASER PRODUCT”.*

Section 7: Antenna and Mast Safety

7.1 Are antenna elements and terminals located and/or insulated to prevent shock hazards and RF burns?

[MIL-HDBK-454A – Par 4.5.3.4] *Transmitter output terminals, antennas and other devices that carry sufficient RF voltage to burn or injure personnel should be protected from accidental contact in the same manner as for ac voltages greater than 30 volts rms.*

7.2 Are antenna tips designed to prevent puncture wounds?

There have been a number of deaths and injuries reported due to personnel walking into sharp antenna terminals.

[TB 43-0129 – Par 2.3] *Ensure that an antenna ball (NSN: 5985-00-930-7223) is placed on the end of the antenna and secured with tape. Periodically check to make sure that it is secure. The antenna tip can cause serious injury and death by penetrating the skull through an eye. If an antenna ball is not immediately available, use a tennis ball or something that is blunt and greater than 1.75 inches in diameter.*

[FORSCOM Reg 385-1, par 5-7.c] *The end of antennas will be blunted with an antenna tip assembly (FSN 5820-437-2353 for the AS1729 or AT-912 and FSN 5985-930-7223 for the MS-118A) and tied down to a level above the heads of pedestrians.*

7.3 Are labels provided near the antenna to warn against contact with overhead electrical lines?

[MIL-HDBK-454A **–** Par 4.8] *Equipment safety markings. Danger, warning, caution, signs, labels, tags and markings should be used to warn of specific hazards such as voltage, current, thermal, or physical. The signs, labels, tags, and markings should be as permanent as the normal life expectancy of the equipment on which they are affixed.*

[FM 24-18 – Par 3-13] *WARNING: When an antenna must be left fully extended while in motion, contact with overhead power lines must be avoided. Death or serious injury can result if a vehicular antenna strikes a high-voltage transmission line. If the antenna is tied down, be sure the tip protector is in place.*

7.4 Are antennas provided with blocking capacitors or coated with dielectric material to insulate against overhead electrical lines?

There have been a number of deaths and injuries reported where antennas contacted overhead high voltage lines. From lessons learned, vehicular mounted antennas capable of hitting power lines should be provided with protection to prevent equipment damage or injury in the event of contact.

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7.5 Where whip antennas can contact overhead electrical lines, are tie down means provided and locations identified?

There have been a number of deaths and injuries reported where antennas contacted overhead obstructions and high voltage lines. Long whip antennas that hit overhead objects can also whip back and injure vehicle occupants or pedestrians near the vehicle. Provisions to tie down antennas prior to traveling under power lines must be provided.

[FORSCOM Reg 385-1, par 5-7.c] *Drivers of vehicles equipped with radio antennas will be given special instructions on the hazards of fire or electrocution from antennas contacting overhead electric power lines. Antennas for all vehicles, both tracked and wheeled, will be tied down to a height considered safe for highway or cross-country travel to avoid contact with power lines, antennas should be no more than 13 feet and no less than 8 feet off the ground.*

7.6 Are antennas (extended or tied down) located to avoid RF shock hazards or unacceptable RF radiation levels at seats, hatches, gunner's rings, and other locations that may be occupied by personnel?

When evaluating antenna radiation hazards, consideration needs to be given to windows, hatches, and where personnel may be standing near the vehicle. Consider Gunners rings and whether weapons can contact antennas when extended or tied down.

[MIL-HDBK-454A Guideline1 **–** Par 4.6.1] *Microwave and rf radiation. All electronic equipment or electrical devices capable of emitting microwave or RF radiation between 3 kHz and 300 GHz should be so designed, fabricated, shielded and operated as to avoid overexposure of personnel. Exposure to RF radiation should meet the Controlled and/or Uncontrolled environment Maximum Permissible Exposure Levels called out in IEEE/ANSI C95.1. In areas where unintended radiation levels exist, equipment design and installation in any unrestricted area accessible to personnel should meet the Uncontrolled environment requirements of IEEE/ANSI C95.1*

[MIL-HDBK-454A Guideline1 **–** Par 4.5.3.4] *Guarding of RF voltages. Transmitter output terminals, antennas and other devices that carry sufficient rf voltage to burn or injure personnel should be protected from accidental contact in the same manner as for ac voltages greater than 30 volts rms.*

7.7 Are lock-out devices provided for remotely-operated antennas posing a mechanical, RF hazard to maintainers?

From lessons learned, any antennas that can be operated remotely must be provided with provisions to prevent transmission or movement during maintenance or repair

[MIL-HDBK-454A Guideline1 **–** Par 4.5.4.3] - *remotely located units shall have provisions for non-overrideble safety switches to allow independent disconnection.*

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7.8 Are winches, collapsible parts, tensioners, and other similar devices provided with safety latches or the like to prevent unintended collapse, free-wheeling, or uncontrolled release of guy cable? *From lessons learned, safety stops must be implemented on winches and similar devices to prevent unintended release of masts or guy wires and possible subsequent collapse.*
7.9 If the answer to question 7.8 is YES, are the safety latches designed to prevent accidental or intentional bypass? *From lessons learned, winches or similar devices must include spring loaded safety catches, for example, to prevent inadvertent release of tension. Safety latches should be designed so that they can't be bypassed by being taped down, bent, or another easy means.*
7.10 For masts greater than 45 feet in height, is a means provided (pulley & rope, etc) to raise any warning beacons that may be required at a particular locality? [TB 43-0134 – Par 2-7] *Antenna masts pose a hazard to aircraft conducting nap-of-the earth missions using Night Vision Devices. A warning device beacon may be required for the antenna masts, depending on the deployment location. Flashlights or chem. lights are usually suitable. It is the responsibility of the operator/supervisor to determine what specific requirements apply prior to erection of the mast. Check with the local Aviation Safety Officer (ASO) to determine specific requirements at your location, before your mission. The local requirements should then become part of your unit Standard Operating Procedures (SOP).*
7.11 Are level indication devices provided to ensure that the mast is level? *From lessons learned, masts must be provided with bubble levels or similar means to ensure that the masts are deployed in a level manner to prevent mast collapse.*
7.12 Are tripping and "clothes- hanger" hazards due to guy wires minimized? *From lessons learned, for any masts requiring guy wires the guy wires should be run along the ground or a means must be provided to mark the guy wires to prevent hazards to foot or vehicular traffic.*
7.13 Can the designated crew size safety setup and tear down the antenna mast? *From lessons learned, more than one person may be required to deploy or retract the antenna mast safely. It must be determined if the planned crew size is adequate to perform this task.*

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7.14 Are alternative methods of recovering the mast during emergencies, component failure, ice buildup, or jamming safe? [TB 43-0129 – Par 2-6] *The TM must address how to avoid injury from any falling ice during mast recovery. The area surrounding the antenna mast should be marked and roped off to avoid falling ice.*
7.15 Are maximum wind speed limits identified for safe mast assembly, removal, and maintenance? [TB 43-0129 – Par 2.5] *Users must ensure that the wind speed is not excessive during deployment/retraction operations. Maximum safe wind speeds must be provided in the system technical manual. Use/reference the chart in the TB to enable the users to determine approximate wind speed.*
7.16 Are stakes suitably sized to prevent pull-out in all soil conditions for worst case wind load conditions? *From lessons learned, stakes must be of the proper size to support the antenna under normal and windy conditions. Provisions such as sandbags, to be set on top of the stakes, must be considered to help to prevent stakes from pulling-out of sandy soil. Ensure that spare stakes are readily available.*
7.17 Are tripods designed so that adjustments can be safely made at any time during erection of the mast should any of the legs sink? *From lessons learned, tripods should have provisions to be able to raise or lower legs during deployment so that leveling corrections can be made to prevent mast tipping.*
Questions 7.18 through 7.22 pertain to antenna masts integrated onto vehicles or shelters.
7.18 Is an audible and visual warning provided to the driver when movement of the vehicle is attempted while the antenna mast is extended? *There have been reported incidents (both military and in industry) of vehicles being driven off with antenna masts extended. An audible and visual indicator needs to be provided so that the vehicle driver will be warned if he tries to move the vehicle with the mast extended. The Electronic News Gathering (ENG) industry has much experience in integrating vans with telescoping antenna masts. Industry safety practices are starting to be incorporated into requirements such as the California Code of Regulations.* [CA COR, Title 8, Ch 4, Sub 5, Group 2, Art 40, Sec 2981(d)] *Audible and visual warnings shall be provided to warn the driver when movement of the Electronic News Gathering*

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(ENG) vehicle is attempted while the mast, dish, or similar structure (antenna) is not stowed. A visual warning readily observable to the driver shall occur when the engine is running and the antenna is not stowed. A non-cancelable audible alarm with a nominal sound loudness of 80-85dB at the driver's position shall occur when movement of the vehicle is attempted unless the elevating antenna is stowed.
7.19 Are mast controls located to assure that the user can continuously and responsibly observe the environment overhead during the raising or lowering of the mast? *Users need to maintain visual contact with the mast during the raising/retracting process, especially where obstructions are near-by. Furthermore, the vehicle can shift as the mast is extended if not level – all the more reason to maintain visual contact during the process. This cannot be done if the controls are located within a shelter or vehicle cab.* [CA COR, Title 8, Ch 4, Sub 5, Group 2, Art 40, Sec 2981(a)] *Positive means, such as momentary contact (continuous pressure) switches, shall be used to raise or rotate elevating antennas, such as microwave masts, dishes, or similar structures. The switch shall be located to assure that personnel operating the elevating antenna will be where they can continuously and responsibly observe the environment overhead during the raising or rotating operation.*
7.20 Are positive means, such as momentary contact (continuous pressure) switches, used to raise and lower the mast? *Users need to maintain visual contact with the mast during the raising/retracting process. Controls should be designed so that users cannot just turn on a switch and walk away during the raising/retracting process.* [CA COR, Title 8, Ch 4, Sub 5, Group 2, Art 40, Sec 2981(a)] *Positive means, such as momentary contact (continuous pressure) switches, shall be used to raise or rotate elevating antennas, such as microwave masts, dishes, or similar structures.*
7.21 Are mast controls (hardware and software) designed to avoid unintentional extension of the mast when the vehicle is moving? *Mast controls must be reliable in order to prevent the mast from accidentally raising when the vehicle is being driven.*
7.22 Do antenna signal cables incorporate discharge units to limit voltages due to lightning or unintentional contact with high voltage lines? *In cases where antenna masts are integrated onto/into shelters, special care needs to be taken to provide adequate surge protection and bonding to prevent equipment and*

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components within the shelter from becoming energized.
Questions 7.23 through 7.34 pertain to Lightning Protection Adequacy. Note: if the mast is electrically continuous, treat it as the down conductor.
7.23 If antenna acts as an aerial terminal, does conductivity equal or better that of #3 AWG solid copper? *From lessons learned, if antennas are not provided with separate air terminals or are acting as air terminals they must be of sufficient size to prevent damage from lightning strikes.*
7.24 If the answer to question 7.23 is NO (e.g. dish antenna), is the antenna contained within a 45^{o} cone from the tip of a provided air terminal? [TR 93-1 – Chapter 3] *If any component of the antenna assembly is outside the cone of protection it is more likely that a lightning strike could damage it.*
7.25 Is down conductor equivalent to #3 AWG solid copper with a minimum strand size of #17 AWG? [TR93-1-Chapter 3] *A #3, flat copper braid also provides good protection but can be more easily handled and less easily damaged compared to solid copper. Stranded cable can also be handled easier than a solid wire. Also, 0.25 inch steel cable is another alternate and is better than an aluminum wire.*
7.26 Are joints mechanically strong & corrosion resistant? TR93-1-Chapter 3] *Connectors used to fasten the down conductor to the ground rod must be tightened using a wrench in order to survive a lightning strike. Hand tightening may not provide adequate strength.* [MIL-HDBK-454A – Par 4.1] *Metals should be corrosion resistant or should be coated or metallurgically processed to resist corrosion.*
7.27 Are resistance of joints less than that of 2 ft.(.6 m) of down conductor? (R=.002 ohms or less – negligible resistance) [TR93-1-Chapter 3] *Connectors used to fasten the down conductor to the ground rod must be tightened using a wrench in order to survive a lightning strike. Hand tightening may not provide adequate mechanical strength. Also, the type of connector chosen must provide maximum surface contact with the ground conductor to minimize resistance.*

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7.28 Will the down conductor remain free of bends or kinks after repeated use? [TR93-1-Chapter 3] *Use copper braid to minimize possibility of kinking. Kinks in the ground conductor will be a failure point in the event of a lightning strike. Therefore, replace damaged or kinked down conductors prior to installation.*
7.29 Is down conductor straight as possible with any turns not less than 90 degrees with 8 inch radius of turn? [TR93-1-Chapter 3] *Kinks in the down conductor will be torn apart by the lightning current causing failure to the protective system.* [TM 5-690 - par 3-4] *Install down conductors so that they offer the least possible impedance to the passage of stroke currents between the air terminals and the earth. The most direct path is the best. The radius of conductor bends shall not be less than 8 inches nor shall the angle of such bends be less than 90 degrees.*
7.30 Is ground rod at least 1/2 inch in diameter, 8 ft long, copper clad steel or equivalent? [TM 5-690 - par 3-2] *Ground rods are commercially manufactured in (1/2, 5/8, 3/4 and 1 inch) diameters and in lengths from 5 to 40 feet. Copper-clad steel ground rods are required because the steel core provides the strength to withstand the driving force and the copper provides corrosion protection and is compatible with copper or copper-clad interconnecting cables.*
7.31 Is ground rod free of paint? [TM 5-690 - par 4-4] *To achieve an effective and reliable bond, the surfaces to be bonded must be free of any foreign materials, e.g., dirt, filings, preservatives, etc., and non-conducting films such as paint, anodizing, and oxides and other metallic films. Commercial paint removers can be used effectively. If chemical solvents cannot be used effectively or are not permitted, mechanical removal with scrapers, wire brushes, power sanders, sandpaper, or blasters should be employed. Final cleaning should be done with a fine, such as 400-grit, sandpaper or steel wool.*
7.32 Does antenna mast configuration during erection, storage, takedown or operation prevent any component of the lightning protection system from mechanical damage or wear? [TM 5-690 - par 3-4] *To keep from exploding, igniting, or otherwise being destroyed, air*

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terminals should be made of copper, aluminum, brass, or bronze. The minimum sizes are 1.27 cm (1/2 inch) in diameter for solid copper, brass, or bronze rods and 1.6 cm (5/8 inch) in diameter for solid aluminum rods.
7.33 If mast is electrically continuous and is acting as the down conductor, is the ground stud adequate? *From lessons learned, ground studs provided on the mast must allow secure attachment of the required size ground strap between the mast and ground rod.*
7.34 Is a safety tip cap provided for the air terminal (lightning rod)? *A tip cap must be installed on the lightning rod prior to handling, deploying, or removal from the mast to prevent injury.*

SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST HANDBOOK
PART 8: BATTERY SAFETY

Section 8: Battery Safety

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This section to be addressed in the future

Section 9: Generators

9.1 Is a main circuit breaker provided and located in an easily accessible location?

This ensures that the generator output power can easily be shut off during an emergency. It also provides overload protection to the generator and supply conductors. Personnel must be able to easily access the circuit breaker without exposing to any unsafe conditions. Refer to Checklist Handbook Section 1, questions 1.57, 1.58, and 1.71-1.75 for additional guidance.

- **NFPA 70-05 –** Article 445.18 states that generators shall be equipped with disconnect(s) by means of which the generator and all protective devices and control apparatus are able to be disconnected entirely from the circuits supplied by the generator. Additional conditions apply. Article 445.12 requires overcurrent protection.
- **MIL-HDBK-454A** Guideline 8 – Par 4.5.1 states that if a main power switch is provided, it should be clearly labeled as such and should cut off all power to the complete equipment.
- **UL 2200 –** par 25.3.1 states an output circuit shall be provided with overcurrent protection for all ungrounded conductors. The overcurrent protection device shall be a circuit breaker, fuse or equivalent means intended for use as branch circuit protection and located within 25 feet (7.62 meters) of the generator output terminals. Par 25.1.1 requires the overcurrent protective device to be accessible.

9.2 Are the following protective devices present with suitable indicators to safeguard against operator injury and/or equipment damage: over-speed, over-temperature, over-voltage, overload and short circuit, low oil pressure and low fuel?

The protective devices can disable the generator operation automatically if one of the above fault conditions is detected. The indicators provide information on the fault conditions to personnel who can implement necessary corrective actions immediately to prevent personnel injury and/or equipment damage.

- **NFPA 110 –** NFPA 110 covers performance requirements for emergency and standby power systems providing an alternate source of electrical power to loads in buildings and facilities in the event that the primary power source fails. Par 5.6.3.3 states the generator prime mover shall be provided with the following instruments: (1) Oil pressure gauge to indicate lubricating oil pressure. Engines with splash-lubricated systems shall not require this gauge. (2) Temperature gauge to indicate cooling medium temperature. Air-cooled engines shall not require this gauge. (3) Hour meter to indicate actual total running time. (4) Battery-charging meter indicating performance of prime mover–driven battery charging means. (5) Other instruments as recommended or provided by the prime mover manufacturer where required for maintenance.
- **NFPA 37-02** – Chapter 9 provides guidance on controls and instrumentation.

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9.3 Is the battle short switch provided and located on the main control panel?

The battle short switch is a switch that when activated can bypass normal interlocks in the generator for continuous operation during mission critical conditions. (This is a unique military requirement.)

- **NFPA 110 –** Section 5.6.5.2 provides guidance on controls, alarms, and warning devices that differ depending on how critical it is for the power source to remain operational.
- **MIL-HDBK-454A – Guideline 1,** Par 4.4.4.2: When a battle short switch is required by the individual equipment specification, a readily visible indicator light shall be provided to indicate when the battle short switch is on.

9.4 Are all supply connection points clearly marked with terminal information and polarity?

The markings ensure that terminals are clearly identified to minimize the potential of connecting to wrong connectors/polarity and creating potential hazards.

- **NFPA 70-05 –** Article 210.5(C) states that where more than one nominal voltage system exists in a building, each ungrounded conductor of a multiwire branch circuit, where accessible, shall be identified by phase and system.
- **MIL-HDBK-454A – Guideline 1,** Par4.4.6: Connectors used in multiple electric circuits shall be selected to preclude mismating. Where design considerations require plug and receptacles of similar configuration in close proximity, the mating plugs and receptacles shall be suitably coded or marked to clearly indicate the mating connectors.
- **UL 2200 –** par 61.2.6 Wiring terminals shall be marked to indicate the proper connections for the unit, or a wiring diagram coded to the terminal marking shall be securely attached to the equipment. Section 61.2 contains other marking requirements such as “copper-only terminals”, the equipment grounding conductor, the grounded conductor, and a grounding electrode conductor as applicable.

9.5 Are all convenience receptacles provided with overcurrent protection as well as ground-fault circuit interrupter protection?

The overcurrent protection opens up a circuit whenever an overload condition occurs. The GFCI opens up a circuit if item connecting to convenience receptacle causes excessive leakage current to ground. The overcurrent protections are provided to ensure equipment safety, and the GFCIs are provided to ensure personnel safety. Refer to Checklist Handbook Section 1, question 1.71 for additional guidance.

- **NFPA 70-05 –** Article 210.8 addresses requirements for the use of ground-fault circuit-interrupter protection for receptacles at certain locations. Article 210.20

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addresses requirements for branch circuits overcurrent and overload protection.

- **UL 2200 –** par 25.3.1 requires output circuit to be provided with overcurrent protection for all ungrounded conductors.

9.6 Are outdoor receptacles protected from the weather whether or not the attachment plug cap is inserted?

The NEC states that receptacles installed in wet locations shall have an enclosure that is weatherproof whether or not an attachment plug cap is inserted. Wet locations are those installed in unprotected areas exposed to weather or where subject to saturation with water or other liquids.

The NEC relaxes this requirement for receptacles installed outdoors in locations protected from the weather or in other damp locations. In those locations, the receptacle shall have an enclosure that is weatherproof when the receptacle is covered (attachment plug cap not inserted and receptacle covers closed). Damp locations are those that are protected from weather and not subject to saturation with water or other liquids but subject to moderate degrees of moisture, such as under canopies, rooted open porches, etc.

Based on the above, a receptacle installed on the exterior of a shelter that is directly exposed to the elements must have a cover that will be weather proof with an attachment plug cap inserted. However, if the receptacle is located at a power entry panel that has a hooded cover, the location may meet the definition of a damp location and may only require a cover that is weatherproof without an attachment plug cap inserted.

- **NFPA 70-05 -** Article 406.8 applies.

9.7 Is a suitable grounding terminal lug provided and identified for connection to an earth-grounding electrode?

Generators need to be grounded to the earth-grounding electrode before use to prevent personnel hazard if there is a fault in the circuit or lightning strikes. The grounding terminal lug on generator provides suitable connection points to install conductor from the generator to the earth-grounding electrode.

- **NFPA 70-05** – article 250.4 provides general performance requirements for grounding and bonding. Article 25.20 specifies which alternating current systems must be grounded. Article 250.34 applies to portable generators and vehicle mounted generators and specifies limited cases where the generator frame does not have to be connected to an earth grounding electrode. Articles 250.8, 250.10, and 250.70 describe accepted grounding connection methods.
- **MIL-STD-454A** – Guideline 1, Par 5.2.3: Ground connection to an electrically conductive chassis or frame should be mechanically secured by soldering to a spotwelded into a soldering lug, or by use of a terminal on the ground wire and then securing the terminal by a screw, nut, and lock washer.

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- **UL 2200 –** par 14.1.1 states that the generator assembly shall be provided with a means for grounding the output circuits in accordance with the National Electric Code, NFPA 70, Article 250. Par 14.1.6 states a fixed unit shall be provided with a terminal for connection of the grounding electrode conductor to the metal enclosure or equipment grounding conductor.

9.8 Is an Army approved grounding system fielded with the generator set and is a storage location provided for it?

The grounding system consists of the grounding electrode conductor, the connection point, and the earth-grounding electrode. The conductor must be as large as possible: at least 6 AWG. The connection point between the conductor and grounding electrode must be tight, electrically continuous, and free of paint and corrosion. The grounding electrode must be an Army approved ground rod, Surface Wire Grounding Kit. For the convenience of and proper deployment, it is imperative that grounding system must be fielded with the generator set and be stored inside the generator housing or other convenience locations clearly marked on the generator set exterior. By doing so, it is more likely to prevent using the generator set without grounding the set first.

- **NFPA 70-05** – Article 25.20 specifies which alternating current systems must be grounded. Article 250.34 applies to portable generators and vehicle mounted generators and specifies limited cases where the generator frame does not have to be connected to an earth grounding electrode. Articles 250, Part III Grounding Electrode Systems and Grounding Electrode Conductor, identifies suitable earth grounding systems
- **MIL-HDBK-454A –** Guideline 1, Par 4.5.2: The design and construction of equipment, excluding self-powered equipment, shall insure that all external parts, surfaces, and shields, exclusive of antenna and transmission line terminals, are at ground potential at all times during normal operation.

9.9 Are components, conductors and shielding appropriately located such that overheating, arching, shorting and contact with moving parts is avoid?

Components and conductors must be mounted, routed, and protected such that they are not damaged due to moving parts, overheating, arcing and contact with moving parts. Where components or conductors can be exposed to physical or thermal damage, supplemental protection is required. Consider user and maintainer actions that could lead to component and conductor damage. Refer to Checklist Handbook Section 1, questions 1.16, 1.28, and 1.29 for additional guidance.

- **NFPA 70-05 -** articles 300 covers wiring that is not an integral part of equipment (see 300.1(B) limitation). For instance, power distribution and branch circuits within a shelter would be covered under article 300. For wiring that is integral to a specific

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piece of equipment, the appropriate product safety standard would apply.

- **NFPA 37-02** – section 4.5.3 covering engine wiring states that wire and insulation materials shall (1) have the capacity to remain flexible over typical engine operating temperature ranges; (2) have the capacity to have the minimum possible absorption of oils, fuels, and other fluids commonly found on or near the engine; (3) be rated for continuous use at the maximum range of temperatures that will occur where installed.
- **MIL-HDBK-454A -** guideline 1, par 4.5.2.4 recommends that cable shielding end at a sufficient distance from exposed conductors to prevent shorting or arcing.
- **MIL-STD-1472F –** Par 5.9.13.6 states that cables shall be routed or protected to preclude mechanical damage and abuse, including damage by doors, lids, use as steps or handholds, or being bent or twisted sharply or repeatedly.
- **UL 2200 –** Section 17.2 covers protection of wiring. Section 20 covers spacing requirements between live parts and ground.

9.10 Are battery terminals and cables marked for polarity and provided with nonconductive guards to prevent accidental shorting?

The polarity markings inform personnel for positive and negative terminals on batteries and reversing the polarity during battery connection is minimized. Refer to Checklist Handbook Section 1, question 1.34 for additional guidance.

High current sources (greater than 25 amperes) are potential fire hazards due to arcing/heating effects, though associated voltages may be at safe levels from an electrical shock standpoint. For instance, a 12 volt car battery typically does not pose a shock hazard, but could instantly weld any metal parts or tools shorting across both terminals due to the hundreds of amperes available at the terminals. The nonconductive guards prevent batteries from shorting if tool is accidentally dropped on the terminals. Refer to Checklist Handbook Section 1, question 1.11 for additional guidance.

- **NFPA 70-05 –** Article 725 covers requirements for Class 2 and Class 3 circuits where current is limited to values considered to be safe from a fire initiation standpoint. Values are further specified in Chapter 9, tables 11(A) and (B), and are limited to 8 Amps max (typically much less). Article 411 covering Low Voltage (<30V) Lighting systems limits these systems to a maximum of 25 amps. Articles 210.5(C) states that where more than one nominal voltage system exists in a building, each ungrounded conductor of a multiwire branch circuit, where accessible, shall be identified by phase and system.
- **NFPA 37-02** – section 4.5.4 states batteries, wiring, and electrical devices shall be protected against arcing and accidental shorting.
- **MIL-STD-1472F –** Par 5.13.7.1.2 states batteries that have ratings greater than 25 amp hours shall have terminal guarding to prevent inadvertent short-circuit. Such guarding shall also prevent short-circuiting the battery in spite of clearly improper

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but possible acts by personnel, such as placing tools across terminals, resting a heavy object on the battery cover, and standing on a battery cover.

- **MIL-HDBK-454A –** par 5.2.4.1 states all power buses supplying 25 amperes or over should be protected against accidental short-circuiting by tools, jewelry or removable conductive assemblies.
- **UL 60950 –** Par 1.2.8.8 defines hazardous energy levels. Par 2.1.1.5 states there shall be no energy hazard in operator access areas. Par. 2.1.2 addresses maintainer protection against energy hazards.
- **UL 2200 –** Par 33.1.1 states that when a separate lead-acid storage battery is intended to be placed in a compartment provided with, or as part of, the engine generator assembly, it shall be secured in position to prevent contact with conducting materials in the area and be readily accessible for servicing. Par 34.3 states that an uninsulated live part involving a risk of electric shock or electrical energy – high current levels shall be located, guarded, or enclosed so as to reduce the risk of unintentional contact by service personnel adjusting or resetting controls, or similar service, or performing mechanical service functions that are performed with the equipment energized.

9.11 Are tools to be used near high voltages, such as load terminal wrench, adequately insulated?

Use of insulated tools helps to reduce the potential of electrical shock when working on or near parts that may be energized.

- **NFPA 70E –** Article 130.7 addresses personal protective equipment, which requires the use of insulated tools where working on or near energized parts.

9.12 Are fuel lines adequately supported and separated from live wires and cables?

Adequately supported fuel lines insure that cracks and leaks do not develop in the fuel lines during normal usage. Separated fuel lines from live wires and cables eliminate the potential of igniting the leaking fuel from the possible electrical sparks.

- **UL 2200 –** Par 35.1.3.8 states that fuel lines shall be supported to minimize chafing and to maintain at least a 2 inch (51 mm) clearance from bare exhaust components. Electrical wiring shall not be tied to fuel lines and shall be routed so that it maintains 1/2 inch (12.7 mm) clearance from fuel lines. Par 35.1.3.9 states that fuel feed lines, valves, and fittings shall be located so that any leakage does not run off or drip on electrical- or exhaust-system parts.

9.13 Are fuel lines projecting through metal apertures protected by grommets and secured to framing members?

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This insures that fuel lines cannot be rubbing against the sharp edges when passing through metal apertures. Securing fuel lines to framing members insure that fuel lines do not move during transport and prevent potential damage by hitting other objects near by.

- **UL 2200 –** Par 35.1.3.8 states that fuel lines shall be supported to minimize chafing.

9.14 Is thermal and sound insulating material treated with fire retardant, free from noxious fumes, unaffected by battery electrolyte or petroleum derivatives, capable of maintaining its shape, position and consistency inherently or by retaining methods, and replaceable?

Generators are usually treated with sound insulating material to reduce noise levels. Insulating material is also provided as thermal protection against high temperatures inside the generators. The insulating material should not ignite under worst case operating conditions nor should give off noxious fumes if ignited. The insulating material should hold its shape inside the high temperature of generators, and should be replaceable if damaged.

- **NFPA 37-02** – section 4.5.3 covering engine wiring states that wire and insulation materials shall (1) have the capacity to remain flexible over typical engine operating temperature ranges; (2) have the capacity to have the minimum possible absorption of oils, fuels, and other fluids commonly found on or near the engine; (3) be rated for continuous use at the maximum range of temperatures that will occur where installed.

9.15 Where safe noise levels can be exceeded during operation or maintenance, are appropriate warning labels provided on the equipment?

If the generator noise levels exceed 85 dBA during operation or maintenance (service panels removed), warning labels shall be affixed on generator to require hearing protection and specifying the hazard distance.

- **MIL-STD–1474 –** Par. 4.3: When steady state equipment noise levels exceed 85dBA at locations specified in 5.1.2.1.2, noise hazard caution signs shall be permanently posted on (or in) the equipment.
- **29 CFR 1910.95(d)(1)** - “When information indicates that any employee’s exposure may equal or exceed an 8-hour-time-weighted average of 85 decibels, the employer shall develop and implement a monitoring program.” A warning label will notify the system users and bystanders to get proper hearing protections and reduce the potential of noise over-exposure.

9.16 Is a type B:C Dry Chemical extinguisher provided with the generator? Specify size.

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Extinguishers are needed to fight fires that could occur with generators. Type B:C fire extinguishers are rated for flammable liquid and electrical related fires, and are suitable to fight generator fires.

- **FM 21-31** – Chapter 3 requires fire point to be set up near the generator set which includes a fire extinguisher.

9.17 Is CARC paint applied only to surfaces that will not exceed 400 deg. F?

Chemical Agent Resistant Coating (CARC) paint is applied to the external surface and should be marked with "CARC". At high temperatures, CARC paint will decompose and generate toxic gas and vapor that are harmful to personnel.

- **AR 750-1** – Par. 7-8.b (10)(a): restrict the application of CARA onto items that attain surface temperatures of 400 degree Fahrenheit and higher.

9.18 Is the generator exhaust located and directed away from operator designated areas?

This minimizes the potential of operator exposure to unacceptable levels of diesel exhaust emissions.

- **MIL-STD-1472 –** Par. 5.13.7.4.2: Carbon monoxide in personnel areas shall be reduced to the lowest level feasible.

9.19 Is the air intake at a sufficient distance from the exhaust?

This insures that the exhaust gas cannot enter the air intake and reduces the generator efficiency. This also reduces the oxygen content in the intake air to sustain the combustion.

9.20 Is the fuel tank designed and located in a manner that will not allow spills or overflow to run into the engine, exhaust or electrical equipment?

The fuel tank spout should be located so that there's adequate space for refueling and so that any spillage or overflow will not flow onto exhaust and hot components, electrical components, wiring, or other items that could initiate a fire or be damaged.

- **NFPA 37-02** – section 6.5.5 states overflows, vents, fuel piping, or fuel tanks shall not be located at or near engine air intake, exhaust piping, mufflers, or filters.
- **UL 2200 –** Par 35.1.2.3 states that when a tank is within or contiguous to the engine compartment the tank location and the facilities for filling shall be such that spillage or leakage drains to the ground and not onto the engine or exhaust-system parts.

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9.21 Is the fuel system equipped with a float switch inside the tank and check valve on the pump to prevent fuel from overflowing when the set is being fueled from the auxiliary fuel connection?

A float switch in the fuel tank is necessary to prevent overflow of fuel from the fuel tank air vent. A check valve in the fuel line is needed to prevent fuel from flowing back to the auxiliary fuel source when the fuel pump is off and keep the refueling pump working non-stop.

- **NFPA 37-02** – section 6.5.3 states stationary-powered fuel pumps supplying fuel tanks shall have “stop” controls sensitive to a tank's high liquid level.

9.22 Where an auxiliary refueling system is integrated, (i.e., power unit and power plant), is a fuel line and jerry can adapter provided for connection to the external fuel container.

An adequate fuel line and jerry can adapter must be designed and provided where an auxiliary refueling system is integrated into the generator for connection to the external fuel container. The jerry can adapter will also limit spills if the can is tipped over and will control fuel vapor from jerry can during fuel transfer.

- **NFPA 37-02** – section 6.6.2 states Engine-mounted tanks for liquid fuels other than Class I fuels shall be filled by a closed piping system. Section 6.6.2.1 states filling from a container shall be permitted when the engine is shut down and engine surface temperature is below the autoignition temperature of the fuel.

9.23 Is the center of gravity and weight of the set distinctly marked?

The marking provides necessary information to ensure safe lifting and transporting of generators.

- **MIL-STD-1472 –** Par 5.13.2.2: The center of gravity and the weight of the equipment shall be distinctly marked.

9.24 Are tie-downs and lifting positions clearly marked?

Clearly marked tie-downs positions insure that adequate locations for securing generators are utilized during transport. Clearly marked lifting positions insure that generators are safely lifted by utilizing the capable lifting points on generators.

- **MIL-STD-1472 –** Par 5.9.11.3.1.2: Where mechanical or power lift is required, hoist and lift points shall be provided and clearly marked.

9.25 Are lifting rings, slings and fork-lift eyes provided?

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Suitable lifting rings, slings and/or forklift eyes must be provided to ensure that generators can be safely lifted by mechanical hoists, forklift trucks, etc.

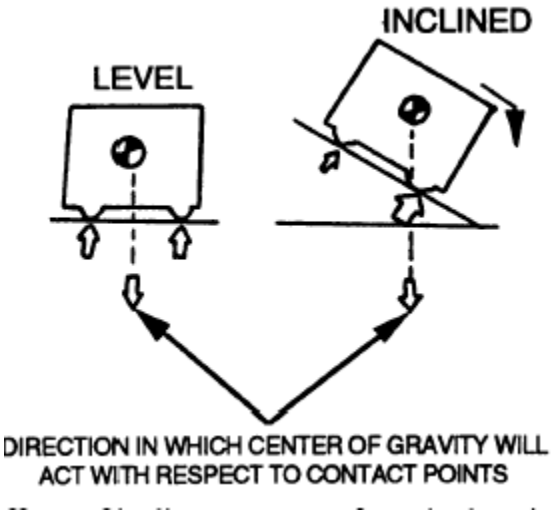
SYSTEM SAFETY DESIGN VERIFICATION CHECKLIST HANDBOOK
PART 10: EQUIPMENT INTEGRATION OF SHELTERS AND TRAILERS

Section 10: Equipment Integration of Shelters and Trailers

10.1 Is the vehicle weight properly distributed and is the vehicle laterally stable?

The equipment installed in the shelter must be evenly distributed on all corners of the shelter. Past problems have resulted because of uneven weight distribution, excessive total weight, and a high center of gravity that caused the system to be laterally unstable. While these subjects are not covered in existing system safety regulations and safety standards, an old Electronic Command Technical Requirement (SCL-1280D), dated 15 March 1965 has detailed requirements relative to these topics. Logically, the heavier components should be installed closer to the shelter floor. Equipment should be distributed throughout the shelter to equalize (to the maximum extent possible) the overall load. In the past, overweight shelters have created roadability problems and can affect safety from the viewpoint that the structure/vehicle could be overstressed, perhaps leading to structural fatigue/failure and possible accidents. Loading ancillary equipment (crew bags, camo nets, water cans, etc) internally or externally onto shelters is a normal practice in the field. Said field practice could pose stability problems for the vehicle if the weight distribution is uneven or the gross vehicle is exceeded. Specific combat load plan should be developed for the vehicle/shelter and addressed in the design and in the TM. The center of gravity, lateral stability, and system weight must be addressed as part of the verification testing process. The center of gravity of the mobile assemblage shall be such the angle between a vertical line (90 degree to the base line) through the center of gravity and a line drawn from the center of gravity to the nearest outer base ground contact point, shall be not less than 25 degrees when projected on a plane which is perpendicular to the longitudinal axis of the assembly.

Users should be aware that ramps and inclines change the way weight is distributed among the wheels; the lower wheels bear weight. With heavier equipment, this may mean that weight is concentrated enough to exceed allowable ramp loads. Shifting the center of gravity also increases the risk that equipment will overturn.



- **MIL-HDBK-759C** – Para 5.13.7.2.6 stated:

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Center of gravity. Equipment should be designed to maximize safety and stability when it is moved on inclines, such as cargo ramps, or lifted by cranes for shipping.

10.2 Does the shelter/equipment center of gravity (COG) fall within the prime mover COG envelope?

The weight, weight distribution and center of gravity with respect to the specified class of prime movers shall be consistent with acceptable cross-country mobility requirements. Each mobile enclosure with equipment installed shall not exceed the gross weight of the specified class of vehicle/ tractor/trailer. Equipment should be distributed throughout the shelter to equalize the overall load. If lateral unbalance is necessary, the roadside shall be heavier and the roadside weight shall not exceed the weight of the curbside by more than 5 percent of the rated payload of the shelter/truck/cargo and van body/ semi-trailer. No vehicle shall be overloaded and its weight shall not exceed its gross vehicle weight. The front and rear axle loading on the prime mover shall not exceed the vehicle manufacturer recommended loading. For semi-trailers, the fore and aft weight distribution shall be such that approximately 1/3 of the gross weight of the trailer (trailer plus payload) is on the fifth wheel plate and 2/3 on the rear suspension system, and in no case shall the fifth-wheel plate exceed 40 percent of the trailer gross weight. Exceeding these requirements constitutes non-compliance of the requirements, and an approval shall be obtained from Military Surface Deployment and Distribution Command (SDDC) Transportation Engineering Agency.

- **MIL-HDBK-454A** – Para 5.3 stated:

Design of rack-mounted equipment should maintain the center of gravity as low as possible to minimize tipping over.

- **MIL-STD-1472F** – Par 5.13.6.4 stated:

Equipment that may tip over and injure personnel due to a high center of gravity should have anchors or outriggers for stability and shall display an appropriate warning.

10.3 Is the center of gravity and equipment weight distinctly marked?

All equipment shall be able to be moved, handled, and lifted safely. All equipment design should place equipment weight as close to the center of gravity as possible. All equipment shall be stenciled with the lifting requirement IAW MIL-STD-1472. Equipment exceeding the carrying limits for a single person lift shall have proper lifting provisions, be labeled to indicate the weight as well as the number of persons required to properly lift the item. Where more than one-person lift is required, a sufficient number of handles must be provided to allow each lifter a proper handhold. Sometimes larger handles will have to be provided to accommodate a MOPP IV gear requirement. All too often we have seen very heavy equipment that has the required lift caution label prescribing a several person lift but has an inadequate number of handles or its handles in location which result in awkward lift postures by personnel. Very heavy items (those requiring more than two-person lift) might be better lifted by mechanical means, such as a davit or hoist. The heaviest items should be placed as low as possible in equipment racks to provide minimal lifting heights. Too often very heavy items are placed in hard to reach locations. Designers need to thoroughly consider these concerns and make adequate provisions for personnel safety during the removal and re-installation of equipment/components.

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- **MIL-STD-1472F** – Para 5.9.11.3 .9 and 5.9.11.5.2 stated:

5.9.11.3.9 : Items weighing more than the one-person lift or carry values for the "Male and Female" Population of Table XVII shall be prominently labeled with weight of the object and lift limitation, e.g., mechanical or two-person lift, three-person lift. Where mechanical or power lift is required, hoist and lift points shall be provided and clearly labeled.

5.9.11.5.2 : Whenever possible, handles, grasp areas, or hoist points shall be located above the center of gravity and in a manner to preclude uncontrolled swinging or tilting when lifted. They shall be located to provide at least 5 cm (2 in) of clearance from obstructions during handling. The location of handles shall not interfere with installing, removing, operating, or maintaining the equipment

10.4 Does the system weight (including crew gear and trailer pintle weight) not exceed the load capacity of the prime mover?

In the past, overweight systems have created roadability problems and can affect safety regarding structure/vehicle overstress and perhaps leading to structural fatigue/failure and possible accidents. Soldiers loading ancillary equipment internally or externally onto the shelter are normal practice in the field. Specific combat load plan should be developed for the shelter/vehicle and addressed in the TM to prevent system overload.

Systems weighing in excess of the prime mover's maximum payload may cause potentially hazardous conditions due to possible brake, engine, tire, and suspension failure. The maximum allowable payload of the shelter's prime mover shall include the weight of the crew plus personal equipment, and spare fuel and water cans. If the vehicle's payload is exceeded, restrictions may then be required as determined through system testing.

Items of equipment developed for movement by any mode of transport should meet the payload limitations imposed by the transport equipment. Staying within the payload capabilities of the transport equipment promotes safe transport, reduces potential damage to transport equipment, and reduces transporter maintenance requirements. When determining the payload and/or gross weight of the transport equipment, the designer must consider all associated items of equipment that are transported with the item or system. Consistent with the definition of gross weight and vehicle payload, associated items of equipment may include such items as camouflage, concertina, tents, extra fuel, water, and tools and spares.

- **MIL-STD-910** – Mobile Tactical Systems Overload Prevention, Para 5.10.4, provides procedures for calculating shelter, trailer, and prime mover payloads, and determination of overloads. For Systems/Equipment/Munitions (SEM) requiring highway transport, the following prime mover characteristics shall not be exceeded. They are: towed load allowance for a cargo truck or truck tractor pintle, towed load allowance for a truck tractor fifth wheel receptacle, vertical pintle load allowance, fifth wheel receptacle vertical load allowance, and prime mover vehicle weight rating.

10.5 Has the vehicle satisfactorily passed roadworthiness testing (e.g. Munson road test)?

All assemblage (shelter/vehicle combination) shall have adequate roadability and be capable of rapid

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movement over highways and cross-country type terrain including steep slopes, rough surfaces, mud and snow. The requirements of weight, weight distribution and center of gravity with respect to the class of prime movers specified shall be consistent with acceptable cross-country mobility. Roadability needs to be addressed as early as possible and should be verified by transportability testing.

Using estimates and similarity to other assemblages in lieu of roadworthiness tests are often inaccurate due to differences between the actual system and the system used for comparison. The lessons learned from prior shelter/vehicle systems have indicated speed restrictions due to insufficient maximum speed testing, non-existent roadability tests, improperly rated vehicle tires, poor system designs resulting in overweight conditions, weight imbalance, and high center of gravity.

10.6 Have no vehicle speed restrictions been placed on the prime mover as a result of system integration?

This subject is of great concern for highly mobile vehicular/trailer mounted systems, since weight and its distribution will greatly impact on the roadability of the overall configuration. Testing of the full system in its normally intended mobile configuration must be performed to determine maximum speeds which may safely made over various surfaces and road types. Perhaps more important is roadability of the system/prime mover. An overweight system will most likely create additional operational restrictions and possible indirect safety concerns (speed restrictions, vehicle structural failure, etc.), which may not be operationally acceptable by the user

10.7 Are adequate instructions provided for placement of detached trailers?

Adequate procedures/tasks should be provided to uncouple and placement of towed trailers. Examples of tasks to be performed are: Unplug the electrical brake light plug from jack of prime mover, lower jack/landing gear into place (i.e. crank jack until trailer lifts off the prime mover, remove safety chains, remove locking pin on trailer hitch and lift latch, and separate vehicle from trailer. Make sure the trailer placement complies with emplacement slope constraints

- **MIL-STD-1472F –** Par 5.13.2.3 stated: The weight capacity shall be indicated on stands, hoists, lifts, jacks, vehicles, and similar weight-bearing equipment, so as to prevent overloading.

10.8 Are safety chains provided to prevent the trailer from detaching from the towing vehicle?

The full trailer must be equipped with a tow-bar and a means of attaching the tow-bar to the towing and towed vehicles. Safety devices in case of tow-bar failure or disconnection must be provided. Every full trailer and every converter dolly used to convert a semi-trailer to a full trailer must be coupled to the frame, or an extension of the frame, of the motor vehicle which tows it with one or more safety devices to prevent the towed vehicle from breaking loose in the event the tow-bar fails or becomes disconnected. If the safety device consists of safety chains or cables, the towed vehicle must be equipped with either two safety chains or cables or with a bridle arrangement of a single chain or cable attached to its frame or axle at two points as far as the configuration of the frame or axle permits. The safety chains or cables shall be either two separate pieces, each equipped with a hook or other means for attachment to the towing vehicle, or a single piece

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leading along each side of the tow-bar from the two points of attachment on the towed vehicle and arranged into a bridle with a single means of attachment to be connected to the towing vehicle. When a single length of cable is used, a thimble and twin-base cable clamps shall be used to form the forward bridle eye. The hook or other means of attachment to the towing vehicle shall be secured to the chains or cables in a fixed posit

- **CFR TITLE 49** – Chapter III, Subpart F, Coupling Devices and Towing Methods, Section 393.70, Para (d) (1)-(8)

10.9 Will the lifting rings support the total weight of the shelter and the installed equipment?

Per MIL-STD-1366, Transportability Criteria, New items of equipment, re-procurements of existing equipment, and modified equipment that meet the definition of a transportability problem item must have a slinging, tie-down, and for cargo carrying equipment, cargo tie-down provisions conforming to MIL-STD-209. MIL-STD-209, Military Standard, Slinging, and Tie-down Provisions for Lifting and Tying Down Military Equipment establishes dimensional limits, design considerations, positioning requirements, and strength requirements to ensure military equipment can be safely and efficiently lifted or tied-down for transport.

- **MIL- STD-1366** – Para 5.7 applies
- **MIL- 209J** – Para 5.0 to 5.5.5 provides lifting requirements

10.10 Are entries and exits free of obstructions?

The layout of equipment within the shelter needs to be carefully planned to allow for operational and maintenance efficiency while also providing for safety. Regardless of what is used as the basic enclosure, safe ingress/egress consideration must be addressed. The entrance/exit door area needs to be clear of all impediments to allow for rapid and unobstructed movement of personnel. The incorporation of two exits should be considered in shelter design. All aisles must allow for reasonable mobility. For raised shelters, external platforms adjacent to entrance/exit doors should be of a non-skid design or have non-skid surfaces. This is especially true of truck tailgates, which may be lowered and utilized as part of the entrance/exit path.

- **MIL-STD-1472F** – Par 5.13.4.2 stated:

Emergency doors and exits. Emergency doors and exits shall be clearly designated, readily accessible, unobstructed, simple to operate, simple to locate in the dark, quick opening in three seconds or less, and require 44 - 133 N (10 - 30 lb) of operating force to open. They shall not themselves, or in operation, constitute a safety hazard. They shall permit one person egress in 5 seconds or less.

- **MIL-HDBK-759C** – Para 5.7.6.5.2 stated:

Wall escape hatches in vehicle-mounted shelters should be clear of all obstructions (side panels or raised tailgate).

10.11 Do the entryway ladders or steps allow safe entrance and exit?

Boarding ladders, where used, often are at a steep angle and do not provide protection from falls. Suggests

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that designers look at their particular system and determine if a ladder/handrail combination is needed. One such ladder known to exist in the inventory under NSN 2540-00-854-4445. It is 72" x 20" has non-slip steps and one handrail. An alternate item having similar dimensions is NSN 2540-01-205-0071. If the shelter is mounted on a different type of carrier (e.g. 5-ton truck instead of a 2-1/2-ton truck), then a boarding ladder with sufficient height from the ground should be used to prevent accidents. Accidents have occurred in the past where personnel were injured by falling off boarding ladders that were too steep. In some instances, sandbags or other objects were used to make up the height. Note that a ladder (NSN 2540-01-432-9930) with adjustable legs has been designed for use with the 5-ton truck.

- **MIL-STD-1472F** – Par 5.7.6.1.3 stated:

Stairs, stair-ladders, fixed ladders, and ramps should be equipped with a handrail on each side. Where one or both sides are open, appropriate intermediate guardrails shall be provided to prevent personnel injury. Non-fixed vehicular-boarding ladders are neither stair ladders nor fixed ladders and are exempt from this requirement. Ladders shall not be selected in such cases, since both hands should be free to grasp the ladder. Stairs and steps should not be used where hand-carrying bulky loads or loads in excess of 13 kg (29 lbs) is required.

- **MIL-HDBK-759C** - Para 5.12.7.3.1 stated:

Ladders should be used whenever personnel have to change elevation abruptly (more than 400 mm) during operation or maintenance of the vehicle. Surfaces upon which personnel step or walk should be non-skid (expanded metal) and be of sufficient length and width to accommodate arctic boots. Ladders should lock in place during use and have no obstructions, edges, notches or burrs which could injure personnel or damage hoses or cables. Markings should be provided indicating any dangers associated with their use. Wherever possible, ladders should be capable of being carried, handled, and positioned by one person, but should never require more than two.

10.12 Is an emergency exit provided and is its location and means of operation labeled?

The incorporation of emergency hatch provides an alternate means of escape from the shelter when the main entrance is obstructed. Emergency exits shall not require a key or tool to open from the inside. Labels must identify location as well as how to open the hatch. In addition, all hatches must be illuminated during blackout conditions using backup batteries and labeled providing any necessary opening instructions. Many exiting shelters utilize single escape hatches, incorporated on the main entrance. This emergency hatch is likely to be obstructed if the main entrance is blocked or damaged by a rear-end collision. There, shelter operated OTM shall have two exits located remote from each other and so arranged as to provide unobstructed egress. Limited space is available on the shelter wall for a second emergency hatch, therefore, the second hatch can e located overhead. Overhead hatch will provide an alternate means of escape if the rear of the shelter is blocked during an accident. If the shelter rolls over onto its roof, the rear exit can be used. If both exits are blocked, the crew can use the axe to tear open a wall or the floor. Vehicles must not utilize raised tailgates during mobile operation, which obstruct personnel from safely exiting the shelter in an emergency. These tailgates must be removed from the vehicle, kept in the horizontal position, or modified (i.e. notched) to allow unobstructed opening of the door or emergency hatch when raised. Also, operators must be informed of any trip hazards that may exist when exiting the shelter in an emergency situation.

- **MIL-STD-1472F** – Par 5.13.4.2 stated:

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Emergency doors and exits shall be clearly designated, readily accessible, unobstructed, simple to operate, simple to locate in the dark, quick opening in three seconds or less, and require 44 - 133 N (10 - 30 lb) of operating force to open. They shall not themselves, or in operation, constitute a safety hazard. They shall permit one person egress in 5 seconds or less.

- **NFPA 501C** – Para 3-2.4, 3-2.1 applies

10.13 Is the emergency exit readily accessible and simple to operate in a high stress, zero visibility situations?

Emergency exits shall not require a key or tool to open from the inside. Emergency exit/hatches must open out from the shelter, so that, in the event of an accident, any equipment within the shelter that becomes loose does not prevent the hatch from opening. In addition, door mounted hatches must open with less than 20 pounds of force. The overhead hatch must be designed to allow opening with less than 50 pounds of force and be easily opened in the dark. In addition, these hatches should be located in the center of the shelter aisle. Hinges should be incorporated to allow complete removal of the overhead hatch from the shelter in the event of blockage. For example, roof hatches could be slid to the right or left and then lifted entirely out of the shelter. Handles on emergency exits must be visible under blackout conditions. Considerations must be made to prevent finger-pinching hazards when closing the hatches. Overhead hatch handles must be located such that head injuries will be minimized when walking inside the shelter (e.g. utilize recessed handles). Emergency hatch dimensions are identified in MIL-STD-1472, Figure 37. The larger dimensions (i.e. "bulky" columns) should be used to allow personnel wearing artic or MOPP IV gear to exit the shelter in an emergency situation.

- **MIL-STD-1472F** – Par 5.7.8.2 applies

10.14 Where extended operations are required on top of the shelter, are ladders, non-slip surfaces, and guardrails or chains provided for the shelter roof?

Systems requiring access to the shelter rooftop will usually trigger concern due to requirements for adequate ladders for climbing to the roof. To enhance personnel safety a non-skid surface should be applied to the roof and a railing or post and chain/rope mechanism should be employed to preclude operators from falling off the roof.

- **MIL-STD-1472F** – Par 5.7.6.6 stated:

The surfaces of exterior personnel platforms and work areas shall be constructed of open metal grating. Exterior personnel platforms where use of open grating is impractical and interior walkways shall be treated with nonskid material. All open sides of personnel platforms shall be equipped with guardrails (with intermediate rails), with a top rail height not less than 107 cm (42 in) and a toe board or guard screen height not less than 15 cm (6 in). Handholds shall be furnished where needed. The distance between the platform edge and the centerline of the railing should be not more than 65 mm (2.5 inches).

10.15 Are egress paths and stairs provided with permanent non-skid surfaces?

All egress pathways must provide permanent non-skid surfaces to prevent slipping. Rugs or carpets that can be removed are not acceptable. Systems requiring access to the shelter roof to usually will require adequate

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ladders for climbing to the roof, non-skid surface applied to the roof, and a railing or post/chain or rope mechanism to preclude operators from falling to the ground. In addition, all shelter aisles must allow for reasonable mobility, and for raised shelters, external platforms adjacent to entrance/exit doors should be of a non-skid design, or have non -skid surfaces. This is especially true of truck tailgates, which may be lowered and utilized as part of the entrance/exit path.

10.16 Is adequate illumination provided in all areas?

Most shelters have lights installed in the ceilings. These lights, unless somehow recessed, require "bump" guards to protect personnel from sharp edges, thermal hazards (bulbs get hot) and possible breakage of the bulb itself. Consideration should be given to sufficient lighting for Personnel/(workstations inside the shelter and to emergency lighting, especially in long shelters/vans/semi-trailers where exits may be a long distance away.

- **MIL-STD-1472F** – Par 5.13.4.5 stated:

Adequate illumination shall be provided in all areas. Warning placards, stairways, and all hazardous areas shall be illuminated in accordance with the recommended levels of Table XVI.

10.17 Are wall, floor, and ceiling fastenings sufficient to prevent equipment from breaking away, falling, or accidentally dislodging?

The fastener hardware selected should provide ample support for weight of racks, and equipment to prevent hazard of equipment breaking loose during transport or an accident. The sheltered system should undergo roadability or transportability testing to verify the structural integrity.

- **MIL-HDBK- 454A** – Guideline 12, Fastener Hardware, and this guideline establishes the selection and application of fastener hardware.

This applies to both to fasteners that keep the equipment together, as well as fasteners that mount the equipment to other surfaces. In the case of power distribution equipment, conduit and splice boxes must be properly secured at the required intervals. Fasteners that could be exposed to moisture or other chemicals should be able to resist corrosion that could lead to failure.

Adhesives may be used to secure parts but must be suitable for the environment, temperature, and able to withstand mechanical impact without breaking. Consider whether brittle materials such as certain epoxies may break when subjected to shock. Wire fasteners that are secured with double-sided adhesive tape have a history of failure and are not recommended.

- **NFPA 70-05 – A**rticle 300.11 states raceways, cable assemblies, boxes, cabinets, and fittings shall be securely fastened in place. Articles covering specific equipment and applications contain additional guidance.

- **UL 60950 –** Par. 4.2.1 states that enclosures shall have adequate mechanical strength and shall be so constructed as to withstand such rough handling as may be expected in normal use. Par 4.2.10 states the mounting means of equipment intended for wall or ceiling mounting shall be adequate.

- **UL 73 –** Par 7.1 states that an appliance shall be formed and assembled so that it will have the strength

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and rigidity necessary to resist the abuses to which it is likely to be subjected. Chapter 8 addresses the used of adhesives to secure parts. Chapter 10 addresses protection against corrosion.

10.18 Are accessories secured or stowed to prevent damage when the vehicle is moving?

Provisions shall be made in the shelter and on the trailer for the storage and securing of equipment from coming loose or damaged. All assemblage/transport configurations shall have sufficient slinging and tie-down points and shall be compatible with military loading system. Number, size, strength, location and marking of tie-down points shall conform to the requirements if MIL-STD-209. Tie-down points and lift points shall be clearly marked and visible to operators during installation/removal/loading/unloading operations.

- **MIL STD-209 J -** Para 5.0 to 5.5.5 provides requirements for lifting and tie-down.

10.19 Is equipment that is designed to have multiple-input power capabilities, or powered by a generator with multiple-voltage output capabilities, protected from damage when connected to incorrect input power/voltage levels?

Equipment shall be provided with a complete electrical power distribution system that conforms to MIL-STD-454. Connection to an external power source (tactical generator or commercial power) shall provide power for all the electrical circuitry, accessories, electronic equipment, lights, outlets and all electrical features. Protection shall be provided to prevent damage and malfunction of the equipment due to frequency drift, current or voltage surges, under/over voltage, external radio frequency (RF) sources, or incorrect phase connection. A frequency meter and voltmeter should be provided and installed to indicate the frequency and voltage of the incoming power for the shelter. The voltmeter shall include a selector switch to permit measurement of each individual phase-to-phase and phase-to-neutral voltage. The power control panel of shelter shall be equipped with a phase sequence monitor/indicator. A colored indicator light shall indicate correct phase connection, and a different colored light and/or audio alarm shall indicate incorrect phase sequence. Under condition of incorrect phase, the main power circuit breaker shall automatically be tripped and/or be held in the off position until phase sequence is corrected.

The electrical power guidelines for military ground vehicles should be in accordance with MIL-STD-1275.

Equipment that can be powered from different power sources must be protected from damage when connected to incorrect input voltage levels, frequency or polarity. This is especially critical with systems have power cables that terminate in pigtails, which rely on a human element for correct power hookup. In this case, the protective means should be automatic. Relying upon an individual to check the voltage reading in a shelter or on a piece of equipment is not automatic, and has led to system damage. Circuitry that monitors for a voltage range and that does not close a power relay until the proper voltage is applied would be an automatic means.

- **NFPA 70-05 -** Articles 406.7 requires that different configuration plugs be used for different supply circuits. Article 551.20 addresses combination electrical systems for recreation vehicles, where wiring and equipment must be rated and installed in compliance with both “voltage system” requirements.
- **UL 60950 –** Par 3.2.2 applies.

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10.20 Is an Army approved earth-grounding system (ground rod, SWGK, etc) provided?

A ground rod or equally effective earth grounding system is required for shelters. The system is connected via braided wire straps or another conductor to the ground stud located within or adjacent to the shelter power entry panel. We have had few problems with the grounding systems for the shelters. One complaint that continually comes to us is that ground rods are difficult to drive into some soils, and even more difficult to remove. CECOM has developed a Surface Wire Ground System (SWGS), which minimizes this problem and provides an equal or better interface with the earth than does the conventional ground rod. The SWGS is an alternate grounding system, which has been designed primary for use with systems requiring high mobility/quick installation and teardown operational scenarios. It is more easily installed and removed and offers a reasonable option in situations where driving/retracting conventional ground rods would be difficult and/or too time consuming. It is not intended to replace the familiar ground rod or to be used as a permanent type facility grounding system. It should be considered as another option for use as situation/circumstances may warrant. As with any grounding system, the SWGS provides a preferred lighting discharge path, enhances safety, and controls noise in signal circuits. The total resistance of the SWGS to ground is equal to or less than that of a single ground rod. When properly installed, the SWGS may better survive a lighting strike than would the common ground rod configuration. Its ability to better survive a lighting strike is based, in part, on the multiple discharge paths created when the system is correctly installed; that is around the periphery of the object being protected and with the three required connections. Voltage step potentials created by lighting strike, may, however, make the soil near the SWGS somewhat more hazardous than the soil surrounding a single ground rod since the SWGS does not penetrate as deeply into the earth. This phenomenon would be of very short duration, similar to the strike itself. Regardless of which grounding system is used, the soil in the immediate vicinity of the SWGS or ground rod will be potentially dangerous during a lighting discharge. For this reason, personnel should make every effort to seek shelter within metal enclosures, vehicles, or other relatively safe locations when electrical storms are imminent. This same precaution applies even if a rounding system is not installed, since personnel may also become possible targets for a direct strike.

- **CECOM TR-98-6 -** Earth Grounding and Bonding Pamphlet provides instruction for earth grounding guidelines.

10.21 Do the grounded and grounding circuits remain isolated throughout the shelter, including at the supply side of the power panel?

Equipment ground wires (grounding conductors) shall be included in the power cable assemblies and shall be utilized to interconnect all ground points of all shelters. The neutral wires (grounded conductor) shall be floated along with the three-line phases and shall be connected to the equipment ground (grounding conductor) at the generator set or other power source. All equipment within a shelter shall be connected to the shelter's grounding system via the grounding conductor within its power cable assembly. Each shelter shall then be connected to earth ground by use of a standard ground rod (NSN 5795-00-878-3791 or equivalent). Neutral and ground must not be connected together within the shelter. They must be isolated from each other (and within the power panel). The only place they will be tied together will be at the generator or at the transformer secondary (if commercial power is being utilized). This provides for the single-point grounding required for safety, as well as EMI/TEMPEST, etc. The ground and neutral are isolated from each other at the shelter for two reasons: (1) The ground wire (often referred to as the

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equipment grounding conductor, EGC) is to be dedicated for carrying only fault currents and if tied neutral, part of the normal current flow back to the generator would pass over this EGC, and (2) should the generator be hooked up incorrectly (cross connection of neutral and a supply phrase) the shelter and equipment exteriors would be a potential above ground – a definite shock hazard. The concept of a single point ground where neutral and the EGC are tied together only at the power source is based on the above considerations and to reduce noise levels frequently generated by multi-ground paths.

10.22 Where a switch is provided to switch between different power sources is the grounded/neutral conductor also switched to avoid ground loops?

This requirement applies if the UPS incorporates a neutral-ground bond on the secondary, as opposed to relying on the primary source neutral-ground bond (refer to question 1.50 comments above). In order to maintain isolation between the neutral-ground point of the UPS secondary and the neutral-ground point at the primary supply location, any switching circuitry within the UPS must switch/interrupt both the line and neutral conductors

- **UL 1778 –** Par 2.6.101 and Annex EE specify when the UPS AC output needs to be grounded to avoid any back feed that could cause current to flow over the grounding conductor.

- **NFPA 70–05 -** Article 250.30 addresses grounding of separately derived power sources (defined as having no direct electrical connection to supply conductors originating in another system). The requirements are intended to ensure adequate grounding of such systems while preventing objectionable current of the grounding system through ground loops.

- **UL 60950 –** Par 1.6.4 states that the neutral conductor shall be insulated from earth and from the equipment body throughout the equipment as if it were a line conductor. However, Annex NAE (U.S. and Canadian regulatory requirements) notes that units having receptacles for the output of AC power, which are generated from an internal separately, derived source shall have the grounded circuit conductor bonded to earth. This latter requirement is not a violation of 1.6.4 since the secondary "separately derived" supply is entirely isolated from ground, and bonding one of the secondary lines will not lead to ground loops. Refer to the NFPA 70-05 NEC Handbook reference for additional details.

10.23 If commercial inverters are used to generate AC voltage, do they internally provide a neutral-ground bond that is disconnected when an external AC power source is connected?

The NEC requires certain power systems to have the neutral and grounding conductors bonded at the power source. This ensures that circuit breakers open rapidly if a piece of equipment has an electrical short to ground. For fixed facilities, this bonding connection is usually made at the service panel. For mobile systems, this connection occurs at the on-board power source. If multiple on-board power systems are used, or if there's an option to use shore power, it's necessary to switch the neutral conductor along with the line conductors when switching between sources. Otherwise, you could create a back-feed situation between parallel neutral-ground connections causing unacceptable current to flow over the grounding conductors, another hazardous condition. Refer to SEL Form Handbook questions 1.50 and 1.51 for more information.

Power inverters create AC power from a DC source, such as a vehicle battery. Certain power inverters have the ability to import external AC power, and then automatically switch to DC power (inverter mode) when primary AC power is lost or disconnected. Such inverters must ensure that a neutral-ground bond is

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maintained when operating from the backup DC source and that this neutral-ground bond is isolated from shore power other power sources as discussed above.

Depending on how the inverter is planned to be used, there may be only certain models that meet NEC requirements for the application. There have been cases where power inverters were selected based on power load requirements but didn't provide the necessary internal ground-neutral bond. After further discussions with the inverter manufacturer, they were able to identify a different model inverter that met all requirements passed on how it was going to be used (mobile application) and wired.

- **NFPA 70-05** - article 250.6 states that grounding of electrical systems circuit conductors, etc will be done in a manner that prevents objectionable currents over grounding conductors. Furthermore, article 250.24 prohibits a grounding connection of a grounded circuit conductor on the load side of the service disconnecting means as this could cause objectionable current to flow over the grounding conductor. Article 250.30 covers grounding of separately derived power sources in a manner that prevents objectionable currents over grounding conductors.

- **UL 60950** – par 1.6.4 states that the neutral conductor shall be insulated from earth and from the equipment body throughout the equipment as if it were a line conductor. However, Annex NAE (U.S. and Canadian regulatory requirements) notes that units having receptacles for the output of AC power which are generated from an internal separately derived source shall have the grounded circuit conductor bonded to earth. This latter requirement is not a violation of 1.6.4 since the secondary "separately derived" supply is entirely isolated from ground, and bonding one of the secondary lines will not lead to ground loops. Refer to the NFPA 70-05 NEC Handbook reference for additional details.

- **UL 1778** – Par 2.6.101 and Annex EE specify when the UPS AC output needs to be grounded to avoid any back feed that could cause current to flow over the grounding conductor.

10.24 Is a ground stud provided at the power entry box and is it suitably identified?

A ground rod or equally effective ground system is required and the system is connected via braided wire straps or other conductor to the ground stud located within or adjacent to the shelter power entry panel.

Coordinate the grounding stud design with the types of grounding wires and straps typically used.

- **NFPA 70-05**- Article 250 stipulates grounding requirements.
- **CECOM TR-98-6** - Provides proper earth grounding and bonding methods for use with tactical systems.

10.25 Are no parts of the vehicle/shelter enclosure or frame used as the AC ground path?

The structural metal of the shelter shall not be used as the AC ground path. An AC ground (green) conductor shall be provided in the cable or raceway in the same manner as the hot and neutral conductors. The AC ground (green) conductors shall return to a single ground bus in the shelter distribution panel.

Hinges and slides typically should not be relied upon if exposed to the elements, since dirt and corrosion in the field could degrade such grounding paths. However, in certain circumstances where hinges would not be exposed to environments that could cause corrosion, hinges may be acceptable. In such cases, the hinges should be checked to make sure they are not exposed to corrosive element, and that they do not incorporate nylon spacers or other nonconductive parts.

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- **NFPA 70-05 -** Article 250.4(A)(5) states that electrical equipment and wiring and other electrically conductive material likely to become energized shall be installed in a manner that creates a permanent, low-impedance circuit capable of safely carrying the maximum ground fault current that may be imposed on it. Parts that could potentially corrode in a particular environment would not be suitable (see 110.3). Article 250, Parts V and VI contain specifics for bonding and equipment grounding. Individual product safety standards would apply for grounding and bonding of parts integral to a specific piece of equipment.

- **UL 60950 – P**ar 2.6.1 states that dead metal parts shall be reliably grounded. Though hinges are not specifically called out and prohibited, par 2.6.5.6 points out that corrosion of grounding parts must be considered. It will be necessary to look at the intended use of the end product. UL 60950 refers to protective bonding conductors as a conductor in the equipment that connects a part of the equipment to the main protective earthing terminal (ground point) within the equipment. The protective earthing conductor is the conductor that connects the protective earthing terminal (ground point) within the equipment to the power source ground (i.e. equipment grounding conductor).

- **MIL-HDBK-454A –** Guideline 1, par 4.5.2.3 states hinges or slides should not be used as grounding paths.

10.26 Are the ground pins of the convenience outlets hard wired to the shelter/system ground point?

A single ground points typically provided within the shelter system to which the various internal grounding conductors and the equipment-grounding conductor are connected. We have seen shelterized system with outlets grounded to shelter wall only. This is unacceptable because this will not provide a low impedance path for all fault currents that may reasonably occur and provide for personnel protection and will not trip the controlling unit breaker.

10.27 Is lightning surge protection provided at the power and signal entry panels for all cables?

The ground rod on the system provides a preferred lighting discharge path. It should prove to be adequate to dump excessive voltages/currents which might travel over long "land lines" connected to the system and which are protected by surge arrestor devices in the power and signal entrance panels.

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10.28 Are all outdoor receptacles ground-fault circuit interrupter (GFCI) protected?

The GFCI sensing system continuously monitors the current balance in the ungrounded 'hot' conductor and the neutral conductor. If the current in the neutral wire becomes less than the current in the 'hot' wire, a ground fault could exist. A portion of the current returns to the supply by some path other than the neutral wire. With a current imbalance as low as 6 milliamperes, the GFCI will interrupt the circuit and this will be shown by a trip or 'off' indicator on the device. The GFCI does not limit the magnitude of the ground fault current. It limits the time that a current of given magnitude can flow. The trip level-time combinations are based on physiological data established for avoiding injury to normal healthy persons.

The principle of operation of ground-fault circuit-interrupters provides a significant advancement in safety for both equipment that is grounded by an equipment-grounding conductor as well as for equipment that is ungrounded. Since the GFCI detects an imbalance of current in both the supply and return paths, it protects equipment supplied by both a 2-wire circuit and a 2-wire with ground circuit. This is the reason some NEC sections will allow a grounding-type receptacle to be supplied on a 2-wire circuit that has GFCI protection.

Unless the device is a circuit breaker type GFCI, it will not protect the circuit conductors against over-current. Separate over-current protection must be provided. Grounding and GFCI protection are used to complement one another, not to replace one another. Periodic tripping tests should be made in accordance with the manufacturer's recommendations, using the test means on the unit. When the test button is pushed, a predetermined value of ground-fault current is supplied to the GFCI, tripping the unit and thereby testing the GFCI.

GFCI will not protect persons from shock hazards where contact is between phase and neutral or between phase-to-phase conductors.

External convenience outlets mounted on the outside of shelters must incorporate GFCI to reduce hazards associated with powering externally used portable/remote tools, equipment, etc. For those unfortunate instances where equipments having excessive filter leakage currents, dedicated outlets with special connectors may be utilized. GFCI protected receptacles shall be clearly labeled/identified.

- **NFPA 70-05** Articles 210.8, 525.23, 550.13, and 551.41 cover GFCI personnel protection requirements for various situations.

10.29 If the answer to question 10.28 is NO, is the socket configuration of each outdoor receptacle that is not connected to a GFCI unique to its special application and unusable for other applications or as a convenience outlet?

Where excessive leakage current exist, a two fold safety problem exists: GFCI (s), If used, will continually trip, rendering the equipment inoperative; and if a ground circuit ever opens, the outer metallic enclosure of the equipment may become energized and create a shock hazard. If low leakage current filters cannot be utilized, redundant ground circuits should reduce the risk to an acceptable level; also GFCI(s) can be replaced with outlets having special connectors dedicated to powering only those equipments having excessive current.

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10.30 Are outdoor receptacles protected from the weather whether or not the attachment plug cap is inserted?

The NEC states that receptacles installed in wet locations shall have an enclosure that is weatherproof whether or not an attachment plug cap is inserted. Wet locations are those installed in unprotected areas exposed to weather or where subject to saturation with water or other liquids.

The NEC relaxes this requirement for receptacles installed outdoors in locations protected from the weather or in other damp locations. In those locations, the receptacle shall have an enclosure that is weatherproof when the receptacle is covered (attachment plug cap not inserted and receptacle covers closed). Damp locations are those that are protected from weather and not subject to saturation with water or other liquids but subject to moderate degrees of moisture, such as under canopies, rooted open porches, etc.

Based on the above, a receptacle installed on the exterior of a shelter that is directly exposed to the elements must have a cover that will be weather proof with an attachment plug cap inserted. However, if the receptacle is located at a power entry panel that has a hooded cover, the location may meet the definition of a damp location and may only require a cover that is weatherproof without an attachment plug cap inserted.

- **NFPA 70-05** - Article 406.8 applies.

10.31 Has the amount of residual leakage current to ground for the entire system been verified through test to be less than 5 mA (3.5 mA if system can be powered from a GFCI protected circuit)? If YES, indicate the amount of current that was measured.

Excessive currents are considered to be anything over 5mA, which is generally considered to be maximum electrical current to which a person can be safely exposed. Leakage current measurements where they are known to exist must be made to verify if the above fixes (question 10.28) are required. A quick simple test to see if you might have this problem is to plug your equipment into a GFCI equipped outlet. If it doesn't trip, you don't have an unsafe leakage current level. TB #5, leakage current Testing, provides instructions on testing for leakage current.

Leakage Current is the residual electrical current that passes over or through conductive parts and ground; parts that normally are not intended to carry current. All electrical equipment produces leakage current. When equipment is properly grounded, equipment LC is dissipated to ground and/or the power source and does not present a hazard to personnel. However, accessible equipment surfaces may become energized should the grounding path open.

Current levels as low as a few microamperes can be sensed under certain conditions. Various studies have determined that at 0.5 mA, most people can perceive the current, but are not likely to have a startle reaction. For cases where a startle reaction only results in an involuntary muscle reaction and does not lead to an accident or increased injury, then the next threshold of concern is the ability to let-go of an energized part (5.0 mA rms). Where products may be used in a wet or damp environment and therefore could be plugged into a GFCI, leakage current levels must be less than 3.5 mA to avoid nuisance tripping.

Frequency has an impact on the above-identified current limits. As frequency increases, the human body becomes less sensitive to LC and hence, current thresholds for perception, startle reaction, and let-go also rise. Safety standards have established an upper threshold limit of 70 mA to prevent small touch-area burns. It's important to note that the 50/60 Hz regions is the worst-case frequency range from a physiological

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response standpoint.

The LC test is carried out using a resistor/capacitor network that represents the body's impedance as well as the body's sensitivity to current frequency. Since this frequency sensitive network reduces the actual leakage current measurement at higher frequencies, the term Measurement Indication Units (MIU) is used. At 60 Hz, 0.5 mA of LC corresponds with 0.5 MIU. At 100 kHz however, a 70 mA sine wave will indicate 0.5 MIU on the LC test meter. Hence, the correct term to use is MIU when recording a measurement or specifying a requirement independent of frequency.

Leakage current measurements should be taken with the equipment power switch on and off and through all modes of operation. If it is possible that the equipment could be powered from a source with reverse polarity, measurements should also be taken under this condition.

Certain UL standards require a leakage current test only if measured voltages for accessible surfaces exceed 42.4 V peak. These standards cover products where leakage current is typically due to complex electronics located in a low voltage secondary circuit or power supply. For most products however, sources of leakage current are components located in the 120/240 V supply circuit (i.e. motors, filters, surge arrestors, transformers, heaters, and the like). For this reason, the LC requirement must be met independent of whatever the measured voltage of the accessible component is.

- **ANSI C101.1 –** The procedure for leakage current testing is specified in detail for typical household and similar appliances rated 20A or less. However, a pass/fail criterion of 0.5 mA is specified for portable appliances (0.75 for stationary/fixed appliances).

- **UL 60950 –** Section 5.1 addresses requirements for touch current and protective conductor current. Touch current is defined as the current through a human body when it touches accessible parts. Protective conductor current is the current flowing through the protective earthing conductor under normal operating conditions. Touch current is measured through an impedance network and shall not exceed 3.5 mA. However, equipment that's stationary and permanently wired or connected with an industrial plug (grounding connection has higher reliability), the leakage current can be up to 5% of rated equipment load current. The protective conductor current is measured using an ammeter without an impedance network.

- **UL 1795 -** The Standard for Hydromassage Bathtubs contains stringent electrical shock requirements since personnel are immersed in water; the individual has a huge surface contact to ground. Requirements do not specify a voltage, but rather state that the current between any two parts accessible to the tub occupant shall not exceed 0.5 mA as measured through a 500 Ohm resistor.

- **MIL-HDBK-454A** – Guideline 1, Par 4.5.2.5 stated:
The equipment leakage current should not exceed 3.5 milliamperes dc or rms. When excessive leakage currents are required by design or operational requirements, redundant grounding or double insulation methods should be incorporated.

10.32 Is a main power switch provided at the shelter entrance?

Shelters usually have their AC power entry panels adjacent to the entrance doors. Immediately behind these panels and inside the shelter are EMI/RFI filters and perhaps surge arrestors, followed by a power distribution panel or cabinet. The location of the power control panel immediately inside the shelter is not only economically desirable, but also provides for safety since the main on-off switch can be more easily

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reached to shut off power during an emergency, especially if a person further in the shelter is in trouble. Although not often seen, an emergency switch "dead-fall" button at the other end of the shelter would further enhance safety if power had to be quickly turned off. Where required, emergency controls shall be readily accessible and clearly identified

The main power switch often serves two safety-related functions: isolate the equipment during maintenance, and provide a means to de-energize the equipment in an emergency. In the latter case, it is important that the main power switch also deactivate any UPS provided output. System designers make take issue with this, stating the UPS must continue powering a system in the event the main circuit breaker (often the main switch) trips due to a power surge. As an alternative, a separate switch can be incorporated to readily deactivate UPS output power in an emergency (electric shock or fire). Where equipment has multiple power sources or switches, clear instructions must be provided that identify how to remove all power from the system.

The disconnect must cut off all power to the system. If it is possible that power polarity can be reversed (non polarized plugs used), then both the phase and grounded (neutral) conductors need to be disconnected.

Where equipment incorporates a backup power source (UPS) that provides over 750 VA, consideration should be given to incorporating a means for connection to a remote emergency power off circuit that disconnects the battery power source.

- **NFPA 70-05 –** Article 230.70 requires a means to disconnect all conductors in a building from service-entrance conductors. Article 240.20 requires circuit breakers to open all ungrounded conductors of the circuit (with certain exceptions). Article 422.30 requires a means of disconnection be provided for appliances. Article 550.11 addresses disconnecting means for mobile homes. Article 551.45(C) addresses mobile recreation vehicles. Article 645-10 addresses disconnecting means for equipment in an Information Technology Rooms. Article 645-11 further requires that the output power of an UPS that's installed in an information technology room also be interrupted when the main disconnect means is activated. This is not required if the UPS is integral to the electronics equipment (not powering wall receptacles - see article 645-15) and is limited to 750 VA output. The NEC does not consider this power level to be a fire hazard, and therefore, includes the exception. However, the possibility of electric shock must be considered where maintenance is conducted within shelters, where many accessible surfaces are grounded, where the UPS powers a number of equipments, where quarters are tight, and so forth. In such cases, the main disconnect should also interrupt the UPS output.

- **UL 60950 – S**ections 3.4.6 and 3.4.7 address disconnect requirements for single and three phase equipment. Sections 3.4.10 and 3.4.11 address interconnected equipment and equipment powered by multiple power sources. Par 1.7.9 states where there is more than one connection supplying hazardous voltage or energy levels, a prominent marking shall describe how to de-energize the entire equipment and which switch controls which part.

Annex NAE (U.S and Canadian regulatory requirements) clause 3.4.10 states that for computer room applications, batteries integral to equipment shall incorporate a means for battery disconnect and a means for connection to the remote emergency power off circuit that disconnects the battery power source where it exceeds 750 VA (with exceptions).

- **UL 1778 –** Par. 2.1.103 states that a battery supply for an UPS provided with a marking indicating that it is suitable for use in a computer room shall incorporate a battery disconnect and a means for connection to

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the remote emergency power off circuit that disconnects the battery power source.

- **UL 891 -** Section 16 applies.

- **MIL-HDBK-454A -** Guideline 1, par 4.5.1 states that if a main power switch is provided, it should cut off all power to the equipment. Equipment that uses an UPS should have provisions to isolate the supply from the equipment.

- **29 CFR 1910 –** Subpart 1910.269(v)(11)(xi) addresses emergency stop buttons for conveyor systems and requires the emergency stop devices to be easily identifiable. Other sections of 29CFR1910 may contain guidance regarding safety controls based on the system configuration and intended use.

- **MIL-STD-1472F -** Par 5.1.2.3.8 states that emergency controls shall be located where they can be seen and reached without delay.

10.33 Are safety switches provided at remotely-located assemblies to protect maintainers?

Equipment having potentially hazardous conditions and capable of being operated remotely shall be provided with a reliable lockout means at the remote equipment to prevent accidental remote operation during maintenance. Any energized parts to the supply side of the interlock that could be accessed during the maintenance procedure should be protected against accidental contact.

- **NFPA 70-05 -** For motors, 430.102 address disconnecting means, which have to be within sight of the motor (with exceptions). Many other products such as hydro-massage tubs, pools, HVAC systems, etc require disconnects at the remote locations.

- **29 CFR 1910 - S**ubpart O requirements for machinery and machine guarding can be referenced and applied.

- **MIL-HDBK-454A** – Par 4.5.4.3 stated:

Safety switches, which will deactivate associated mechanical drive units, should be provided for the purpose of disconnecting these units without disconnecting other parts of the equipment. Such remotely located units and assemblies should have provision for non-overrideable safety switches to allow independent disconnection in the associated equipment.

10.34 Are terminals, plugs, and other exposed parts located within power distribution panels that may exhibit over 30 volts or 20 amps, guarded against accidental contact if exposed during maintenance?

The electrical hazards we most frequently see of this type are exposed voltages (over 30V AC or DC) to operators, and exposed high current (over 25A) and high voltage (70V AC/DC or higher) to operators and/or maintainers. Specific requirements for protecting the user/maintainer from these voltages/currents are contained in MIL-STD-454. Generally speaking, transparent dielectric protective covers are placed over the hazardous terminals and caution labels are also added. Holes drilled into the barriers large enough to allow test probes to pass will facilitate testing without having to remove the barriers, which often are not replaced. For voltages of 500V AC/DC or higher, separate enclosures with interlocks are required.

High voltage circuits and capacitors within the equipment may retain electrical charges after power is

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removed, and not infrequently have caused hazards. Automatic discharge devices and/or bleeder resistors are required to assure that all high voltage circuits drop to less than 30V within two seconds after power is removed.

Test points on high voltage equipment/circuits must never require measuring more than 300V AC or DC. Potential voltage dividers may be utilized in the circuitry to step down the high voltage and allow for this limit; thus a 250V reading might correspond to the presence of 750V.

Refer to Sel Form 1183 Handbook questions 1.6 for more details.

- **MIL-HDBK-454A** – Para 4.5.3, 4.5.3.1 and 4.7.2 stated:

4.5.3 : The design should incorporate methods to protect personnel from accidental contact with voltages in excess of 30 volts rms or dc during normal operation of a complete equipment.

4.5.3.1 : All contacts, terminals and like devices having voltages greater than 30 volts rms or dc with respect to ground should be guarded from accidental contact by personnel if such points are exposed to contact during direct support or operator maintenance. Guards or barriers may be provided with test probe holes where maintenance testing is required.

4.7.2 Power switch location. Equipment power switches should be selected and located so that accidental contact by personnel will not operate the switch.

10.35 Where transmitting equipment exists, and room permits, are shorting rods provided?

Shorting rods should be provided with all transmitting equipment where voltages are in excess of 70 volts rms or dc. Where size permits, shorting rods should be stored within the transmitting equipment, permanently attached, and readily accessible to maintenance personnel. The permanently attached rod should be connected through a flexible stranded copper wire (covered with a transparent sleeving) to the stud provided at the transmitter main frame. Where size does not permit internal storage of the shorting rod, a grounding stud should be provided to permit attachment of a portable shorting rod. The connection to the stud should be such that accidental loosening or high resistance to the ground is prevented.

- **MIL-HDBK-454A** – Par 4.5.5.2 stated:

Shorting rods should be provided with all transmitting equipment where voltages are in excess of 70 volts rms or dc. Where size permits, shorting rods should be stored within the transmitting equipment, permanently attached, and readily accessible to maintenance personnel. The permanently attached rod should be connected through a flexible stranded copper wire (covered with a transparent sleeving) to the stud provided at the transmitter main frame. Where size does not permit internal storage of the shorting rod, a grounding stud should be provided to permit attachment of a portable shorting rod. The connection to the stud should be such that accidental loosening or high resistance to the ground is prevented.

10.36 Are fuel lines that are inside the shelter made as short as possible?

The danger presented by fuel lines is that they contain flammable liquid, which in the event of leakage or rupture make for a very unsafe condition with fumes, especially if there is an ignition source close by. The least amount of fuel line equates to the least amount of surface area that could be punctured or worn through should be utilized. It is also safe practice not to route fuel lines near a heat/ignition source and clamping the

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lines in such a manner as to keep them from any undo stress of shock and vibration, while being in a location where other loose items may not come into contact with it. If metal fuel line is being used care should be taken to avoid the line from being given any potential voltage or cause of static discharges etc. Currently there are no known systems where fuel lines are routed through the shelters. There are fuel lines located in shelters tunnels where the generator is located and hooks up to the HMMWV fuel tanks. Whether the fuel tank of the vehicle is utilized or the generator has its own fuel tank or runs off both the previous considerations apply. There are other systems upon trucks where generators are operated by running off of fuel tanks that are solely for that generator or sister-ring usage off of the vehicles tank where the above paragraph also applies.

10.37 Is there a heater fuel shut-off valve inside the shelter?

If a shelter or any other kind of enclosure is heated by a liquid or gas fuel source, then there should be either a mechanical or an electro-mechanical shut off valve inside, and one possibly outside the shelter/enclosure in case of emergency or for maintenance. There are no fuel heaters of these types in shelters/trailers currently. The fact that these heaters are considered to be unsafe when compared to electrical heating has led to, most, if not all systems being heated by electrical heaters with ether forced air or convection delivery methods.

10.38 Is a fuel line and jerry can adapter provided for connection to the external fuel tank or container?

As in all cases of refueling with liquid fuels, care should be taken with flammable liquids to make sure they don't leak or splash all over the place hence becoming fire hazards. When fueling of an external reservoir (e.g. jerry can or some other kind of vessel), quick connections that prevent leakage and spills should be incorporated into the systems design. It should be stated in the OP or TM whether system/item needs to be non operational when fuel source is switched or added too.

10.39 Are fuel lines and fuel sources suitably protected from potential damage and sources of heat?

*As in **10.36** above, it is also safe practice not to route fuel lines near a heat/ignition source and clamping the lines in such a manner as to keep them from any undo stress of shock and vibration, while being in a location where other loose items may not come into contact with it. If metal fuel line is being used care should be taken to avoid the line from being given any potential voltage or cause of static discharges etc. Such sources of heat could include exhaust manifolds, electrical components and heaters. They should also not be in interference with any other moving parts nor should they be part of any grounding system if they are composed of metal.*

10.40 Are battery compartments designed to prevent gas buildup within the shelter (i.e. forced-air ventilated to the outside)?

Forced positive ventilation venting to the outside of the helter (and away from sources of ignition) is essential. Alarm systems are required to assure that the ventilation fan is working and that the vent door is

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open.

- **MIL-HDBK-454A** – Par 4.7.4 stated: Battery Enclosures should be vented. The enclosure design should prevent shattering, or fragmenting of enclosure parts or covers in the event of a violent gas venting or rupture of battery cells causing explosive high pressure within the compartment.

10.41 Is a warning device provided to indicate when either the battery vent lid or door is closed or when the ventilation fan is inoperable?

An interlock might be used to shut off the charging circuit as an additional precaution/more positive means when ventilation is not present due to fan failure and/or vent door closing. Overcharging protection is required where batteries would be recharged by a battery charging system built into the shelter.

10.42 Is the vehicle exhaust sufficiently separated from shelter openings to avoid an accumulation of carbon monoxide in the shelter?

Ventilation or other protective measures shall be provided to keep gases, vapors, dust, and fumes within the Permissible Exposure Limits specified by 29 CFR 1910 and the limits specified in the American Conference of Governmental Industrial Hygienists Threshold Limit Values. Intakes for ventilation systems shall be located to minimize the introduction of contaminated air from such sources as exhaust pipes.

Vehicle exhaust may create a carbon monoxide (CO) hazard. Operating scenarios may require vehicle engines to be running to provide both power to equipment and mobility. If speeds are slow and/or generators are mounted on same vehicle, CO hazards may occasionally occur unless extreme care is taken to route exhausts away from occupied enclosures, air intakes, etc. Testing needs to be performed to assure that the hazard is negligible, or if deemed necessary, CO monitors must be incorporated to alert personnel if unsafe levels occur. Certain local environmental conditions (wind direction, barometric pressure, etc.) may increase the probability of such an occurrence.

10.43 Is a Carbon Monoxide (CO) alarm provided and does it meet the storage temperature requirements for the system?

Although a shelter may have been tested and met OSHA and ACGIH air quality requirements as discussed in item 10.42 above, certain unanticipated conditions may occur where CO levels could increase, such as collocating too many systems in a tight area, having vehicles with running engines parked near shelter intakes, etc. It's prudent to provide a CO alarm for such cases. The CO alarm should be selected to meet the operational temperature limits of the shelter, as well as not be damaged when subjected to the storage temperature limits.

- **NFPA 1192 –** section 6.4.6 covers Carbon Monoxide (CO) Detectors. All recreational vehicles equipped with an internal combustion engine or designed with features to accommodate future installation of an internal combustion engine and all truck campers shall be equipped with a CO detector listed as suitable for use in recreational vehicles and installed according to the terms of its listing.

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10.44 Is a type B:C Carbon Dioxide or Dry Chemical extinguisher provided for electrical equipment and located near shelter exit? Specify size.

Fire extinguishers are the first line of defense against unfriendly fires and should be installed regardless of other fire control measures.

Virtually all fires are small at first and might be extinguished easily if the proper type and amount of extinguishing agent were applied promptly. Portable fire extinguishers are designed for this purpose, but their successful use depends on the following conditions:

1. *The extinguisher must be located properly and be in good working order.*
2. *The extinguisher must be the proper type for the fire, which occurs.*
3. *The fire must be discovered while still small enough for the extinguisher to be effective.*
4. *The fire must be discovered by a person ready, willing, and able to use the extinguisher.*

Fire extinguishers should be mounted adjacent to the exit door(s) to allow for possible fire fighting without having walking through the shelter. For high cost, mission critical equipment, automatic fire suppression systems are highly recommended. Halon systems are now being replaced (along with CFCs) with non-ozone depleting substances. The available alternatives to Halon include carbon dioxide (CO2) or dry chemical extinguishers. The health and safety effects on the operator when CO2 fire extinguishers are used in shelters were tested by the US Army Aberdeen Test Center. Based upon the test and the risk assessments made by the US Army Center for Health Promotion and Preventive Medicine (USACHPPM), CO2 fire extinguishers may be utilized for extinguishing fires in shelters. However, operators must be warned to exit the shelter and fight any fire from the outside. In addition, operators are to be instructed to ventilate the shelter after discharge of the CO2 fire extinguishers and prior to operator re-entry into the shelter. For shelterized systems operated on the move, fire extinguishers must always be within reach of seated operators. If space exists, the extinguisher should be mounted under or behind each operator's seat and be easily reached in an emergency. If a fire extinguisher cannot be mounted on the operator's seat, then two fire extinguishers are required in large shelters, such as the S-250. On extinguisher must be located near the front of the shelter to fight a fire in front of the shelter, particularly a fire blocking the exit. The rear fire extinguisher would allow an operator seated in the rear (or located outside) of the shelter to fight a fire in the front of the shelter without passing through the fire to access the front fire extinguisher. One fire extinguisher will be required in smaller shelters (e.g. S-250), mounted as close to the exit as possible, and within reach of the seated operator.

- **NFPA 10** – Portable Fire Extinguishers, contains requirements for the selection, installation, inspection, maintenance, and testing of extinguishers.

- **ANSI/UL 711** – Rating and Testing of Fire Extinguishers, is included in the requirements of NFPA 10, Portable Fire Extinguishers.

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10.45 Are ceilings, walls, and other surfaces adjacent to aisles free of electrical components and switches that are vulnerable to damage by being hit or snagged?

The layout of equipment within the shelter needs to be carefully planned to allow for operational and maintenance efficiency while also providing safety.

Most shelters have lights installed in the ceiling. These lights, unless recessed, require "bump" guards to protect personnel from sharp edges, thermal hazards (bulbs get hot) and possible breakage of bulb itself in the event of an accidental head bump. We have experienced that a plastic ceiling light switch bumped off and exposed a live metallic actuator, causing a shock hazard. In addition, electrical components and switches protruded into the aisles are vulnerable to ingress/egress traffic, and unguarded protruding switches could cause snag hazards. In the event of breakage of electrical components, personnel could be exposed to dangerous voltage and electrical shock hazards.

10.46 Are controls, connectors, or other parts that project into walkways or located at foot level protected from mechanical damage?

Controls, connectors, or other equipment that protrude into the aisle or located at foot level in the shelter are likely to subjected to foot traffic damage or damage due to wash down (water spray). Safeguards should be provided or install the items at higher locations to preclude damages.

- **MIL-STD-1472F** – Par 5.9.13.6 stated:

Cables shall be routed or protected to preclude mechanical damage and abuse, including damage by doors, lids, use as steps or hand holds, or being bent or twisted sharply or repeatedly.

10.47 Are climbing rings, handholds, rails, etc., provided where needed?

To enhance personnel safety, climbing rings and handholds should be provided to access the shelter roof. In addition, railing or post and chain/rope mechanism should be employed to preclude operators from falling off the roof.

- **MIL-STD-1472F** – Para 5.13.6.2, 5.12.8.8 and 5.13.5.6 stated:

5.13.6.2 :Handrails, safety bars, or chains shall be installed around platforms and across stair or step openings in platforms, ledges, and catwalks. Such guards shall be placed 91 - 110 cm (36 - 43 in) above the standing surface. An intermediate guardrail shall be provided. Chains shall be used only where it is not feasible to install handrails or safety bars. Kickboards, 15 cm (6 in) high, shall be installed.

5.12.8.8 : Suitable handholds and footholds shall be provided to facilitate personnel access and movement.

5.13.5.6 : Handholds or footholds should be furnished where needed to assist personnel in climbing onto equipment or in performing intended tasks.

10.48 Are handles recessed rather that extended where they might be hazardous?

Considerations must be made to prevent mechanical hazards when walking inside a shelter. Avoid protruding handles into the shelter aisle. Utilize recessed handles to minimize personnel "head bump" injuries (i.e. overhead emergency hatch handles) or "snag" (clothing) hazards.

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- **MIL-STD-1472F** – Par 5.7.1.2 stated:

Handles on cabinets and consoles shall be recessed whenever practicable, to eliminate projections on the surface. If handles cannot be recessed, they shall be configured, located, and oriented to preclude injuring personnel or entangling their clothing or equipment.

10.49 Can EMI emitted by the equipment cause any degraded or erratic operation of other equipment?

Mission equipment package integration into host platforms could pose EMI /EMC induced errors or degrade operation of other electronic equipment and controls. Appropriate grounding, bonding, and shielding of equipment combined with appropriate internal filtering in equipment should be incorporated to help to reduce the chance of Electromagnetic Interference (EMI) and to ensure Electromagnetic Compatibility (EMC) of equipment. In addition, testing should be conducted to identify any operational anomalies.

10.50 Where equipment is installed on platforms with weapons or turrets, has a test been conducted to ensure that EMI cannot cause uncontrolled turret movement or weapons misfire?

Added electrical equipment can induce electrical noise in the vehicle platforms (i.e. Bradley Platform) or can interfere with function of other components in the host vehicle. Appropriate grounding, bonding, and shielding of equipment combined with appropriate internal filtering in equipment should be incorporated to help to reduce the chance of Electromagnetic Interference (EMI) and to ensure Electromagnetic Compatibility (EMC) of equipment. Vehicular platforms with weapons or turret, integrated with electronic mission equipment, should have EPG conduct EMI and EMC testing of the added mission equipment to ensure that EMI would not cause uncontrolled turret movement or weapon misfire. In addition, Aberdeen Test Center (ATC) should conduct operational testing of the platform while mission equipment is being operated to identify any anomalies.

10.51 Where shelter equipment is operated unattended with the vehicle on-the-move, is a smoke alarm provided to warn the vehicle driver of a fire condition in the shelter?

A smoke alarm is necessary to warn personnel of fire and smoke conditions at the earliest opportunity. This is even more important when the equipment is operated unattended. The alarm must adequately warn drivers in the cab of the vehicle to avoid a situation where they continue driving the vehicle while the system is on fire.

- **NFPA 1192 –** section 6.3.1 covers Smoke Alarms, which are required in each fifth wheel, travel trailer, truck camper, or motor home. The smoke alarm must be listed as suitable for use in recreational vehicles and installed according to the terms of its listing.

♦ OPERATION ON-THE-MOVE ♦

10.52 Is the shelter to be occupied and operated only when the system is stationary (No on-the–move operations)? If NO, answer questions 10.53 – 10.63

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Until recently, shelterized C-E systems have primarily been operated when stationary. However, as the need for continuous communications on the battlefield increases, On the Move (OTM) operations of these systems will become more essential. All systems that will be used for OTM operations must be designed for such operation, and evaluated and tested following the recommendations of the Test Integration Working Group (TIWG), and guidelines contained in CECOM TR-95-3. IAW with AR 385-16, any potential hazards identified as a result of testing and evaluation must be evaluated by the appropriate program manager to determine if the system is acceptable for mobile operations or if modification is required.

10.53 Have suitable seats and restraints been provided for the required number of users?

Properly designed seating will minimize potential injury that is possible during mobile operation. Seating design must take into consideration the operation of the system during all possible condition of travel, such as operation on primary and secondary roads, and events such as sudden braking, turning, and collision. During mobile operation, riding personnel must not be required to leave their seats since injury may result from being bounced about the shelter. For example, personnel may be thrown into equipment or other occupants during sudden stopping, acceleration, or motor vehicle accidents. This requirement must be trained to shelter occupants and addressed in Technical Manuals (TMs) and Standard Operation Procedures (SOPs). CECOM TR-95-3, dated May 1995, provides guidance on seats and restraints.

- **MIL-STD-1472F** – Par 5.6.3.1.4 stated:

Seats, restraint systems, safety harnesses, belts, controls or any equipment that must be adjusted for the comfort or performance of the individual user shall be adjustable for the range of personnel using them.

10.54 Is equipment positioned so that personnel will not bump or rub against it when riding over rough terrain?

System layout considerations affect the center of gravity, lateral stability, and loading of the shelter. Equipment and operator locations within a mobile shelter must be based on such aspects as the necessary orientation of the operator to the equipment for ease of use and safety, size of controls and displays and the amount of time each equipment is to be operated during mobile operation. All equipment must be oriented such that the operators will face forward to the greatest extent possible and not perpendicular to the direction of travel, to minimize injury and side effects of motion, such as motion sickness. A wraparound console containing all equipment to be operated during OTM operations, facing forward or backward to the direction of travel should be considered to minimize seat movement within the shelter.

10.55 Where equipment requires frequent viewing and access, is the operator not required to twist in his seat, which could diminish set belt effectiveness in an accident?

Properly designed seating will minimize potential injury that is possible during mobile operation. Seating design must take into consideration the operation of the system during all possible conditions of travel, such as operation on primary and secondary roads, and events such as sudden braking, turning, and collision. During mobile operation, riding personnel must not be required to leave their seats since injury may result from being bounced about the shelter. The dimensions and adjustments for the design of seating should be in accordance with SAE J899. A five point, adjustable and quick-release harness to secure the operator to the

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seat should be considered. The harness must not interfere with or entangle the operator during emergency egress from the shelter. The harness must also accommodate all percentile users. A wraparound console containing all equipment to be operated during OTM operations, facing forward or backward and not perpendicular to the direction of travel should be considered to minimize injury due to seat movement and operator twisting in his seat, which could diminish seat belt effectiveness and the side effects of motion sickness.

10.56 Is the equipment suitably mounted to prevent loosening or dislodging when the vehicle is driven over rough terrain or in the event of an accident or rollover?

Individual equipment in the shelter shall require proper mounting devices, and where rack mounted with slide-out mechanisms, must have locking devices to secure the equipment shelves and limit stops to preclude accidental dropping of the item. The mounted equipment shall withstand shock and vibration induced during vehicular transport over all types of roads and cross-country terrains or in the event of a vehicular accident.

10.57 Can users in the shelter maintain reliable communication with the driver at all times?

An intercom system between the vehicle driver and shelter occupants must be provided for constant communications during OTM operations for emergency situations. The intercom will allow the shelter occupants to alert the vehicle driver of any emergency situations that may occur within the shelter or external to the shelter of which the driver may be unaware, and vice versa. The use of Active Noise Reduction (ANR) headsets should be considered to filter out noise within the shelter while allowing clear communications. ANR headsets should also be considered for use by vehicle drivers who may be exposed to excessive engine noise (i.e. operation of the HMMWV above 25 mph).

- **MIL-STD-1472F** – Par 5.3.11.2.6 stated:

Dedicated lines should be provided for frequent or emergency communications.

10.58 Can operators access fire suppression systems, communications systems, and other critical controls while in a seated position?

The intercom systems, Fire extinguishers and critical controls must always be within reach of the seated operators. It is recommended that an Emergency control Panel (ECP) located in both the vehicle cab and shelter, be provided as a backup to the intercom system. The ECP would be used to warn personnel of hazardous conditions which may be either life threatening or capable of causing system loss. Situations such as equipment over temperature conditions, fire, power shutdown, or a Nuclear, Biological, or Chemical (NBC) event would be indicated on the panel and punctuated with an audio alarm. The ECP in the shelter would alert shelter occupants of emergencies external to the shelter, which have been identified, by cab occupants or external sensors. The ECP in the cab would alert cab occupants of emergencies within the shelter or situations external to the vehicle. All emergency controls and displays in the shelter should be physically grouped together on the ECP and separated from non-critical controls and indicators. The ECP must be located near the operator's main workstation at eye level to allow the operator to quickly focus attention in only one area and to allow a quicker response than if the controls were spread throughout the work area. If space exists, the fire extinguisher should be mounted under or behind each operator's seat

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and be easily reached in an emergency. If a fire extinguisher cannot be mounted to the operator's seat, the two fire extinguishers are required in large shelters, such as the S-280. One extinguisher must be located near the front of the shelter and the other near the exit. The front extinguisher would allow an operator seated in front of the shelter to fight a fire anywhere in the shelter, particularly a fire blocking the exit. The rear fire extinguisher would allow an operator seated in the rear (or located outside) of the shelter to fight a fire in the front of the shelter without passing through the fire to access the front fire extinguisher. One fire extinguisher will be required in smaller shelters (e.g. S-250), mounted as close to the exit as possible, and within reach of the second operator. The use of Carbon Dioxide (CO2) fire extinguishers can cause oxygen deprivation in confined spaces, such as shelters. If CO2 extinguishers are used, the effects of it use must be identified in both training and in the TMs. It is recommended that dry chemical fire extinguishers be used in this environment. Fire axes should also be included and located near the shelter exit. Axes may aid in unblocking obstructed exits or emergency exits. These items must be located to allow for unimpeded removal and use.

10.59 Is adequate airflow and temperature control maintained and can the user access the ECU controls while in a seated position?

Heating, cooling, and ventilation may be by an Environmental control Unit (ECU) to provide climatic control for the electronic equipment and personnel operating space. All personnel operating spaces of all enclosures shall be adequately ventilated. The shelter must maintain an interior temperature that provides a safe and comfortable work environment. The ECU needs to have an intake of fresh/clean air, or the shelter needs to have a separate fresh air intake. Contaminated air, such as from generators, prime movers, or other sources, must not be allowed to be drawn in by the ECU or fresh air intakes. If the Shelter uses an ECU/Gas Particulate Filter Unit (GPFU) in a closed loop system, interlock must be incorporated to preclude simultaneous operation of ventilation fan and the GPFU during the Chemical Biological mode of operation. The ECU controls must always be within reach of the seated operators with seat belts fastened.

10.60 Is the use of batteries that can vent poisonous gasses, such as lithium sulfur dioxide batteries, avoided?

Battery power often is preferable or the only practical means of providing electrical energy to equipment. Batteries may also be utilized as a backup power source. Normally, a battery is contained in a box or enclosure. This battery box configuration must be designed to provide any needed ventilation and preclude major system damage or serious personnel injury in the event of a violent gas venting or rupture of battery cells. Adequate ventilation may be required, depending on battery type, to prevent the build up of explosive and/or toxic mixture. Obviously, sources of all ignitions near the battery/box vent must be relocated or guarded to prevent fire/explosion. However, with the introduction and use of Lithium-Sulfur Dioxide (Li-SO2) batteries, it was discovered (accidentally) that some battery boxes could not safely accommodate the rapid and substantially more violent venting which sometimes occurred. Potential does exist for violent venting of a Li-SO2 battery or the fragmentation of a battery box and injury to occur if the user is standing in the path of "flying" battery box parts. A violent venting is defined as an incident that results in visible damage to the battery box. Consideration needs to be given to battery selection/battery box construction and safety during the development of the equipment or during market surveys for NDI equipment. Even though relative few violent venting are expected annually, when they do occur the user can be protected with

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a relatively small investment. The cost differences between initially designing or procuring safe battery/battery box and an unsafe battery/box can be relatively small, if any. The cost rises significantly when the equipment is fielded or soldier is injured. As a result of the improvements in battery manufacturing and quality assurance, there has been an overall reduction in the number of incidents involving the Li-SO2 batteries. However, due to the nature of the product, the vast quantities of batteries procured/consumed and the potential for user abuse, violent venting incidents can never be totally eliminated. If the potential for an incident to occur remains, then Li-SO2 batteries being procured for equipment should be avoided. Consideration to use other type of batteries that minimize the potential and severity of injury to personnel should be evaluated to maintain the user's confidence in the safety of the equipment.

10.61 Is emergency power and lighting available in the event of primary power loss?

Consideration should be given to provide emergency power and lighting and/or exit signs in large shelters/vans/semi-trailers, etc, where exits may be farther away. Batteries may be utilized as backup power sources. Whatever battery configuration or type is being considered as part of the design process, AMC Regulation 700-83 requires that battery assignment approval be obtained from the AMC Battery Management Office, ATTN: AMSEL-LC-P, Fort Monmouth, NJ 07703. This approval process is intended to minimize the proliferation of battery types and also assures that the battery power and current producing requirements are well within the capability of the battery selected. The latter will, of course, enhance safety.

10.62 Is adequate noise protection provided for the users?

The total noise within the shelter must be addressed from both an operational impact and from a safety viewpoint. This should include all equipment under the most active operational scenario to include any reasonably expected externally generated noises (such as generators, etc). Predecessor systems have required the addition of considerable noise reduction barriers/insulation to reduce the overall noise exposure to an acceptable level. Refer to MIL-STD-2474 for guidance.

- **MIL-STD-1472F** – Par 5.3.11.2.2 and 5.3.8.4 stated:

5.3.11.2.2 : Headsets should be used when any of the following conditions exists: (a) ambient noise levels are so high that protective devices are required to protect the ears of the listener; (b) different listeners must receive different messages; and (c) reverberation interferes with loudspeaker listening. Use binaural headsets if the listeners will be in intense noise. Earphone cushioning should provide comfort for extended periods of wear. Earphones should cover the outer ear without causing uncomfortable pressure. The earpiece should be held firmly in place, yet be easy to remove. A well-marked and accessible place should be provided for headset stowage. Corded headsets should have jacks placed in such a way and have cords sufficiently long that the cord does not interfere with the operator's activities.

5.3.8.4 : If listeners will work in high ambient noise (85 dBA or above), binaural rather than monaural headsets shall be provided. Unless operational requirements dictate otherwise, binaural headsets shall be wired so that the sound reaches the two ears in opposing phases. Their attenuation qualities should be capable of reducing the ambient noise level to less than 85 dBA. Provisions should be incorporated to furnish the same protection to those who wear glasses.

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10.63 Do critical commands that can be accidentally keyed require a second confirming action?

- **MIL-STD-1472F** – Para 4.5 stated:

A fail safe design shall be provided in those areas where failure can cause catastrophe through damage to equipment, injury to personnel, or inadvertent operation of critical equipment.

Section 11: Equipment Integration of Vehicle Cabs

11.1 Does placement of equipment or interconnecting cables avoid interference with pre-existing controls, indicators, or other equipment & panels requiring access?

The equipment must not interfere with existing vehicle controls, instrument panel indicators, and access panels. Consider indicators viewed by and controls accessed by the user as well as panels accessed by the vehicle maintainer. If labels are blocked, the must be reproduced and installed in a readily visible area. Equipment must not interfere with air conditioning and heater vents as well as fire suppression systems. If equipment is placed over access panels, it should be mounted so that it can be easily removed or swung out of the way. Otherwise, vehicle maintenance procedures will be impacted. Furthermore, there will be an increased potential for equipment damage since vehicle maintainers will have to remove the equipment and cables and may not know the proper removal procedures.

Don't forget to make sure that any C4SIR equipment access doors to hard disc drives, batteries, etc., can be opened and the internal components removed without impediment.

Consider what other C4ISR equipment may be required to be co-hosted in the same vehicle. All safety evaluations must be from a "system of systems" standpoint. It's not good enough to say "no other systems will be cohosted" since many vehicles receive SINCGARS, loud speakers, VIS, FBCB2 BFT, IED Jammers, smoke grenade launchers, etc. as needed in the field. Check with system managers and user representative if in doubt.

Consider differences between vehicle variants, armor kits, cold weather kits, etc. There have been cases where the addition of arctic heater switches, air conditioning power and Freon lines, and other components have interfered with the placement of installation kits designed for a standard vehicle. Many up-armored vehicle variants are having air conditioning and automatic fire suppressions systems installed; they need to be accounted for. The vehicle platform PM must be consulted as they will help ensure that all vehicle variants, add-on kits, and vehicle PMCS are considered.

Furthermore, it is strongly recommended that a user representative (preferably an experienced vehicle operator) be consulted during equipment space claim studies and initial fit checks. They can provide valuable field experience on how the vehicle/system is operated and over what terrain, how users move around the cab and interact with the controls, what other equipment is installed, what views are critical, where gear is stored, where they step during egress, etc.

- **MIL-STD-1472 –** section 5.4.1.3.8 states that the size, shape, and location of controls shall be designed to ensure that the operation of any one control shall not interfere with the operator's ability to use other controls and to perform other duties. Section 5.9.4.1 states structural members or permanently installed equipment shall not visually or physically obstruct adjustment, servicing, removal of replaceable equipment or other required maintenance tasks. Panels, cases, and covers removed to access equipment shall have the same access requirements as replaceable equipment. Mounting provisions shall be directly visible and physically accessible to the maintainers. Section 5.9.11.2 states extensions and connected appurtenances, accessories, utilities, cables, wave guides, hoses, and similar items shall not interfere with removing, replacing, or carrying an item. If such extensions and connected appurtenances interfere with these tasks, they shall be easily removed or disconnected from the equipment before handling. Easy disconnect shall consist of hand operable quick disconnect or standard hand tool operable disconnects in that order of preference.
- **49 CFR 571.101** – section S5.1 lists controls that must be operable by the driver and displays that must be visible to the driver.

11.2 Are equipment and associated cables located so that they will not trip, snag, or significantly impede soldier egress through primary or secondary egress paths?

A secondary egress path must be available to all vehicle occupants in the event of an accident or rollover. Consider all vehicle variants (2 door vs 4 door, metal vs canvas top) and add-on kits (armor, cold weather, etc.) Consider 5th percentile and 95th percentile soldier sizes, as well as soldiers wearing cold weather and flak jackets, side arms, etc. Any evaluation must be conducted with all equipment installed, all cabling

Section 11: Equipment Integration of Vehicle Cabs

connected, any security padlocks installed, and other crew gear or required systems and radios.

The best design approach is to place only the essential equipment up front. For instance, keep a computer display up front but the processor unit in the rear of the vehicle; use remote controllers for radios, etc. Co-host systems where possible. Minimize the size of the equipment and the mounting brackets that are used. Every additional component, cable, and bracket is another potential infringement into the driver/passenger space.

If a procedure must be relied upon to minimize impact hazards, consider whether it is reasonable that the procedure will be followed. For instance, if a system can be used on the move but is supposed to be angled or stowed for safety reasons, soldiers may ignore the procedure.

Consider what other C4ISR equipment may be required to be co-hosted in the same vehicle. All safety evaluations must be from a "system of systems" standpoint. It's not good enough to say "no other systems will be cohosted" since many vehicles receive SINCGARS, loudspeakers, VIS, FBCB2 BFT, IED Jammers, etc. as needed in the field. Check with system managers and user representatives if in doubt.

- **NFPA 1152 –** Article 6.2.1.1 requires recreational vehicles to shall have a minimum of two exits located remote from each other and so arranged as to provide a means of unobstructed travel to the outside of the vehicle. Article 6.2.5.1 states the alternate exit, if not an exterior passage door, shall provide an opening of sufficient size to permit unobstructed passage, keeping the major axis parallel to the plane of the opening and horizontal at all times, of an ellipsoid generated by rotating about the minor axis an ellipse having a major axis of 24 in. (610 mm) and a minor axis of 17 in. (432 mm).

- **MIL-STD-1472** – Section 5.13.4.2 states emergency doors and exits shall be unobstructed. Section 5.7.6.8 states catwalks, tunnels, and crawl spaces shall be designed to accommodate operations performed therein and personal clothing and equipment. Section 5.13.4.4 states workspace around areas where maintenance is performed shall be free of obstructions which could cause injury to personnel, either through accidental contact with the obstruction or because the obstruction requires an awkward or dangerous body position. Section 5.7.7.3 provides guidance on whole-body access dimensions.

  Section 5.6.2 states systems, equipment, and facilities used by operators, maintainers, and supporters shall be designed for full operation by the range of service personnel. Section 5.6.3.1.1 states that suitable adjustments in design-critical dimensions shall be made for light or heavy clothing, flying suits, helmets, boots, body armor, load-carrying equipment, protective equipment, and other worn or carried items.

11.3 Is equipment positioned so that personnel will not bump or rub against it when riding over rough terrain?

Minimize the size of the equipment and the mounting brackets that are used. Every additional component, cable, and bracket is another potential infringement into the driver/passenger space. Avoid placing equipment with corners and edges near occupants. Provide guards and padding as necessary.

Observe elbow, knee, and arm rest locations. Consider 5th percentile and 95th percentile soldier sizes, as well as soldiers wearing cold weather and flak jackets, side arms, etc. Any evaluation must be conducted with all equipment installed, all cabling connected, any security padlocks installed, and other crew gear or required systems and radios.

Talk to user representatives (preferably an experienced vehicle operator) as they can provide valuable insight into how the vehicle is operated, over what terrain, how well the restrain system works and how much they bounce around in the vehicle.

Consider whether any adjustable mounts are durable enough so that once a display or component is positioned out of the way, it does not migrate from that location due to vibration or during off-road riding conditions. For instance, the RAM Ball adjustable mounts (universal ball and socket mounting system) will often support heavier displays well when in a vertical position, but may migrate out of a horizontal position

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due to vehicle vibration. Need to consider the worst case vehicle vibration profile and the weight that the RAM Ball needs to support. Cold temperatures and dirt can also reduce the grabbing effectiveness of the RAM Ball.

- **MIL-STD-1472** – Section 5.12.2.1 provides guidance on vehicle operator seating dimensions and clearances. Section 5.6.2 states systems, equipment, and facilities used by operators, maintainers, and supporters shall be designed for full operation by the range of service personnel. Section 5.6.3.1.1 states that suitable adjustments in design-critical dimensions shall be made for light or heavy clothing, flying suits, helmets, boots, body armor, load-carrying equipment, protective equipment, and other worn or carried items.

  Section 5.6.2 states systems, equipment, and facilities used by operators, maintainers, and supporters shall be designed for full operation by the range of service personnel. Section 5.6.3.1.1 states that suitable adjustments in design-critical dimensions shall be made for light or heavy clothing, flying suits, helmets, boots, body armor, load-carrying equipment, protective equipment, and other worn or carried items.

11.4 Does the equipment location prevent increased personnel injury in the event of a vehicle accident or rollover?

Consider movement of the soldier and what they can hit and whether corners need padding, etc. This cannot be done by simply putting on the seat belt and leaning forward as far as possible. The body flexes much more when in an accident. Seat belts may also provide only limited protection, especially in the case of a rollover where the soldier can slip out of the top restraint. Avoid relying on procedural controls such as wearing a helmet to reduce injury severity due to hitting a surface. Such procedures cannot be relied upon all of the time, and the face and neck are not protected by the helmet.

Even if equipment is padded to limit head deceleration, consider whether the equipment can cause neck injuries. This especially applies to equipment mounted from the ceiling.

The best design approach is to place only the essential equipment up front. Minimize the size of the equipment and the mounting brackets that are used. Every additional component, cable, and bracket is another potential infringement into the driver/passenger space and provides another item that can be hit during and accident/rollover.

Consider 5th percentile and 95th percentile soldier sizes, as well as soldiers wearing cold weather and flak jackets, side arms, etc. Any evaluation must be conducted with all equipment installed, all cabling connected, any security padlocks installed, and other crew gear or required systems and radios. Any adjustable components and mounts should be assessed in various positions that may be used by the operator.

Consider what other C4ISR equipment may be required to be co-hosted in the same vehicle. All safety evaluations must be from a "system of systems" standpoint. It's not good enough to say "no other systems will be cohosted" since many vehicles receive SINCGARS, loud speakers, and FBCB2 as needed in the field. Check with system managers and user representatives if in doubt.

Placement of equipment directly in front of the wheeled vehicle passenger poses a high risk hazard in the event of an accident. This includes adjustable mounts that can position displays in front of the passenger. Avoid relying on "proper stowage procedures prior to vehicle movement" – if it's more comfortable for the passenger to have the equipment positioned in front while on the move, the will do so.

Mounting equipment to an A-pillar may also present a significant risk in an accident as well as may interfere with egress and the driver's field of view. The leg area may look like a good spot for mounting equipment but must be carefully assessed. Often that space is necessary to protect femurs and knees in the event of an accident. The vehicle platform PM must be consulted as they will have vehicle accident and injury statistics that can help assess equipment placement hazards. User representatives (preferably an experienced vehicle operator) can also provide valuable insight into how the vehicle is operated, over what terrain, how well the restrain system works and how much they bounce around in the vehicle.

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- **MIL-STD-1472** – Section 5.6.2 states systems, equipment, and facilities used by operators, maintainers, and supporters shall be designed for full operation by the range of service personnel. Section 5.6.3.1.1 states that suitable adjustments in design-critical dimensions shall be made for light or heavy clothing, flying suits, helmets, boots, body armor, load-carrying equipment, protective equipment, and other worn or carried items.
- **49 CFR 571.201** – sections S5 and S6 provide guidance to ensure that surfaces located within the head impact area are designed to limit the deceleration of the head.
- **49 CFR 571.208 –** The purpose of this standard is to reduce the number of deaths of vehicle occupants, and the severity of injuries, by specifying vehicle crashworthiness requirements in terms of forces and accelerations measured on anthropomorphic dummies in test crashes, and by specifying equipment requirements for active and passive restraint systems.

11.5 Are any required corner guards or padding suitable to protect against injury and are they design so they are not lost or removed during LRU swap-out?

The best option is to move equipment and corners out of the potential head impact zone. Where guards and pads must be used to reduce impact severity, pads must be thick enough to provide adequate deceleration of the head or other body parts in the event of an accident. Corners will typically require thicker padding than flat surfaces. Guards should be integral to the installation kits rather than the equipment so that they aren't lost upon equipment removal.

- **49 CFR 571.201** – sections S5 and S6 provide guidance to ensure that surfaces located within the head impact area are designed to limit the deceleration of the head.

11.6 Is the equipment suitably mounted to prevent loosening or dislodging when the vehicle is driven over rough terrain or in the event of an accident or rollover?

Equipment must not break away and cause injury/death in an otherwise survivable accident. Since vehicles are designed so that personnel can survive a 30 mph impact, all cab mounted equipment must be able to withstand 20G loading (per TACOM guidance as derived from FMVSS standards). This should be verified through structural analysis or testing (often, fasteners will be the weak point - but not always). Simply driving the vehicle over a dirt road for a few miles will not prove-out the adequacy of the brackets in an accident. There have been a number of reported cases of equipment breaking away and injuring personnel.

Ensure proper installation techniques are used to prevent loosening of equipment mounts due to vehicle vibration (lock washers, etc). If epoxy based studs (Click Bond fasteners) are used to mount equipment, tethers may be required as a redundancy. Even if Click Bond fasteners are selected to meet the 20G criteria, they may give way during an accident due to flexing of the vehicle frame.

Ensure that ancillary equipment such as keyboards, handsets, etc have designated storage locations when not in use.

Where equipment must be installed sideways or upside-down, ensure that the LRUs can be securely installed and that they won't come loose in these positions. There was a case where a component was mounted upside-down and due to the awkward location and LRU's bulky cables, users didn't always properly seat the LRU into the vehicle mount. As a result, the equipment would come loose and fall when the vehicle was driver over rough terrain.

- **49 CFR 571.207 –** S4.2.(a) requires that each occupant seat shall withstand 20 times the mass of the seat in kilograms multiplied by 9.8 applied in a forward longitudinal direction. This equates to a 20G force.
- **49 CFR 571.210** - S4.2.1 requires that seat belts, anchorages, attachment hardware and attachment bolts withstand a 5,000 pound force.

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- **NFPA 70** – Article 551.30(C) requires that storage batteries and generators be secured in place to avoid displacement from vibration and road shock. Article 551.57 states a means shall be provided to securely fasten appliances in place when the recreation vehicle is in transit. No additional guidance is provided beyond these performance requirements.
- **NFPA 1152 –** Article 5.2.4.1 requires propane tanks to be secured in place so they do not become dislodged when a load equal to eight times the container's filled weight is applied to the filled container's center of gravity in any direction. Article 5.10.3.5 applies the same requirement to fuel tanks.
- **MIL-STD-810 –** method 516.5, procedure V covers testing intended to verify the structural integrity of materiel mounts, tiedowns or containment configuration during simulated crash conditions. Table 516.5-I specifies test shock responses to be used if measure data is unavailable. For ground vehicles, it specifies a force of 75G and an effective shock duration of 8 – 13 msec.

11.7 Where the equipment is installed in up-armor variants, is the equipment suitably mounted to prevent dislodging in the event of blast-induced shock?

Up-armored vehicle will have additional requirements for blast survivability which are more severe than the 20G criteria. The vehicle platform PM must be consulted to determine what the blast survivability criteria is and whether a blast analysis is required. In the case of the M1114, blast testing revealed that the radio rack area experienced a longitudinally averaged value of 78g's, a transversely averaged value of 87g's, and a resultant of 117g's. There have been reported cases of equipment coming loose and injuring personnel during blast events.

The vehicle platform PM will often place restrictions on cutting or drilling the armor plating. Two alternatives are to mount equipment using existing take-off points or to use epoxy based fasteners such as those by Click Bond. However, tethers may be required as a redundancy for the later to keep equipment from becoming a projectile if it breaks loose. Redundant tethering may also be required for equipment supported by a RAM Ball adjustable mount.

11.8 Is the mounting hardware designed and installed such that when the equipment is removed, the remaining mounting hardware does not pose a mechanical hazard to personnel?

Equipment LRUs are often removed for repair or security reasons. They also may not have to be installed for every mission or every time the vehicle is to be driven. Empty mounts must not present a hazard.

- **MIL-STD-1472 –** section 5.13.5.4 states all exposed edges and corners shall be rounded to a radius not less than 0.75 mm (.03 in). Sharp edges and corners that can present a personnel safety hazard or cause equipment damage during usage shall be suitably protected or rounded to a radius not less than 1.3 mm (.05 in).

11.9 Are sharp or protruding edges, surfaces, or corners avoided with equipment in operating or stowed position?

Evaluate all corners, edges, exposed bolts, etc with keyboards/displays folded up or down. This is especially important with equipment mounted from vehicle ceilings which can cause head and neck injuries in the event of an accident. Consider 5th percentile and 95th percentile soldiers. Consider what surfaces may be hit during egress. There have been cases where soldiers stepping up into high cab vehicles (HEMTT, FMTV) would hit equipment mounted from the ceiling since the equipment was above their line of sight when climbing into the cab.

- **MIL-HDBK-454A –** Guideline 1, par 4.7 states sharp projections on cabinets, doors, and similar parts should be avoided. Doors or hinged covers should be rounded at the corners and provided with stops to hold them open.

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- **MIL-STD-1472 –** section 5.13.5.4 states all exposed edges and corners shall be rounded to a radius not less than 0.75 mm (.03 in). Sharp edges and corners that can present a personnel safety hazard or cause equipment damage during usage shall be suitably protected or rounded to a radius not less than 1.3 mm (.05 in).

11.10 Do hinged or adjustable mounting hardware avoid pinch/shear hazards?

Watch for potential pinch points that could occur during system setup, adjustment, or operation. Typical handhold locations should be considered when equipment is handled. Fold-out hinges used to limit equipment adjustment can act as scissors if improperly designed and/or placed. There have been reported cases where soldiers received injuries from scissor type hinges when they used force to un-jam the hinges. Regarding the RAM Ball display mounts (universal ball and socket mounting systems), watch for "knuckle-busting" conditions and scrapes due to soldiers try to tighten the RAM ball handle in confined spots.

- **MIL-STD-1472F –** Par 5.9.10.5 addressing latches and catches can be referenced, which states the spring action or snap-down force shall not be strong that it could injure a maintainer. Section 5.13.7.2.1 states a guard shall be provided on all moving parts on which personnel may become injured or entangled. Section 5.13.7.2.2 states adequate finger clearance shall be provided between rungs of telescoping ladders.

11.11 Are mounting screws and bolts properly sized to prevent projections?

Ensure proper lengths of bolts so that they don't create snag hazards. Consider from both a user and maintainer standpoint, where hands may been to reach to access cable connectors, etc..

- **MIL-HDBK-454A –** Guideline 1, par 4.7 states sharp projections on cabinets, doors, and similar parts should be avoided.
- **NFPA 1152 –** Article 5.1 states all design, construction, and workmanship shall be in conformance with accepted engineering practices.
- **MIL-STD-1472** - Section 5.13.4.4 states workspace around areas where maintenance is performed shall be free of obstructions which could cause injury to personnel, either through accidental contact with the obstruction or because the obstruction requires an awkward or dangerous body position.

11.12 Is the equipment located so that it will not be stepped on or otherwise damaged by personnel during ingress or egress?

Ensure that the C4SIR equipment cannot be damaged by a soldier stepping on or pushing off the equipment for leverage. Certain vehicles may have a variant that includes a gunner's ring or a canvas top that would permit soldiers to stand. Leverage is critical especially with the weight of some of the Gunner Protection Kits being added, and soldiers will not see what they are pushing off of. Additional guards may be required to protect equipment. User representatives (preferably an experienced vehicle/system operator) can also provide valuable insight into how the vehicle is operated, how users move around the cab and where they step during operations and egress.

Pay extra attention to the protection of touch sensitive displays. If they get a "dink" in the surface, that point may be sensed as a command selection on the screen or it may cause the screen curser to always scroll to the damage point.

- **NFPA 70 -** Article 551.40(B) states that electrical devices, fittings, and equipment installed in recreation vehicles shall be listed and used only in the manner in which they have been tested and found suitable for the intended use.
- **MIL-STD-1472** – section 4.9 states systems and equipment shall be sufficiently rugged to withstand

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handling in the field during operation, maintenance, supply, and transport. Section 5.13.2.5 states "NO-STEP" markings shall be provided when necessary to prevent injury to personnel or damage to equipment.

11.13 Does equipment location avoid intrusion into step or standing locations?

Certain vehicles may have a variant that includes a gunner's ring or have designated step locations for access to the top of the vehicle. Equipment must not interfere with the safe egress to the top of the vehicle. User representatives (preferably an experienced vehicle operator) can also provide valuable insight into how the vehicle/system is operated, how users move around the cab and where they stand or step during egress.

- **MIL-STD-1472 –** section 5.7.7.3 states where "step down" through a top access exceeds 69 cm (27 in), appropriate foot rests or steps shall be provided.

11.14 Are equipment controls and switches protected from accidental activation?

Consider location of elbows and hands relative to switches and the typical tasks and motions a soldier may make. Can crew gear contact the switches? Consider various soldier seating positions as well as equipment he may be carrying or wearing. There was a case where a system power switch was located out of the way and behind a seat, but soldiers should occasionally hit it while stowing their M16.

- **MIL-STD-1472 –** section 5.4.1.8. provides guidance on control location and design. Controls shall be designed and located so that they are not susceptible to being moved accidentally or inadvertently, particularly critical controls where such operation might cause equipment damage, personnel injury, or system performance degradation.

11.15 Do critical commands that can be accidentally keyed require a second confirming action?

Soldiers bouncing around in a vehicle while riding over rough terrain can unintentionally activate equipment or certain processes. Commands having safety impact should not be able to be activated without a confirming action.

- **MIL-STD-1472 -** 5.12.3.4 covering control of hazardous operations, states the operation of switches or controls which initiate hazardous operations shall require the prior operation of a locking control.

11.16 Are interconnecting cables run neatly and tied down to avoid any tripping and snag hazards?

Consider potential damage to cables as well as soldier egress issues. Also consider the potential for damage at the connector points based on where the equipment is installed. There have been reported cases of PLGR DAGR power cable connectors being damaged due to location as well as their smaller and less-rugged design.

- **MIL-STD-1472F –** Par 5.9.13.6 states that cables shall be routed or protected to preclude mechanical damage and abuse, including damage by doors, lids, use as steps or handholds, or being bent or twisted sharply or repeatedly.
- **NFPA 1152 –** Article 5.1 states all design, construction, and workmanship shall be in conformance with accepted engineering practices.
- **SAE J1292 –** Section 3.9.1 states wiring and related devices shall be installed in a workmanlike manner, mechanically and electrically secure.

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11.17 Are cables routed and equipment connectors protected against damage from personnel, crew gear and cargo storage?

Soldiers will use all possible space to store crew gear, munitions, and other supplies. Avoid running cables where such gear can be placed on top of the cables. Otherwise, additional mechanical protection may be required.

Also consider the potential for damage at the connector points based on where the equipment is installed. There have been reported cases of PLGR/DAGR power cable connectors being damaged due to location as well as their smaller and less-rugged design. Also check any adjustable mounts to see if there are positions where the equipment can hit or put any stress on the connectors. Cables and connectors tapping power from the NATO Slave connector below the HMMWV passenger seat are susceptible to damage from the soldier's feet.

- **NFPA 70 –** Article 551.47 list wiring methods approved for the environment. It also states that exposed nonmetallic cable shall be protected where subject to physical damage.
- **SAE J1292 –** Section 3.9.1 states wire routing shall be such that maximum protection is provided by the vehicle sheet metal and structural components. Section 3.9.2 states smooth protective channels especially designed for wiring and built into the vehicle body structure should be used when practical. Avoid areas of excessive heat, vibration, and abrasion. Extra protection (such as braid, loom, conduit, etc.) should be provided when these areas cannot be avoided.
- **SAE J1614 –** Section 4.8.2 states harness routing shall be such that maximum protection is provided by the machine covering and structure. Section 4.8.4 states wiring shall be located to afford protection from exposure to moving mechanisms, stones, abrasives, grease, oil, water, and fuel.
- **SAE J1673 –** section 3.2.2 states cable insulation shall be selected IAW the vehicles working environment. Systems must allow for physical and environmental factors such as flexing, heat, cold, bend, fluid exposure, dielectric, abrasion, short circuit and pinch resistance among others. Section 3.6.2 states that wiring routing should afford maximum protection by proper integration into the vehicle sheet metal and structural components. Wiring assemblies should fit into smooth protective channels, especially designed for wiring as part of the vehicle, where practical. Section 3.6 contains further guidance on wiring assembly installation and protection.
- **MIL-STD-1472** – section 5.9.13.6 states cables shall be routed or protected to preclude mechanical damage and abuse, including damage by doors, lids, use as steps or hand holds, or being bent or twisted sharply or repeatedly.
- **ANSI/RVIA 12V –** Section 5-1 states conductors shall be protected against physical damage and shall be supported. Wiring shall be routed away from sharp edges, moving parts, or heat sources.

11.18 Are cable ties and adhesives suitable to withstand the environment and rough handling?

Epoxy based studs (such as Click Bond fasteners) used to mount equipment must be durable. Redundant mounting may be required if they can break in a high G event (accident). Keep in mind that even if Click Bond fasteners have been selected to withstand a 20G force, bending and flexing of vehicle surfaces during an accident can break them loose depending on how and to what surfaces they are attached. Adhesive backed tie wrap mounts do not hold up well in unprotected environments and should not be used.

- **SAE J1292 –** Section 3.9.5 states that clips for retaining cables and harnesses shall be securely attached to body or frame members and cable or harness.
- **MIL-STD-1472** – section 5.9.13.2 states unless wiring ducts or conduits are used, mechanically (not adhesively) mounted cable clamps shall be provided to ensure correct routing of electrical cables within and between equipment items to ensure that cables do not hinder or obstruct equipment maintenance and to facilitate the mating of cables with their associated equipment items, and to prevent chafing due to contact with adjacent structure.

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- **SAE J1292 –** section 3.9.4 states that clips for retaining cables and harnesses should be securely attached to body or frame member and cable or harness.
- **SAE J1673 –** section 3.6.5 states that Clips for retaining cables and harnesses should be securely attached to body or frame member and cable or harness. Section 3.6.6 states all wire harness fasteners and components used for the purpose of routing, packaging, and retaining the harness shall be adequately protected against corrosion.

11.19 Are power cables jacketed and rated for heavy usage?

Power cables must be jacketed and properly rated to resist water, oil, wear, and other mechanical damage. Power cables with a single layer of insulation are not suitable if exposed to the harsh environment of a vehicle cab. There have been a number of cases where the single layer 18 AWG zip cord provided for the PLGR shorted and caught fire due to wear and damage of the insulation.

- **NFPA 70 -** Article 551.44(P) states that where use of flexible cord is permitted, it shall be listed for hard usage and for use in wet environments.
- **SAE J1292 –** Section 3.9.2 requires extra wiring protection (such as braid, loom, conduit, etc.) where wiring is not provided adequate protection by the vehicle sheet metal and structural components.
- **SAE J1673 –** section 3.2.2 states cable insulation shall be selected IAW the vehicles working environment. Systems must allow for physical and environmental factors such as flexing, heat, cold, bend, fluid exposure, dielectric, abrasion, short circuit and pinch resistance among others.
- **ANSI/RVIA 12V –** Section 5-1 states conductors shall be protected against physical damage and shall be supported.

11.20 Are conductors that supply equipment power properly fused?

Do not rely on fusing at the equipment side to protect power cables. Cables are subjected to all kinds of abuse and vehicle fires due to shorted cables have been reported. Fuses should be located close to the power tap point to protect the length of the power cable against electrical shorts.

Make sure that any COTS adapters used to tap power from NATO Slave connectors incorporate fusing at the supply-side plug. Typically, the vehicle provided NATO Slave plug is tied directly to the vehicle batteries without any fusing. COTS cable sets have been found without any fusing incorporated during past inspections.

- **NFPA 70 -** Article 551.30(E) requires that overcurrent protection be provided for supply conductors as an integral part of a listed generator or shall be located within 18 inches of their point of entry into the vehicle.
- **SAE J1292 –** Section 3.10 requires short circuit protective devices for all low voltage circuits selected top prevent wire damage when subject to extreme current overload. They are to be located at the battery feed side of switches.
- **SAE J1673 –** section 3.7 states the current to all high voltage circuits shall pass through overload protective devices connected to the battery feed side of switches. Section 3.2.5.3 provides additional guidance on the selection of cables and circuit protection devices.
- **ANSI/RVIA 12V –** Section 3-1 states all conductors shall be provided with overcurrent protection. Section 3-5 states the overcurrent-protective device shall be installed in an accessible location on the vehicle within 18 in. (457 mm) of the point where the power source connects to the vehicle circuits.

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11.21 Is the connection of equipment power cables directly to the vehicle battery terminals avoided?

Avoid tapping power directly from the battery. This has often been done in the past. But with the exponential increase in fielded C4ISR systems doing this, battery servicing by the vehicle maintainer has become a nightmare. Vehicle maintainers often do not have access to equipment TMs. Leads to the battery terminals have a greater chance of damage or being rewired incorrectly in the field. There have been a number of such reported cases. Consult the vehicle platform PM for a suitable power tap location.

11.22 Where equipment power cables connect to the vehicle power source, are wires properly tagged to show proper polarity and connection?

Proper, clear polarity marks are required at power hookup locations. Avoid short tags or sleeving at terminations as they can be cut off. There isn't one specific color coding standard for DC power cables. However, there are a number of practices that are readily obvious: red and black, POS and NEG, + and -. Using black and white isn't as obvious and should be supplemented with the above recommendations. Differentiate between 12V and 24V hookup if critical to proper operation of equipment. Maintainers servicing the vehicle equipment and batteries and have no idea what the extra cables are for and don't have access to all manuals.

Where equipment is designed to operate from a 12V DC supply and is mounted in a 24V powered vehicle such as a HMMWV, make sure that there are no equipment shorting hazards if the equipment is powered from the vehicle battery that is at +12V from chassis. There was a reported case of an early design PLGR that was powered in such a manner and which had a metal memory battery cover come in contact with the vehicle chassis. This created a reverse charge through the memory battery, causing it to rupture.

- **MIL-STD-1472 –** section 5.9.13.7 states cables shall be labeled to indicate the equipment to which they belong and the connectors with which they mate.

11.23 Are sharp bends in cables avoided?

Cables will sustain damage to the insulation if they are bent to sharply, especially in cold temperatures. Typical bending limitations are anywhere from 5 to 12 times the diameter of the cable. Any evaluation should be made with all equipment installed and all cables installed and while moving any adjustable components and displays.

- **NFPA 70 –** Article 300.34 states that the conductor shall not be bent to a radius less than 8 times the overall diameter for nonshielded conductors or 12 times the overall diameter for shielded or lead-covered conductors during or after installation. For multiconductor or multiplexed single conductor cables having individually shielded conductors, the minimum bending radius is 12 times the diameter of the individually shielded conductors or 7 times the overall diameter, whichever is greater. Other articles may recommend other bend radii for different cable types.
- **MIL-STD-1472** – section 5.9.13.6 states cables shall be routed or protected to preclude mechanical damage and abuse, including damage by doors, lids, use as steps or hand holds, or being bent or twisted sharply or repeatedly.
- **SAE J1673 –** section 3.6.4 states to avoid small bending radius for wires. As a general rule, the minimum radius is 5X diameter of cable. Also avoid bending the wires exiting a connector, this may provide a leak path in the rear seal of the connector.

11.24 Is the vehicle alternator adequately rated for the added equipment electrical power load?

Vehicle alternators are usually not protected against overload with a single main breaker. Total vehicle load must be determined (as well as what other C4SIR equipment may be installed) and an adequate margin maintained. There have been reported cases where a system that added only 4 amps load ended up

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burning up HMMWV alternators as it was the "straw that broke the camel's back" when the system was operated with the worst case load and temperature limits.

- **ANSI/RVIA 12V –** Section 2-2 states that addition to the original equipment manufacturer wiring system shall be permitted if it can be documented that the wiring system can safely support such additional amperage loads.

11.25 If commercial inverters are used to generate AC voltage, do they internally provide a neutral-ground bond that is disconnected when an external AC power source is connected?

No matter which AC power source powers a system, it is important that a ground-neutral bond be maintained so that circuit breakers can rapidly clear any electrical faults. At the same time, it's important to isolate the ground-neutral connections of different power sources from each other. Otherwise, a back-feed situation will be created between the parallel neutral-ground connections which would cause unacceptable AC current to flow over the grounding conductors.

Close attention needs to be paid to systems that incorporate on-board AC power sources and that also use external power, since the on-board power source will have a ground-neutral bond connection. This connection point needs to be isolated from the external power source to prevent current from back flowing through the on-board power source onto the grounding conductor. Switching the neutral conductor along with the phase conductors when selecting between on-board or external power will avoid this problem.

Certain power inverters (inverters generate AC voltage from a DC power source) may incorporate internal switching which will sense when AC shore power has been dropped or disconnected and will automatically switch to battery backup. Such switching must ensure the 1) a ground-neutral bond exists when on battery backup, and 2) the ground-neutral bonds for shore and backup are isolated from each other.

Certain inverters may rely on the external shore power ground–neutral bond point rather than providing a second internal connection. This is permitted by the NEC in article 250.30 Grounding Separately Derived AC systems where the inverter would be "solidly connected" to the other grounded power source. This is not suitable for mobile applications since the connection will be lost as soon as the shore power cable is disconnected.

Bottom line: consult with the inverter manufacturer to make sure the chosen inverter is suitable for the application described above. There have been cases where inverters have been selected which do not provide an isolated ground-neutral connection. Later when the inverter manufacturer was contact, they stated that a different inverter had to be used for the specific application in order to meet the NEC requirement.

- **NFPA 70 -** article 250.30 addresses grounding of separately derived power sources (defined as having no direct electrical connection to supply conductors originating in another system). The requirements are intended to ensure adequate grounding of such systems while preventing objectionable current of the grounding system through ground loops.

  Article 551.30 (RVs) states that generators (inverters would also apply) shall be installed to ensure that current-carrying conductors from the generator and from an outside source are not connected to a vehicle circuit at the same time. The grounded (neutral) conductor is considered a current-carrying conductor per the NEC.

  Special note: some may question whether the National Electrical Code applies to mobile systems installed in HMMWVs and other tactical vehicles. Article 90.3 states that the first 4 chapters of the NEC, covering wiring methods, materials, protective means, and other equipment apply in general and that the later chapters supplement or modify the general rules. Article 551 covering recreation vehicles must therefore also comply with NEC chapters 1-4. Furthermore, Article 551.4 states "a recreational vehicle not used for the purposes as defined in 551.2 (temporary living quarters for recreational use) shall not be required to meet the provisions of Part I pertaining to the number or capacity of circuits required. It shall, however, meet all other applicable requirements of this article if the recreational vehicle is provided with an electrical installation intended to be energized from a

Section 11: Equipment Integration of Vehicle Cabs

120- or 120/240-volt, nominal, ac power-supply system."

11.26 Is electromagnetic interference (EMI) which can cause any degraded or erratic operation of other equipment avoided?

EMI must be evaluated for vehicle platforms associated with weapons systems, fire control systems, or where other unwanted or erratic operation may create a hazard (turret rotation, antenna mast activation, degradation to Driver Visions Enhancement equipment, etc).

Also consider where ammunition and weapons are stored and whether radiated emissions or heating could be a concern. There was a case where electronics equipment was mounted below fuze storage location and required an analysis for fuze susceptibility to heat and radiated emissions by the Army Fuze Safety Board

- **MIL-STD-464A –** Par 4.1 states the system shall be electromagnetically compatible among all subsystems and equipment within the system and with environments caused by electromagnetic effects external to the system. Safety critical functions shall be verified to be electromagnetically compatible within the system and with external environments prior to use in those environments. Verification shall address all life cycle aspects of the system, including (as applicable) normal in-service operation, checkout, storage, transportation, handling, packaging, loading, unloading, launch, and the normal operating procedures associated with each aspect.

11.27 Where equipment is installed on platforms with weapons or turrets, has a test been conducted to ensure that EMI or co-hosted software cannot cause uncontrolled turret movement or weapons misfire?

The platform PM will need to conduct live fire testing to ensure any weapons systems cannot be unintentionally activated. This also applies to smoke grenade launchers. There have been reported cases where radiated emissions from antenna cables caused turrets to move whenever the radio was keyed.

Software can also have unanticipated interactions with the host platform system. All software updates and patches may require evaluation and testing by the host platform product manager.

- **MIL-STD-464A –** Par 4.1 states the system shall be electromagnetically compatible among all subsystems and equipment within the system and with environments caused by electromagnetic effects external to the system. Safety critical functions shall be verified to be electromagnetically compatible within the system and with external environments prior to use in those environments. Verification shall address all life cycle aspects of the system, including (as applicable) normal in-service operation, checkout, storage, transportation, handling, packaging, loading, unloading, launch, and the normal operating procedures associated with each aspect.

11.28 Is all equipment suitably grounded to chassis?

It is important that all equipment enclosure and other noncurrent-carrying conductive parts be grounded to ensure that circuit breakers or other overcurrent protective devices will clear as rapidly as possible during an electrical fault. In addition, grounding helps to ensure that personnel are not exposed to any voltage differences that may be generated between any accessible equipment enclosures and/or other conductive surfaces. This latter point is especially important in the vehicle environment where the soldier is in contact many metal surfaces and may also be sweaty (reduced body resistance).

Where equipment is designed to operate from a 12V DC supply and is mounted in a 24V powered vehicle such as a HMMWV, make sure that there are no equipment shorting hazards if the equipment is powered from the vehicle battery that is at +12V from chassis. There was a reported case of an early design PLGR that was powered in such a manner and which had a metal memory battery cover come in contact with the vehicle chassis. This created a reverse charge through the memory battery, causing it to rupture.

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- **NFPA 70 –** Article 551.30 requires generators to be mounted so as to be effectively bonded to the vehicle chassis. Article 551.55 requires that all exposed parts of electrical equipment be effectively bonded to the grounding terminals or enclosure of the distribution panelboard. Article 551.56 also requires that any exposed parts that can become energized be effectively bonded as well.

  Furthermore, article 551.20(C) requires that that chassis of power converters (convert 120V AC to low voltage DC) be bonded to the vehicle chassis with a minimum 8 AWG copper conductor. This is to reduce the possibility of damage to the power supply cord by large DC fault currents that may find their way back to the vehicle frame or battery through the ac grounding conductor of the converter.

- **ANSI/RVIA 12V –** Sections 2-3 and 2-5.1 require auxiliary batteries and power converters (converters generate DC voltage from an AC power source) to be suitably grounded to chassis.

11.29 Does the driver's field of view through the driver and passenger windshield and windows remain unobstructed with the equipment installed and adjusted in any position? Can the driver clearly see all mirrors?

Peripheral vision to the driver is extremely important for situational awareness and continually identifying potential driving hazards. The driver's peripheral vision through the passenger side windshield and window must not be obstructed. Do not rely on the driver having to look around equipment to see what may be coming from a blind spot. Think of any close-call situations you've had where you saw an oncoming car in the last second in the corner of your eye! Consider mirrors as well. Address any limitations created with add-on armor kits. There have been a number of accident & fatality investigations where obstruction to the driver's field of view was determined to be a contributing factor.

Consider what other C4ISR equipment may be required to be co-hosted in the same vehicle. All safety evaluations must be from a "system of systems" standpoint. It's not good enough to say "no other systems will be cohosted" since many vehicles receive SINCGARS, FBCB2 BFT, IED Jammers, smoke grenade launchers, etc. are added as needed in the field. Check with system managers and user representative if in doubt. There have been cases where the addition of other equipment prevented the proper positioning of a computer display out of the driver's field of view.

Numerous state vehicle codes restrict the placement of objects on or near the windshield or side windows which can block the driver's field of view while driving the vehicle.

- **MIL-STD-1472 –** Section 5.12.5 addresses driver visibility. The operator shall have forward visibility through a lateral visual field of at least 180° and preferably 220°. Truck design should enable the operator, in the normal operating position, to view the ground at all distances beyond 3 m (10 ft) in front of the vehicle. Upward visibility shall extend to not less than 15° above the horizontal. Side and rear enclosures should be designed to permit the operator to view the rear of the vehicle (directly or by use of mirrors) in order to observe the load and to facilitate trailer attachment and backing maneuvers. A glare-proof, west-coast type and spotter-rearview mirror shall be provided on each side of the cab, located in such a manner as to afford the operator rearward vision from the normal operating position.

- **MIL-HDBK-759C** - Section 5.12.5 addresses ground vehicle driver visibility. Section 5.12.5.4 addressed mirrors, and 5.12.5.5 address windshields and windows.

- **49 CFR 392.9** - subpart 3 states the commercial motor vehicle's cargo or any other object does not obscure the driver's view ahead or to the right or left sides (except for drivers of self-steer dollies), interfere with the free movement of his/her arms or legs, prevent his/her free and ready access to accessories required for emergencies, or prevent the free and ready exit of any person from the commercial motor vehicle's cab or driver's compartment.

- **49 CFR 571.111** – This section provides requirements for rear view mirrors to provide a clear and reasonably unobstructed view to the rear.

- **SAE J2331 -** This SAE standard provides a procedure for evaluating and documenting the masking

Section 11: Equipment Integration of Vehicle Cabs

effects caused by parts of the base machine with equipment within a visibility test circle around the eye position of the seated operator. Though the focus is on earthmoving machines, the procedure may be useful in assessing the masking effects of C4SIR installation kits, add-on armor, etc.

11.30 Where the driver's view can be obstructed by adjustable displays or equipment, can the equipment be aligned with existing vehicle obstructions to minimize impact? Are labels provided to warn the driver to do so and are the adjustable mounts designed so they don't progressively move/shift out of position due to vehicle motions and vibrations?

Where computer displays can be adjusted so that the driver's field of view is obstructed, then procedures must be implemented to line up the display with existing vehicle obstructions such as the A-pillar. Make sure to consider whether any procedure developed to control this hazard is reasonable and will be followed. For instance, if the system can be used on the move but the display must be positioned at an awkward viewing position or folded in a stow position, then users will most likely avoid the procedure.

Consider whether any adjustable mounts are durable enough so that once the display is properly positioned, it does not migrate from that location due to vibration or during off-road riding conditions. Consider whether cold weather and dirt can reduce effectiveness of adjustable mounts. There was a reported case of a RAM Ball adjustable mount used to support a display from a HEMTT ceiling above the driver's field of view. However, the mount eventually would migrate out of its horizontal position due to gravity and vehicle vibration, resulting in the display progressively blocking the driver's view out of the curbside of the vehicle. The display mount had to be relocated and redesigned.

Any labels outlining proper alignment procedures must be readily visible to the driver. The best location for the label would be where the driver sees is when looking toward the direction of the equipment that may be blocking his field of view.

- **MIL-STD-1472 –** Section 5.13.1 states the order of precedence for satisfying system safety requirements is 1) design for minimum risk; 2) incorporate safety devices; 3) provide warning devices; and 4) provide procedures and training. Section 5.13.2 states conspicuous labels or placards shall be placed on, or adjacent to, any equipment that presents a hazard to personnel. These labels or placards shall describe the hazard and state appropriate precautions. Labels and placards should also describe the consequences of not complying with the stated warning. They shall be located so as to be apparent to operators, maintainers, and transient personnel. Section 5.13.8 states training materials, devices, simulators, and other equipment using embedded training, should incorporate safeguards, safety warnings, and procedures developed for the system.

11.31 Is the equipment so located that it will not divert the driver's attention?

The primary concern is how the interaction with a display may interfere with the driver's primary purpose – driving the vehicle. Though certain information and mapping systems can improve driver efficiency and safety, the system will require the driver to look head-down inside of the vehicle, diverting attention away from the out-the-window (OTW) view.

If such information is to be presented to the driver, it must be presented in a manner that minimized the visual, attentional, and cognitive resources of the driver. Presenting too much information on the display would result in an excessive number of variables to be analyzed by the driver. Information that is not properly displayed or is excessive could cause a divergence of the visual attention from the primary task of driving in repeated occasions, which could affect driving performance and safety due to the forward view uncertainty buildup.

Only simple search tasks with the most important information should be presented. Minimize the attention and eye allocation time per task (includes number of dwells as well as the mean time per dwell). Consider that system requiring manual interaction will also result in lengthier task completion times, longer eyes-off-the road times, longer and more frequent glances to the device.

Section 11: Equipment Integration of Vehicle Cabs

If a display can be oriented toward the driver and must be stowed to control this potential hazard, consider whether a viewing restriction is a reasonable control. If the display can be used on-the-move and shows information that the driver may be interested in, then it's likely he will not follow that procedure.

There are numerous papers available on the internet that discuss the driver workload effects of in-vehicle information system tasks.

- **MIL-STD-1472 –** section 5.2.6.13.7 addresses attention distraction with helmet mounted displays. HMDs should minimize attentional distraction and user cognitive load demand by providing only task-oriented, essential, integrated information with minimum memory requirements.

11.32 Where the equipment requires frequent viewing or access, is twisting or other motion by the operator avoided which could cause repetitive motion stress?

Frequently accessed equipment should be mounted in as optimal a location as possible without straining the operator. However, placement of equipment at the optimal location must not present significant personnel safety hazards to the operator (crash safety, driver field of view obstructions, etc).

- **MIL-STD-1472 –** section 5.2.1.4.1 Location. Displays shall be located and designed so that they may be read to the required degree of accuracy by personnel in their normal operating or servicing positions without need to assume uncomfortable, awkward, or unsafe postures.

11.33 Where equipment requires frequent viewing and access, is the operator not required to twist in his seat, which could diminish seat belt effectiveness in an accident?

Seat belts provide optimal protection when the driver is seated properly.

- **MIL-STD-1472 –** section 5.2.1.4.1 Location. Displays shall be located and designed so that they may be read to the required degree of accuracy by personnel in their normal operating or servicing positions without need to assume uncomfortable, awkward, or unsafe postures.

11.34 Where night vision goggles are used, is direct or reflected light from indicators or displays avoided where it can interfere with driver night vision driving? Are lighting security issues avoided?

Need to make sure the display, backlighting, and any indicators do not interfere with night vision goggles. NVGs don't just shut down - they degrade. In other words, faintly seen object at optimal conditions will suddenly disappear. Consider not only the light given off by the display, but also how the passenger is illuminated by the display and his reflection in windows and other reflective surfaces. If the display is not NVG compatible, then the amount of degradation can only be determined by test.

Can the user black-out the screen and any backlighting LEDs with a single control? This is a useful feature, provided the user is not required to regularly view the display while OTM. A display blackout switch may not be practical if it's envisioned that the user will need to regularly view the data on the display.

Lighting security – can the enemy see you? Consider lighting security (blackout) requirements as well.

- **MIL-STD-1472** - section 5.2.1.4.4 states displays shall be constructed, arranged, and mounted to prevent reduction of information transfer due to reflection of the ambient illumination from the display cover. Reflection of instruments and consoles in windshields and other enclosures shall be avoided. Section 5.2.1.2.1.2 states where night vision device compatibility is required, the spectral output of all light emitting from or illuminating a display should be not greater than 600 nm in wavelength. The lighting shall be continuously variable to the full OFF position. In the OFF position, no current shall flow through the lamps. Section 5.12.5.9 states blackout lighting systems, if required, shall be designed to preclude accidental operation of external lights and signals.

Section 11: Equipment Integration of Vehicle Cabs

11.35 Is equipment heat load dissipated adequately so that cab temperatures will not increase significantly?

The added thermal load due to the addition of C4SIR equipment must be considered.

- **MIL-STD-1472 –** section 5.8.1.3 states that the effective temperature or CET within personnel enclosures used for detail work during extended periods shall be not greater than 29.5°C (85°F) (see Figure 34).

11.36 Is the use of batteries that can vent poisonous gasses, such as lithium sulfur dioxide batteries, avoided where the equipment cannot be readily jettisoned from the vehicle?

LiSO2 batteries can vent poisonous sulfur dioxide gas. If such batteries vent and cannot be readily jettisoned from the vehicle, soldiers may be forced to exit the vehicle in a hostile environment.

- **MIL-STD-1472 –** section 5.13.7.4.1 states personnel shall not be exposed to the concentrations of toxic substances in excess of the limits specified in either the Department of Defense (DoD) Occupational Safety and Health (OSH) standards or specialized standards applicable to military unique equipment, systems or operations.

Section 12: Transit Case Mounted Equipment

12.1 Where COTS is mounted in the transit cases, is additional protection against the elements provided for when the case is open?

COTS products Listed by a Nationally Recognized Testing Laboratory (see SEL Form 1183 Handbook questions 1.1 – 1.4) must be used within the limitations identified by the manufacturer and the product Listing category. They must be used and installed per the manufacturer's user & installation instructions. If a COTS product is intended for rack mounting in a dry, office-type environment, then additional design features and procedural controls need to be implemented to control hazards when used in less-hospitable environments.

Certain transit cases are designed to hold the equipment while it is operated, with covers at the front and rear removed for access to controls, cables, and connectors. Under those conditions, the internal COTS equipment could be exposed to moderate amounts of moisture in damp or partially protected areas (leaking tents, wind-blown rain near doorways, etc). It is therefore prudent to mount certain electronics components, power strips, and the like, so that dripping or pooling water does not come in contact with energized parts. For instance, power strips can be mounted deep inside the case or near the top where there is greater protection against the elements.

- **NFPA 70-05 -** Article 110.3 requires listed equipment to be used and installed in accordance with any instructions included in the listing. Article 110.11 states that unless identified for use in the operating environment, no conductors or equipment shall be located in damp or wet locations; where exposed to gases, fumes, vapors, liquids, or other agents that have a deteriorating effect on the conductors or equipment; or where exposed to excessive temperatures.

12.2 Is GFCI protection integrated into the power cord?

GFCIs are utilized to de-energize the circuit of the transit case mounted equipment when there are excessive leakage currents in the system. This protects personnel from potential electrical hazard when contacting any metal surface of the transit case that may become energized with the grounding path opened.

Equipment operated in wet or damp environments must be plugged into a GFCI. Where transit cases are provided with very long power cables (grater than 50 ft), those cables could be passed inside of shelters or buildings and plugged into receptacles are not required to be GFCI protected. In addition, very long power cables are more susceptible to damage. It is therefore prudent to incorporate GFCI protection into long power cables.

- **NFPA 70-05** Articles 210.8, 525.23, 550.13, and 551.41 cover GFCI personnel protection requirements for various situations.

12.3 Are metal parts which could become energized, such as the rack-mount frame

Section 12: Transit Case Mounted Equipment

members, adequately bonded to the equipment ground?

Certain transit cases are provided with metal brackets that support rack mounted equipment. Though such part do not contain any energized parts or normally conduct current, they could become energized due to a fault in the equipment or a power cable and therefore must be grounded.

- **NFPA 70-05 -** article 250.4 provides general performance requirements for grounding and bonding. Specific details grounding methods are addressed throughout Article 250 as well as in other articles (see table 250.3).
- **UL 60950 –** par 2.6.1 applies. UL 60950 uses the IEC terminology of earthing rather than grounding. Protective earthing is required from a safety standpoint (ensuring parts that could assume a hazardous voltage in the event of a sincle fault).

12.4 Are ground studs and bonding straps provided to permit bonding between cases?

In addition to the grounding requirements for equipment within the transit case, it's important to be able to bond to other collocated equipment. Personnel can sustain much worse injuries when contacting two metal surfaces at different potentials with bare hands (a low resistance path provided across the chest) than by contacting a surface energized to ground while wearing boots (a high resistance path to earth). For this reason, equipment and shelters located within armslength of each other (6-8 feet) must be bonded together to eliminate any hazardous voltages that may develop between such enclosures should a fault occur. This can be done either by running a bonding conductor between the two system's grounding terminals or to a common grounding system.

Transit cases and other remoted equipment can pose an increased hazard in this area. Often, radios and other Command & Control equipment are remoted from different shelters & systems to one location, such as inside of a tent. Since the earth grounding resistance for the different shelters can vary, potentials can exist between the remoted equipment. There have been cases where as much as 100v was measured between two radios mounted on the same table, spaced inches apart, due to a fault located elsewhere!

It is not the intent of this requirement to make the operator carry and install ground rods with all remote, portable equipment. Rather, the operator can interconnect to other equipment (via the ground lug) or other existing grounding system that may be locally available (grounded shelter, water pipe, steel structure, etc), eliminating unnecessary hazard exposure.

The grounding lug should be selected so that it can be used with typical grounding straps and grounding wires, etc.

- **NFPA 70-05 -** article 250.4 provides general performance requirements for grounding and bonding. Specific details grounding methods are addressed throughout Article 250 as well as in other articles (see table 250.3).

Section 12: Transit Case Mounted Equipment

12.5 Is an earth grounding system supplied if it can be powered more than 25 feet from the power source?

The earth grounding system ensures that a redundant ground for the transit case system is provided if the ground wire from the long power cable is open.

Portable equipment interconnected to other system via long lengths of signal line may have large surges induced due to EMP or nearby lightning strikes. In addition, long power cables are more susceptible to damage and could loose the grounding connection. To prevent the operator from becoming the discharge path to ground for the surge, it is recommended to have the equipment bonded to a suitable ground. Refer to SEL Form 1183 Handbook questions 1.35 and 1.53 for additional guidance.

- **NFPA 70-05 -** article 250.4 provides general performance requirements for grounding and bonding. Specific details grounding methods are addressed throughout Article 250 as well as in other articles (see table 250.3). Article 800.100 discusses grounding requirements for shielded cables and surge protective devices used with communications circuits.

12.6 Is overcurrent protection incorporated, located on the front panel, and clearly identified?

Overcurrent protection for transit case mounted equipment opens the circuit of the system if the current reaches a value that will cause an excessive or dangerous temperature in components or conductor insulation. A clearly identified overcurrent protection on the front panel is readily visible to the operator, who can implement an immediate action to resolve the overcurrent issue, or can activate the overcurrent protection device prior to the hazard occurrence. Refer to SEL Form 1183 Handbook questions 1.71 for additional guidance.

- **MIL-HDBK-454A –** Requirement 8, Par 4.1.1: Current overload protection shall be provided for primary circuits.
- **NFPA 70-05 -** articles 110.9 & 10 provide general requirements. Article 210.20 addresses requirements for branch circuits. Article 215.3 addresses requirements for feeders. Article 230 part VII addresses requirements for services. Article 240 provides general requirements for overcurrent and overload protection. Article 430 addresses overload and overcurrent protection requirements for motors. Article 408.4 requires a circuit directory on the face or inside of a panel board or at each switch on a switchboard.

12.7 Can the system be stacked or secured in a manner that will prevent it from tipping?

Most transit cases are required to be stacked during transport or operation. Straps or inter-locking mechanism must be designed to secure stacked cases. Non-skid material

Section 12: Transit Case Mounted Equipment

should be considered applying on bottom and top surfaces of stacked cases to prevent slipping in a slope.

Consider stability of the system with any moving parts in the worst-case position. If equipment requires disassembly to avoid damage during high wind conditions (antenna dish, etc), ensure controls are in place to avoid disassembly during high winds.

- **UL 60950 –** Par 4.1 states under conditions of normal use, equipment shall not become unstable.
- **MIL-STD-1472F –** Par 5.13.6.4 states equipment that may tip over and injure personnel due to a high center of gravity should have anchors or outriggers for stability and shall display an appropriate warning.
- **MIL-HDBK-454A –** Guideline 1, par 5.3 states the design of rack-mounted equipment should maintain the center of gravity as low as possible to minimize tipping over.

12.8 Does the system prevent tipping if weight is applied to a drawer or cover that can be extended?

If a drawer or cover is designed to be extended in transit cases, the system shall be adequately designed to insure that tipping does not occur when extended. Caution labels may be required to control the hazard. See item 12.7 above for additional guidance.

12.9 Are leveling systems provided for setup in uneven terrain?

Adequate leveling systems to prevent tipping should be considered in design of transit case mounted equipment, if setup the system is required in uneven terrain.

12.10 Are legs or other similar mechanisms provided with pads to prevent sinking in soft soil conditions?

If transit cases are required to be set up in all kind of environments, legs or other similar mechanisms provided with pads help to prevent transit cases from sinking in soft soil conditions and from possibly submerging into rainwater.

12.11 Are adequate handles and warning labels provided for repositioning the equipment with the transit box covers removed?

If equipment is required to be repositioned when the transit case covers removed, handles or grasp areas allows personnel to easily/safely reposition equipment. Labels on the equipment indicate unit weight and required no. of personnel for lifting.

- **MIL-STD-1472F –** Par 5.9.11.3.1.1 and 5.9.11.3.1.2: It cites that handles and labels shall be provided for items requiring to be lifted by more than one person.

Section 12: Transit Case Mounted Equipment
12.12 Where transportation or storage orientation are important, is the transit case labeled “This Side Up”? *Equipment inside transit cases could be damaged if transit cases are transported or stored upside down. Labels indicating the upside of the transit cases instruct personnel to follow the requirement.*
12.13 Are pressure relief valves provided for the transit cases? *Dangerous pressure can build up inside transit cases during operation or storage if covers are not removed. Pressure relief valves shall be installed on transit cases to relieve pressure inside.*
12.14 Are transit cases designed, or internal equipment mounted in a manner which will protect electronics from water if placed or operated on wet or saturated ground? *Electronics should be protected from water entry if placed on saturated ground. Refer to item 12.1 for additional guidance.*

PART 13: SOFTWARE SAFETY

Section 13: Software Safety

This section to be addressed in the future

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APPENDIX C. ABBREVIATIONS.

ANSI	American National Standards Institute
APHC	U.S. Army Public Health Center
ATEC	U.S. Army Test and Evaluation Command
BII	basic issue items
°C	degrees Celsius
CG	center of gravity
CBRN	Chemical, Biological, Radiological, and Nuclear
C-E LCMC	Communications-Electronics Lifecycle Management Command
cm	centimeter
COTS	commercial off-the-shelf
DA PAM	Department of the Army Pamphlet
dB(A)	decibel (A-weighted sound level)
DS	Directorate for Safety
DT	Developmental Test
DTIC	Defense Technical Information Center
°F	degrees Fahrenheit
FS	full scale
GOTS	government off-the-shelf
HAWG	Hazard Analysis Working Group
HAZMAT	hazardous material
HHA	Health Hazards Assessment
HHAR	Health Hazard Assessment Report
HMMP	Hazardous Materials Management Plan
in.	inch
ISO	International Organization for Standardization
JHA	Job Hazard Analysis
Lavg	time-weighted average noise level
MIL-STD	Military Standard
MOS	military occupational specialty
NET	new equipment training
NFPA	National Fire Protection Association

APPENDIX C. ABBREVIATIONS.

OSHA	Occupational Safety and Health Administration
PEO	Program Executive Office
PPE	personal protective equipment
RH	relative humidity
RSC	Recommendation for Safety Confirmation
RSR	Recommendation for Safety Release
SAR	Safety Assessment Report
SDS	Safety Data Sheet
SKOT	Sets, Kits, Outfits, and Tools
SOP	Standard Operating Procedure
TM	Technical Manual
TOP	Test Operations Procedure
TWA	Time Weighted Average
UL	Underwriters Laboratory
WBV	Whole Body Vibration

APPENDIX D. REFERENCES.

1. TOP 01-2-608B, Sound Level Measurements, 3 April 2019.

2. MIL-STD-810H, Environmental Engineering Considerations and Laboratory Tests, 31 January 2019.

3. MIL-STD-1474E, Noise Limits, 15 April 2015.

4. ITOP 04-2-822, Electronic Measurement of Airblast Overpressure & Impulse Noise, 25 September 2000.

5. MIL-STD-1472H, Human Engineering, September 2020.

6. TOP 02-2-622, Toxic Hazards Testing for Military Equipment and Materiel, 14 May 2020.

7. TOP 02-2-614A, Toxic Hazards Testing for Military Vehicles, 14 May 2020.

8. MIL-STD-882E, Department of Defense Standard Practice for System Safety, 11 May 2012.

9. TOP 02-2-800, Center of Gravity, 26 September 2006.

10. TOP 02-2-801, Weight Distribution and Ground Pressure (Wheeled and Track Vehicles), 26 September 2006.

11. ISO 2631-1, Mechanical Vibration and Shock-Evaluation of Human Exposure to Whole Body Vibration, Part 1: General Requirements, 1997.

12. ISO 2631-5, Mechanical Vibration and Shock-Evaluation of Human Exposure to Whole Body Vibration, Part 5: Method for Evaluation of Vibration Containing Multiple Shocks, 2018.

13. TOP 01-1-014B, Ride Dynamics and Evaluation for Human Exposure to Whole Body Vibration, 16 November 2020.

14. Health Hazard Assessor's Technical Guide 351C, Hazards Related to Musculoskeletal Trauma, Vibration, Shock and Thermal Stress, March 2021.

15. ISO 5349-2, Mechanical Vibration – Measurement and evaluation of human exposure to hand-transmitted vibration – Part 2: Practical guidance for measurement at the workplace, 2001-08.

16. ANSI Z535.3, American National Standard Criteria for Safety Symbols, 2017.

APPENDIX D. REFERENCES.

17. OSHA 29, CFR1910.145, Specifications for Accident Prevention Signs and Tags.

18. TOP 02-2-508, Automotive Safety and Health Hazard Evaluation, 24 November 1982.

19. TOP 01-2-807, Thermal Comfort Testing for Vehicle Operator/Passenger Workspaces (Truck Cabs), 10 September 2007.

20. TOP 02-2-820, Tactical Vehicle Climate Control Testing, 31 March 2017.

21. ITOP 01-1-057, Safety Critical Software Analysis and Testing, 14 May 2010.

22. MIL-STD-461G, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, 11 December 2015.

23. MIL-STD-464C, Electromagnetic Environmental Effects Requirements for Systems, 1 December 2010.

24. TOP 01-2-511A, Electromagnetic Environmental Effects System Testing, 20 November 2013.

25. TOP 03-2-616A, Electromagnetic Radiation Hazards Testing for Non-Ionizing Radio Frequency Transmitting Equipment, 19 December 2012.

26. American Conference of Government Industrial Hygienists (ACGIH), Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, 2021.

27. U.S. Department of Health and Human Services, NIOSH Pocket Guide to Chemical Hazards, Sept 2010.

28. OSHA, 29 CFR 1910, Permit-Required Confined Spaces for General Industry, 14 Jan 1993.

29. NFPA Code 30, Flammable and Combustible Liquids Code, 2021.

30. DA PAM 40-501, Army Hearing Program, 8 January 2015.

APPENDIX E. APPROVAL AUTHORITY.

CSTE-CI 11 February 2022

MEMORANDUM FOR

Commander, U.S. Army Operational Test Command
Director, U.S. Army Evaluation Center
Commanders, ATEC Test Centers
Technical Directors, ATEC Test Centers

SUBJECT: Test Operations Procedure 10-2-508A, Safety and Health Hazard Evaluation of General Equipment

1. Test Operations Procedure (TOP) 10-2-508A, Safety and Health Hazard Evaluation of General Equipment, has been reviewed by the U.S. Army Test and Evaluation Command (ATEC) Test Centers, the U.S. Army Operational Test Command, and the U.S. Army Evaluation Center. All comments received during the formal coordination period have been adjudicated by the preparing agency.

2. Scope of the document. This TOP provides guidance for the safety and health hazard evaluation of general equipment. It describes developmental test procedures required to determine whether general equipment is free from design, operational, or maintenance hazards. Safety checklists and a hazard analysis format are provided to assist in the assessment of hazards.

3. This document is approved for publication and has been posted to the Reference Library of the ATEC Vision Digital Library System (VDLS). The VDLS website can be accessed at https://vdls.atc.army.mil/.

4. Comments, suggestions, or questions on this document should be addressed to U.S. Army Test and Evaluation Command (CSTE-CI), 6617 Aberdeen Boulevard-Third Floor, Aberdeen Proving Ground, MD 21005-5001; or e-mailed to usarmy.apg.atec.mbx.atec-standards@mail.mil.

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Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to the following address: Policy and Standardization Division (CSTE-CI-P), U.S. Army Test and Evaluation Command, 6617 Aberdeen Boulevard, Aberdeen Proving Ground, Maryland 21005-5001. Technical information may be obtained from the preparing activity: Soldier Systems Division (TEAT-WFS), 6943 Colleran Road, Aberdeen Proving Ground, MD 21005-5059. Additional copies can be requested through the following website: https://www.atec.army.mil/publications/documents.html, or through 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.