METRIC/INCH-POUND

KSC-STD-E-0001C
AUGUST 12, 2008
Supersedes
KSC-STD-E-0001B
April 28, 1995

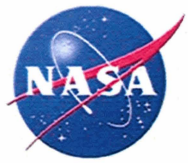
DESIGN OF ELECTRICAL CONTROL AND MONITORING SYSTEMS, EQUIPMENT (GSE), AND PANELS, STANDARD FOR

ENGINEERING DIRECTORATE

National Aeronautics and
Space Administration

John F. Kennedy Space Center

KSC FORM 16-12 (REV. 6/95) PREVIOUS EDITIONS ARE OBSOLETE (CG 11/95)



METRIC/INCH-POUND

KSC-STD-E-0001C
AUGUST 12, 2008
Supersedes
KSC-STD-E-0001B
April 28, 1995

DESIGN OF ELECTRICAL CONTROL AND MONITORING SYSTEMS, EQUIPMENT (GSE), AND PANELS, STANDARD FOR

Approved by:

Patrick A. Simpkins
Director of Engineering

JOHN F. KENNEDY SPACE CENTER, NASA

CONTENTS

This page intentionally left blank.

ABBREVIATIONS, ACRONYMS, AND SYMBOLS

°C	degree Celsius
°F	degree Fahrenheit
μ	micro
A	ampere
AC	alternating current
AIA	Aerospace Industries Association
AIAA	American Institute of Aeronautics and Astronautics
AN	Army-Navy
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
AWG	American Wire Gage
COTS	commercial off-the-shelf
dB	decibel
DC	direct current
DTL	detail
ECC	electromagnetic compatability compliance
EEE	electrical, electronic, and electromechanical
EGSE	electrical ground support equipment
EIA	Electronic Industries Alliance
EMI	electromagnetic interference
ESE	electrical support equipment
ETFE	ethylene tetrafluoroethylene
F	farad
FED	federal
GB	guidebook
GEIA	Government Electronics and Information Association
GP	general publication
GSE	ground support equipment
HDBK	handbook

Hz	hertz
I/O	input/output
IEC	International Electrotechnical Commission
IPC	Association Connecting Electronics Industries
k	kilo (1×10^{3})
KAPL-E	Kennedy Approved Parts List–Electrical
KNPR	Kennedy NASA Procedural Requirement
KSC	John F. Kennedy Space Center
LCD	liquid-crystal display
LCS	Launch Control System
LED	light-emitting diode
m	meter, milli (1×10^{-3})
M	mega (1×10^{6})
M&P	materials and processes
MIL	military
MSFC	George C. Marshall Space Flight Center
NAS	National Aerospace
NASA	National Aeronautics and Space Administration
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NPD	NASA Policy Directive
PC	printed circuit
PRF	performance-based
RF	radio frequency
rms	root mean square
SAE	Society of Automotive Engineers
SPEC	specification
STD	standard
UL	Underwriter's Laboratory
Ω	ohm

DESIGN OF ELECTRICAL CONTROL AND MONITORING SYSTEMS, EQUIPMENT (GSE), AND PANELS, STANDARD FOR

1. SCOPE

This standard establishes the minimum design requirements for electrical control and monitoring systems, ground support equipment (GSE), and panels that support processing systems both automated (e.g., Launch Control System [LCS]) and manual. This standard does not apply to the design requirements of institutional-type systems and equipment.

2. APPLICABLE DOCUMENTS

The following documents form a part of this document to the extent specified herein. When this document is used for procurement, including solicitations, or is added to an existing contract, the specific revision levels, amendments, and approval dates of said documents shall be specified in an attachment to the Solicitation/Statement of Work/Contract.

2.1 Governmental

2.1.1 Specifications

Federal

A-A-59551	Wire, Electrical, Copper (Uninsulated)
W-F-1814C	Fuses, Cartridges, High-Interrupting Capacity

John F. Kennedy Space Center (KSC), NASA

KSC-E-165	Electrical Ground Support Equipment, Fabrication, Specification for
KSC-SPEC-E-0002	Modular Enclosures (Cabinets, Consoles) and Accessories, Radio Frequency Interference Shielded, Specification for
KSC-SPEC-E-0029	Compound, Potting and Molding, Elastomeric, Specification for
KSC-SPEC-E-0031	Electrical Cables, General Specification for

Military

MIL-C-17	Cables, Radio Frequency, Flexible and Semirigid, General Specification for

MIL-C-22931	Cables, Radio Frequency, Semi rigid, Coaxial, Semi-Air-Dielectric, General Specification for
MIL-C-28876	Connectors, Fiber Optic, Circular, Plug and Receptacle Style, Multiple Removable Termini, General Specification for
MIL-C-83522	Connectors, Fiber Optic, Single Terminus, General Specification for
MIL-C-83526	Connectors, Fiber Optic, Circular, Environmental Resistant, Hermaphroditic, General Specification for
MIL-DTL-3890	Lines, Radio Frequency Transmission (Coaxial, Air Dielectric), General specification for
MIL-DTL-5015	Connectors, Electrical, Circular Threaded, AN Type, General Specification for
MIL-DTL-22992	Connectors, Plugs and Receptacles, Electrical, Waterproof, Quick Disconnect, Heavy Duty Type, General Specification for
MIL-DTL-38999	Connector, Electrical, Circular, Miniature, High Density, Quick Disconnect (Bayonet, Threaded, and Breech Coupling), Environment Resistant, Removable Crimp and Hermetic Solder Contacts, General Specification for
MIL-HDBK-454	Department of Defense Handbook, General Guidelines for Electronic Equipment
MIL-L-3661/5	Lampholders, Indicator Lights, Indicator-Light Housings, and Indicator-Light Lenses, Dusttight Housing Style LH73
MIL-L-15098	Lamp, Glow, General Specification for
MIL-PRF-27F	Transformers and Inductors (Audio, Power, and High-Power Pulse), General Specification for
MIL-PRF-8805	Switches and Switch Assemblies, Sensitive, Snap Action (Basic, Limit, Push Button and Toggle Switches), General Specification for

MIL-PRF-19500	Semiconductor Devices, General Specification for
MIL-PRF-22885	Switch, Pushbutton, Illuminated, General Specification for
MIL-PRF-39012	Connectors, Coaxial, Radio Frequency, General Specification for
MIL-PRF-49291	Fiber, Optical, General Specification for

National Aeronautics and Space Administration (NASA)

NASA-SPEC-5004	Welding of Aerospace Ground Support Equipment and Related Nonconventional Facilities

2.1.2 Standards

Federal

FED-STD-595	Colors Used in Government Procurement

John F. Kennedy Space Center (KSC), NASA

KSC-STD-132	Potting and Molding Electrical Cable Assembly Terminations, Standard for
KSC-STD-164	Environmental Test Methods for Ground Support Equipment, Standard for
KSC-STD-E-0002	Hazardproofing of Electrically Energized Equipment, Standard for
KSC-STD-E-0006	Instrumentation and Communications Cable Applications, Standard for
KSC-STD-E-0009	Cable Numbering, Outside Plant Communication System, Standard for
KSC-STD-E-0010	Soldering of Electrical Connections (Hand or Machine), Standard for
KSC-STD-E-0012	Facility Grounding and Lightning Protection, Standard for
KSC-STD-E-0015	Marking of Ground Support Equipment, Standard for

KSC-STD-G-0003	Launch Support and Facility Components, Qualification of, Standard for

George C. Marshall Space Flight Center (MSFC)

MSFC-STD-156	Riveting, Fabrication and Inspection, Standard for

Military

MIL-STD-129	Military Marking for Shipment and Storage
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-464	Electromagnetic Environmental Effects Requirements for Systems
MIL-STD-810	Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests
MIL-STD-1472	Department of Defense Design Criteria, Human Engineering
MS14003	Switch, Toggle, Positive Break, Environmentally Sealed, Solder Lug, Four Pole, 469 Mounting Bushing, 25 Amperes
MS35335	Washer, Lock, Flat-External Tooth

National Aeronautics and Space Administration (NASA)

NASA-STD-5005	Ground Support Equipment
NASA-STD-8719.13	Software Safety Standard
NASA-STD-8739.8	Software Assurance Standard

2.1.3 Drawings

John F. Kennedy Space Center (KSC), NASA

79K01010	Cable Identification Marker Tape
79K19600	Electrical Cable Fabrication Requirements

79K22638	Solderless Electrical Connections Procedure, Specification for
79K28125	Fiber Optic Cable Specification for Kennedy Space Center
75M11300	Marker Tape
75M50393	Plate Identification, Ground Support Equipment, Kennedy Space Center

2.1.4 Policy Directives

John F. Kennedy Space Center (KSC)

KNPR 8720.2	KSC Reliability, Maintainability, and Quality Assurance Procedural Requirements

National Aeronautics and Space Administration (NASA)

NPD 8730.2	NASA Parts Policy

2.1.5 Publications

John F. Kennedy Space Center, (NASA)

GP-435, Vol. I	Engineering Drawing Practices – Ground Support Equipment
GP-864, Vol. IIA	Electrical Ground Support Equipment Cable Handbook
KSC-NE-9187	Sensors, Transducers, and Signal Conditioning Systems Selection Process (Draft)

National Aeronautics and Space Administration (NASA)

NASA-GB-8719.13	NASA Software Safety Guidebook
NASA/TP—2003–212242	EEE-INST-002: Instructions for EEE Parts Selection, Screening, Qualification, and Derating

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specified procurement functions should be obtained from the procuring activity or as directed by the Contracting Officer.)

2.2 Non-Governmental

Aerospace Industries Association/National Aerospace (AIA/NAS)

NASM256	Nut – Self Locking, Plate, Right Angle, 250 F
NASM21042	Nut, Self-Locking, 450°F, Reduced Hexagon, Reduced Height, Ring Base, Non-Corrosion Resistant Steel
NASM21045	Nut, Self-Locking, Hexagon-Regular Height, 450°F, 125 KSI Ftu
NASM21046	Nut, Self-Locking, Hexagon-Regular Height, 800°F, 125 KSI Ftu
NASM21047	Nut, Self-Locking, Plate, Two-Lug, Low Height, Steel, 125 KSI Ftu, 450° F
NASM21048	Nut, Self-Locking, Plate, Two Lug, Low Height, CRES, 125 KSI Ftu, 450° and 800°F
NASM21049	Nut, Self-Locking, Plate, Two Lug, 100 ° CSK, Low Height, Steel 125 KSI Ftu, 450 °F
NASM21050	Nut, Self-Locking, Plate, Two Lug, 100° CSK, Low Height, CRES, 125 KSI Ftu, 450° & 800°F
NASM21083	Nut, Self-Locking, Hexagon Non-Metallic Insert, Low Height, 250 Degrees F
NASM21245	Nut, Self-Locking, Hexagon, Thin, 450 Degrees F, 80 KSI FTU
NASM24693	Screw, Machine, Flat Countersunk Head, 100°, Cross Recessed, UNC-2A and UNF-2A
NASM35206	Screw, Machine-Pan Head, Cross-Recessed, Carbon Steel, Cadmium Plated, UNC-2A
NASM35207	Screw, Machine-Pan Head, Cross Recessed, Carbon Steel, Cadmium Plated, UNF-2A (IN./MM)
NASM35333	Washer, Lock, Flat-Internal Tooth

NASM35338	Washer, Lock-Spring, Helical, Regular (Medium) Series

American National Standards Institute/American Institute of Aeronautics and Astronautics (ANSI/AIAA)

ANSI/AIAA R-100	Recommended Practice for Parts Management

American National Standards Institute/Government Electronics and Information Association (ANSI/GEIA)

GEIA-STD-0005-2	Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High Performance Electronic Systems

American Society for Testing and Materials (ASTM)

ASTM B 152	Standard Specification for Copper Sheet, Strip, Plate and Rolled Bar
ASTM B 633	Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel
ASTM B 700	Standard Specification for Electrodeposited Coatings of Silver for Engineering Use
ASTM F 844	Standard Specification for Washers, Steel, Plain (Flat), Unhardened for General Use

Electronic Industries Alliance/Electronic Components, Assemblies, and Materials Association (EIA/ECA)

EIA/ECA-310	Cabinets, Racks, Panels, and Associated Equipment

Association Connecting Electronics Industries (IPC)

IPC-2221	Generic Standard on Printed Board Design
IPC-2222	Sectional Design Standard for Rigid Organic Printed Boards
IPC-HDBK-001	Handbook and Guide to Supplement J-STD-001 (Includes J-STD-001 B-C-D Comparison) – With Amendment 1 and 2

International Electrotechnical Commission

IEC 61131	Programmable controllers

National Electrical Manufacturers Association (NEMA)

NEMA MW 1000	Wire, Magnet
NEMA HP 3	Electrical and Electronic PTFE (Polytetra-fluoroethylene) Insulated High Temperature Hook-up Wire; Types ET (250 Volts), E (600 Volt), and EE (1000 Volts)
NEMA HP 4	Electrical and Electronic FEP (Fluorinated Ethylene Propylene) Insulated High Temperature Hook-Up Wire, Types KT (250 Volt), K (600 Volt), and KK (1000 Volt)

National Fire Protection Association (NFPA)

NFPA 70	National Electrical Code

Society of Automotive Engineers (SAE) International

SAE AMS 2422	Plating, Gold
SAE AS50861	Wire, Electric, Polyvinyl Chloride Insulated, Copper or Copper Alloy

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of Precedence

In the event of conflict between the documents referenced herein and the contents of this document, the contents of this document shall supersede except where otherwise noted. The NASA contract, purchase order, or program-level documentation shall take precedence over the contents of this document in the event of conflicting requirements. Nothing in this document supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 General Requirements

General design requirements for control and monitoring systems and equipment (GSE) shall be in accordance with NASA-STD-5005. Detailed design requirements are specified herein.

3.1.1 Design Objectives

The design objectives for electrical control and monitoring equipment are performance, reliability, simplicity, maintainability, and personnel safety. Consideration should be given to the ease of modification. When using parts of equipment, take necessary precautions to ensure that the parts are being used within their environmental, mechanical, and electrical ratings.

3.1.1.1 Redundancy

Redundant systems, subsystems, or components shall be physically oriented or separated such that the failure of one will not prevent the other from performing its intended function.

3.1.1.2 Reliability

Systems and equipment shall be designed to meet system availability and/or dependability requirements. Systems and equipment shall be designed to minimize the probability of system failure and reduce the severity of the failure effect of the system. At a minimum, systems shall be designed to be fail-safe. GSE shall be designed to prevent propagation of failures to the flight hardware.

3.1.1.3 Qualification

Components shall be qualified in accordance with the KSC-STD-G-0003.

3.1.1.4 Expandability

Equipment shall be capable of a minimum of 10 percent expansion or modification without major redesign.

3.1.1.5 Operability

The design shall include all features that will result in stable operation and reduced maintenance requirements.

3.1.2 Parts

3.1.2.1 Standard Parts

Parts covered by KSC or other NASA specifications shall be used in lieu of other Government or commercially specified standard parts whenever the application can be satisfied by those parts.

3.1.2.2 Nonstandard Parts

Parts not covered by KSC, other NASA center, military, or other specifications denoted herein are considered nonstandard and require approval from the KSC Contracting Officer.

3.1.2.3 Commercial Off-the-Shelf (COTS) Parts

COTS equipment, parts, items, or components should be used to the maximum extent possible when the following conditions are met:

a. The devices satisfy the hardware function.

b. The devices will not degrade the safety or reliability of the flight or ground systems.

c. The devices provide a cost savings that will exceed possible cost increases resulting from unique maintenance or logistics requirements, modifications, or an increase in the complexity of the interfacing equipment.

In all cases, a qualification test procedure that satisfies the requirements of 3.1.1.3 shall be established to ensure that all vendor-designed, vendor off-the-shelf, or vendor-furnished items are covered by the materials and processes (M&P) requirements of NASA-STD-5005. Where detailed M&P information may not be available or it may be impractical to impose all the detailed requirements specified, the qualification test procedure should include special considerations for off-the-shelf hardware. The procedure shall include provisions for ensuring that hardware is satisfactory from an overall M&P standpoint.

3.1.2.4 Electrical, Electronic, and Electrotechnical (EEE) Parts

Use of EEE parts shall be in accordance with NPD 8730.2. Screening, qualification, handling, and management of EEE parts shall be in accordance with NASA/TP-2003-212242 (EEE-INST-002) or ANSI/AIAA R-100. Only EEE parts commensurate with the criticality of the application and the life cycle of the GSE shall be used. Determination of the EEE grade shall be based on the specific circuit function and its associated criticality in accordance with KNPR 8720.1.

3.1.3 Programmable Logic Controllers

Programmable logic controllers incorporated into the design of GSE should meet the requirements of IEC 61131-3.

3.1.4 Software

Software incorporated in the design of GSE shall meet the requirements of NASA-STD-8739.8 and NASA-STD-8719.13, NPR 7150.2 or those specified in the statement of work.

3.1.5 Firmware

Firmware incorporated in the design of GSE shall meet the requirements of NASA-STD-8739.8 and NASA-STD-8719.13, NPR 7150.2 or those specified in the statement of work.

3.1.6 Documentation

Drawings and specifications shall be provided in accordance with GP-435, Volume I.

3.1.7 Materials

Materials used shall be as specified herein. When not specified, materials selected shall be the best quality for the application and shall be approved for use by the Contracting Officer.

3.1.7.1 Corrosion Resistance

Materials used shall be corrosion-resistant or shall be suitably processed or protected to resist corrosion in accordance with NASA-STD-5008.

3.1.7.2 Fungus Resistance

Materials that provide no nutrition to fungi should be used, as identified in MIL-HDBK-454, Requirement 4, Table 4-I, Group I, except when one of the following criteria is met:

a. Materials are used inside environmentally sealed containers whose internal relative humidity (RH) at ambient conditions is less than 60 percent.

b. Materials are used inside electrical boxes in which the temperature is always equal to or greater than the surrounding temperature.

c. Materials have edge exposure only.

d. Materials are normally stowed with no risk of condensation in stowage locations.

e. Materials are fluorocarbon-based polymers (including ethylene tetrafluoroethylene [ETFE]) or silicones.

Alternate materials shall be tested for fungus resistance in accordance with MIL-STD-810. When fungus-nutrient materials are used, they shall be treated to prevent fungus growth. Materials not meeting this requirement shall be identified, including any action required such as inspection, maintenance, or replacement periods. Fungus treatment shall not adversely affect unit performance or service life or constitute a health hazard to higher-order life. Materials so treated shall be protected from environments that would be sufficient to leach out the protective agent.

3.1.7.3 Dissimilar Metals

Dissimilar metals shall not be used in intimate contact unless suitably protected against electrolytic corrosion. (See KSC-E-165 for the potential tendency of metals for galvanic corrosion.)

3.1.7.4 Toxic and Corrosive Fumes

Materials selected for design shall release no toxic or corrosive fumes during normal use or in the event of ignition or overheating.

3.1.7.5 Conformal Coating

Printed circuit (PC) boards housed in equipment expected to be exposed continuously to outdoor or corrosive environments shall receive conformal coating following construction and testing. The conformal coating shall be applied in accordance with NASA-STD-8739.1.

3.1.8 Interchangeability

Mechanical and electrical interchangeability shall exist between like assemblies, subassemblies, and replaceable parts, regardless of manufacturer or supplier. (Interchangeability, for the purpose of this standard, does not mean the exchange of identical parts or assemblies but requires that a substitution of like assemblies and parts be easily accomplished without physical or electrical modifications to any part of the equipment.) In the design of equipment, sufficient provisions shall be made for design tolerances to accommodate various sizes and characteristics of any one component within the limiting dimensions and characteristics required by the component specification and without departure from the specified performance.

3.1.9 Maintenance Provisions

Control and monitor equipment shall be designed so that it can be easily installed and maintained. Fault location accessibility and serviceability features that will lead to simplified maintenance shall be of prime consideration in design.

3.1.10 Self-Verification

Circuits shall incorporate self-verification techniques whenever practical.

3.1.11 Checkout Provisions

Satisfactory operation of all components shall be demonstrated. The checkout design shall include a thorough examination of the system for compliance with the specified requirements.

3.1.12 Environmental Protection

Design efforts for environmental protection shall be dictated by the natural environment of the area and the manmade environment of a specific location. Equipment exposed to the environments of KSC shall be tested to meet the requirements and conditions of KSC-STD-164. Equipment designed for operation in hazardous areas shall meet the requirements of KSC-STD-E-0002.

3.1.12.1 Controlled Interior Environment

GSE expected to function within a controlled interior environment shall be designed to operate under the following temperature and humidity conditions:

a. temperature: +15.6 degrees Celsius (°C) (60 degrees Fahrenheit [°F]) to +26.7 °C (80 °F), with extremes of an uncontrolled temperature of +11.1 °C (52 °F) to +40.6 °C (105 °F) for a maximum of 1 hour;

b. humidity: nominal 55 percent, with a range of 45 percent to 70 percent at 21 ±5 °C (70 ±10 °F).

3.1.12.2 Cooling

The specified operating temperature ranges of the various equipment parts shall be maintained. The cooling system selected shall be the simplest and most efficient, with consideration to heat load dissipation, equipment reliability, size, weight, and power requirements.

3.1.12.2.1 Natural Cooling

Simple cooling techniques not requiring external cooling provisions shall be used to the maximum extent possible.

3.1.12.2.2 Forced-Air Cooling

Forced-air cooling shall be used wherever natural cooling is not sufficient or where a significant reduction in overall size and weight can be realized. Exhaust and recirculating fans and blowers shall be driven by brushless motors. Fan noise should be minimized. Minimum differential pressures consistent with adequate cooling shall be maintained.

3.1.13 Special Tools

The design of the equipment shall minimize the need of special tools for tuning, adjustment, and maintenance.

3.1.14 Human Factors

The principles of human factors engineering shall be followed in the design of electrical control and monitor equipment in accordance with MIL-STD-1472. These include (but are not limited to) consideration of the following:

a. the intellectual, physical, and psychomotor capabilities of the intended users,

b. human space limitations for operations and maintenance,

c. visual and auditory perceptual requirements,

d. arrangement and readability of control and instrument displays,

e. safety factors, including minimizing potential human error, especially under stress, in the operation and surveillance of the equipment,

f. comfort factors as they relate to efficiency of operation, and

g. the effects of climate and mechanical service conditions on the ability of personnel to perform as required.

3.1.15 Marking

Marking of equipment shall be in accordance with KSC-STD-E-0015 except that engraving shall be done with a square cutter to ensure a uniform width of letters.

3.1.15.1 Reference Designators

Reference designators for components and assemblies shall be in accordance with GP-435. The reference designators will be assigned by the Engineering Directorate.

3.1.15.2 Serial Numbers

Serial numbers shall be required on those items, components, or assemblies that contain limited-life parts (e.g., valves or regulators) or require periodic maintenance, servicing, or calibration (e.g., pressure transducers, gages, switches, or torque wrenches).

3.1.15.3 Communication Cable Numbering

Cable numbering for fixed wire outside plant portions of communication systems shall be in accordance with KSC-STD-E-0009.

3.1.15.4 Shipment or Storage

Marking for shipment or storage shall be in accordance with MIL-STD-129.

3.1.15.5 Governmental Property

Marking of Government property shall be in accordance with MIL-STD-130.

3.1.16 Workmanship

Particular attention shall be devoted to neatness and thoroughness of soldering, wiring, impregnation of coils, marking of parts and assemblies, plating, painting, riveting, machine screw assemblage, welding, and brazing. Parts shall be free of burrs and sharp edges.

3.1.16.1 Cleaning

Units shall be thoroughly cleaned of loose or excess solder, metal chips, and other foreign material after final assembly. Burrs, sharp edges, and resin flux that might crumble shall be removed.

3.1.16.2 Wire Strapping

Wire stripping shall be done in accordance with NASA-STD-8739.3.

3.2 Detail Requirements

3.2.1 Electrical Power Requirements

3.2.1.1 Facility Power

Facility power shall be provided in accordance with NFPA 70.

3.2.1.2 Electrical Ground Support Equipment (EGSE) Power

EGSE power is supplied by transformers, static power supplies, motor-generator sets, or batteries that are ESE items rather than a part of the facility. The power sources shall use the following nominal alternating-current (AC) and direct-current (DC) voltages as applicable:

a. AC voltages:

120/240 volts (V) root mean square (rms), 60 hertz (Hz)

120/208 V rms, 60 Hz

240/480 V rms, 60 Hz

277/480 V rms, 60 Hz

400-Hz power will be made available upon request from the using site.

b. DC voltages:

28 V

56 V

3.2.1.3 DC Emergency Power

When loss of DC power will cause hazardous conditions, those power systems shall be backed up by batteries connected in a manner that ensures uninterrupted power for safing of GSE systems.

3.2.1.4 AC Emergency Power

Though AC is not available or sufficient for powering all KSC equipment during emergencies, it is available in various locations for operating fire alarm systems, stairway lighting, safety systems, and some vital equipment and is sufficient for safing of GSE systems as backup to the DC emergency power.

3.2.2 Electromagnetic Compatibility Compliance (ECC) Requirements

3.2.2.1 ECC Shielding

ECC shielding for the suppression of electromagnetic interference shall be used so that the finished equipment conforms to the requirements of MIL-STD-461.

3.2.2.2 Corona Protection

Corona suppression shall be used where applicable to prevent damage to equipment and generation of electromagnetic interference.

3.2.2.3 Transient Suppression

Transients shall be suppressed as required for equipment protection and electromagnetic interference suppression. In the application of suppressors, the operation of associated circuit elements shall not be unduly affected.

3.2.3 System Compatibility

System compatibility shall conform to the requirements of MIL-STD-464.

3.2.4 Switching

Redundant switching techniques shall be employed in design where failure of a switching circuit would be catastrophic.

3.2.4.1 Contact Racing

Switching circuits shall be designed so that contact racing does not exist.

3.2.4.2 Remote Operation

Switching circuits for remote operation of associated components shall use digital data links or relays.

3.2.5 Displays

Indications requiring operating acknowledgement or action shall be displayed on legend lamps, cathode ray tubes, counters, meters, liquid-crystal displays (LCDs), or recorders. Data display buses shall be separated from power buses to preclude a data display device failure from affecting command/control.

3.3 Electrical Interconnections

3.3.1 Shielding

Any shielding system, other than lightning shield systems, shall consist of a network without closed loops, insulated from ground potential, except at a single point-to-ground. Shields shall not be used as signal or power return conductors. Shields over individual conductors shall be grounded at one point.

3.3.2 Internal Wiring

The design of internal wiring used for electrical interconnection of components or parts within electronic GSE should be in accordance with MIL-HDBK-454 and the requirements of KSC-E-165. Wire terminations shall be in accordance with KSC-E-165.

3.3.3 Electrical Power Cable

Power cables designed for 60 Hz AC shall be in accordance with NFPA 70.

3.3.4 Instrumentation and Communication Cable

Instrumentation and communication cable shall be in accordance with KSC-STD-E-0006.

3.3.5 Fiber-Optic Cable

Fiber-optic cabling shall be in accordance with 79K28125.

3.3.6 Electrical Control Cable

The design of electrical control cables shall be in accordance with GP-864, Vol. IIA.

3.3.7 Electrical Cable

Flexible, multiconductor, neoprene-jacketed, electrical cable shall be in accordance with KSC-SPEC-E-0031 or NFPA 70.

3.3.7.1 Electrical-Cable Fabrication

Electrical cables for control and monitoring systems and equipment shall be fabricated in accordance with 79K19600.

3.3.7.2 Electrical-Cable Assemblies

Electrical-cable assemblies shall be identified at each end of the cable and labeled in accordance with 79K01010 or 79K19600.

3.3.8 Wiring and Cabling

Wires and cables shall be placed and protected to avoid contact with rough or irregular surfaces or sharp edges.

3.3.8.1 Support

Wires and cables shall be properly supported and secured to prevent undue stress on conductors and terminals.

3.3.8.2 Clearance

Wires, cables, and heat-emitting parts shall have enough clearance to prevent damage to or deterioration of the wires or cables.

3.3.8.3 Connector

The wiring of connector contacts to terminal-board terminals shall proceed, pin to terminal, in corresponding numerical or alphabetical order.

3.3.8.4 Terminal

There shall be no more than three wires per terminal and two wires per lug on a part.

3.3.9 Potting and Molding of Electrical Connectors

Potting and molding of electrical connectors, using epoxy resin potting compositions and elastomeric compounds, shall be in accordance with KSC-STD-132. Elastomeric potting compounds shall conform to KSC-SPEC-E-0029.

3.4 Rack, Panels, and Modular Enclosures

Electronic racks, panels, and modular enclosures used in interior applications shall be in accordance with ANSI/EIA 310.

3.4.1 Bonding and Grounding

Bonding and grounding of metal and equipment for safety of personnel and equipment shall be in accordance with KSC-STD-E-0012.

3.4.2 Ignitionproofing

Ignition proofing as specified in KSC-STD-E-0002 shall be used on equipment designed for use in hazardous areas (see 6.2.f).

3.4.3 Welding

Welding of electrical assemblies and subassemblies shall be in accordance with NASA-SPEC-5004.

3.4.4 Soldering

3.4.4.1 General Soldering

Soldering of electrical connections shall be in accordance with NASA-STD-8739.3 and NASA-STD-8739.2 for surface-mount technology. All solderable plating and protective finishes

based on tin shall contain a minimum lead content of 3 percent by weight. Guidance for tin whisker mitigation can be found in GEIA-STD-0005-2. Soldering shall not be used for structural applications.

3.4.4.2 Hand Soldering

Hand soldering of electrical connections shall be in accordance with the following:

a. NASA-STD-8739.3, when the GSE interfaces directly with a flight item;

b. KSC-STD-E-0010, when the GSE does not interface with flight hardware.

3.4.5 Plating

Deposited metallic coatings shall be as specified herein. The plating thickness in all cases shall be adequate to ensure conformance for conductivity and corrosion resistance.

3.4.5.1 Zinc

Zinc plating shall conform to ASTM B 633.

3.4.5.2 Gold

Gold plating shall conform to SAE AMS 2422.

3.4.5.3 Silver

Silver plating shall conform to ASTM B 700.

3.4.6 Lacing and Tying

Lacing and tying shall be in accordance with KSC-E-165.

3.4.7 Fabrication

Fabrication shall be in accordance with KSC-E-165.

3.4.8 Finishing

Finishing of metal panels and enclosures shall be in accordance with KSC-E-165. Colors shall conform to FED-STD-595. All panels and enclosures in a specific area shall be of the same color.

3.4.9 Riveting

Riveting shall be in accordance with MSFC-STD-156.

3.4.10 Inductors

Inductors shall conform to MIL-PRF-27.

3.4.11 Semiconductors

3.4.11.1 Standard Semiconductors

Standard semiconductors shall be elected from military specifications. (Standard semiconductor devices are manufactured in accordance with MIL-PRF-19500 and are listed in QML-19500 [MIL-HDBK-454].)

3.4.11.2 COTS Semiconductors

COTS semiconductors shall be rated industrial grade for use in control and monitoring systems.

3.4.12 Connectors

3.4.12.1.1 Electrical Multiconductor Connectors

Electrical multiconductor connectors shall be selected from the following basic family of connectors: MIL-DTL-5015, MIL-DTL-22992, MIL-DTL-38999; or from GP-864, Vol. IIA. When multiconductor connectors must be used in hazardous locations, they shall be waterproof and threaded. Operational provisions and controls shall be put in place to avoid the mating or demating of connectors when the connector pins are energized.

3.4.12.1.2 Fiber-Optic Connectors

Fiber-optic connectors shall conform to MIL-C-28876, MIL-C-83522, and MIL-C-83526.

3.4.12.2 Protective Covers or Caps

Protective covers or caps shall be specified for all electrical connector plugs and receptacles when they are not connected. Protective covers or caps shall meet the following requirements:

a. be moistureproof,

b. protect sealing, surface, threads, and pins from damage,

c. resist abrasion, chipping, or flaking,

d. comply with cleanliness requirements for plugs and receptacles on which they are used, and

e. be made of materials that are compatible with the connector materials.

3.4.12.3 Coaxial (Radio Frequency [RF]) Cable

Connectors for coaxial (RF) cable shall be in accordance with MIL-PRF-39012.

3.4.12.4 General-Purpose Connectors and Accessories

General-purpose connectors and accessories shall be standard parts selected from GP-864 (Kennedy Approved Parts List–Electrical [KAPL-E]).

3.4.12.5 Miniature Quick-Disconnect Connectors and Accessories

Miniature quick-disconnect connectors and accessories are preferred parts and shall be selected from GP-864, Vol. IIA (KAPL-E).

3.4.12.6 Heavy-Duty Connectors and Accessories

Heavy-duty connectors and accessories shall be preferred parts selected from GP-864, Vol. IIA (KAPL-E).

3.4.13 Printed Circuit (PC) Boards

3.4.13.1 NASA-Provided PC Boards

PC boards shall be designed in accordance with IPC-2221 and IPC-2222 and shall be fabricated in accordance with KSC-E-165. Specifications and standards prepared and published by the Association Connecting Electronics Industries (IPC) may be used in applications where such use will ensure acceptable items.

3.4.13.2 COTS PC Boards

PC boards shall be designed in accordance with IPC-2221 and shall be fabricated in accordance with IPC-HDBK-001, with Amendments 1 and 2.

3.4.14 Sensors and Transducers

Sensors and transducers for GSE systems shall be selected according to KSC-NE-9187.

3.4.15 Relays

Relays shall be hermetically sealed units and shall have continuous duty-rated coils. Relays shall be selected on the basis of application with regard to operate/release time, pickup/dropout voltage, and coil resistance. Transient suppression across the relay coil should be considered in order to minimize electromagnetic-interference (EMI) surges caused by coil inductances.

3.4.15.1 Relay Sockets

Relay sockets shall be bottom-mounting sockets. Standard part sockets may be selected from GP-864, Vol. IIA (KAPL-E).

3.4.16 Switches

3.4.16.1 Low-Current Switches

Low-current switches (under 1 ampere [A]), should have a wiping-type operation and/or gold-plated contacts whenever possible to prevent ohmic contact resistance over time. Where units are miniature, sealing is preferred prior to soldering in order to prevent flux contamination. Derating of 25 to 50 percent is preferred, especially for inductive loads.

3.4.16.2 High-Current Switches

High-current switches (over 1 A) should be industrial-rated, be approved/recognized by Underwriters Laboratory (UL) or another independent test laboratory, and have derating of at least 25 percent. Inductive loads shall have an additional 25-percent to 50-percent switch current derating. Arc suppression capacitors, or other transient suppression devices, typically 0.1 microfarad (μF) at 200 percent of working AC voltage, are recommended across contacts. Contacts shall be silver-plated. For corrosive environments, switches shall be located in an air-conditioned environment. For equipment located outdoors, switches shall be purged with dry air or GN_2, hermetically sealed, or provided with other means to ensure a stable, dry environment. Wiping contacts also serves to eliminate corrosive buildup.

3.4.16.3 Safety- or Reliability-Critical Circuits

For outdoor or potentially corrosive environments, sealed MIL-STD-qualified or MS-qualified switches are preferred. These include MS14003, MIL-PRF-8805, and MIL-PRF-22885. For critical circuit functions, switches with contact redundancy are preferred.

3.4.16.4 Heavy-Duty Pushbutton or Key Switches

Heavy-duty, high-cycle switches, such as crane pendants and emergency stops, shall be industrial-control type, National Electrical Manufacturer's Association (NEMA) 1-, 12-, or 13-rated.

3.4.16.5 Rotary Switches

Rotary switches shall be of ceramic-wafer and preferably enclosed construction. High-current rotary switches shall be of power tap construction with silver-plated contacts. Nonshorting types are normally specified. For corrosive environments, switches shall be located in an air-conditioned environment. For equipment located outdoors, switches shall be purged with dry air or GN_2, hermetically sealed, or provided with other means to ensure a stable, dry environment. Wiping contacts also serves to eliminate corrosive buildup.

3.4.17 Fuses

Fuses shall be approved or recognized by UL. Fuses shall be mounted on front or rear panels or other easily accessible areas. Care shall be taken to select fuse ratings at two to four times the maximum nominal circuit current. Slo-blo fuses are preferred where two times the fuse rating has to be used for inductive and/or higher-current circuits. Wiring shall be capable of momentary surge currents at the selected fuse capacity. Fuse rating shall be marked near the fuse holder or blocks and on schematics. The 31.8-millimeter (mm) by 6.4-mm (1.25-inch by 0.25-inch) fuses are preferred to typical AC-connected chassis or assemblies at up to 15-A rating. The effects of blown fusing on critical circuit operation will be considered.

3.4.17.1 Cartridge Fuses

Cartridge fuses shall be in accordance with W-F-1814C.

3.4.17.2 Fuse Holders

Fuse holders shall be UL-approved or UL-recognized. Twenty-ampere-rated fuse holders are mandatory for use with fuses over 10 A. Front-panel-mounted holders shall be neon-indicating, where no pilot light exists.

3.4.18 Indicators

Indicators shall be light-emitting diodes (LEDs) or neon. When used as indicator lights, LEDs should conform to the applicable specification sheets of MIL-PRF-19500. Where incandescent light is necessary, long-life and push-to-test lamps should be considered. For safety and hazard annunciation, consideration shall be given to the ambiguous condition of the unpowered state or burnout. Neon indicators shall be MIL-L-3661/5, with a 22-kilohm (kΩ) to 100- kΩ internal resistor or equivalent, and a MIL-L-15098 lamp (NE-51H, etc.). It is preferable to provide an AC power indicator on an AC line-operated chassis.

3.4.19 Legend Lights

Legend lights for information-indicating circuits shall be rectangular and shall have space for at least two rows of lettering, in accordance with KSC-STD-E-0015. The lens lettering shall be legible with lamps either on or off. The lens color shall be as follows:

a. Red indicates danger, failure, or a condition prohibiting operation.

b. Yellow or amber indicates technical hold, caution, or controlled interruption.

c. Green indicates operation has been successfully completed.

d. White indicates operation is in progress.

3.4.20 Meters

LED or backlit LCD digital panel meters are preferred for 1.27-centimeter (0.5-inch) or larger displays. Analog meters shall be used where trend information is more important than digital accuracy. Pivot-and-jewel types or taut-band types are preferred, with white face and black scale. Meters on any panel or within racks or consoles, when design permits, shall be the same in size and appearance. Test jacks should be provided to verify calibration conveniently. If meter bounce or a fast-varying signal is digitally monitored, a sample hold circuit should be provided.

3.4.21 Transformers

Transformers shall be in accordance with MIL-PRF-27F.

3.4.22 Circuit Breakers

Circuit breakers shall be used in all electrical power lines carrying over 5 A. Circuit breakers must be able to interrupt the short-circuit capacity of the circuit to which they are connected; each application must be examined for all its probable uses.

3.4.22.1 Power Circuits

Power circuits shall be protected by companion-trip or common-trip magnetic circuit breakers. Circuit breakers shall be trip-free.

3.4.22.2 Subminiature Circuit Breakers

Medium-voltage circuits (50 V to 120 V; 0.05 A to 20 A) shall be protected by subminiature circuit breakers, where the interrupting capacity for short circuits shall not exceed 500 A at 110 VAC.

3.4.23 Terminals

3.4.23.1 Crimp-Type Terminals – 79K22638

Crimp-type solderless terminals shall be used wherever possible for terminating wiring cables or trunk wiring.

3.4.23.2 Binding Posts and Test Jacks

Binding posts and test jacks shall be made of nylon or other high-impact-strength materials.

3.4.23.3 Terminal Blocks

Barrier-type terminal blocks shall be selected from the standard parts list of GP-864, Vol. IIA (KAPL-E).

3.4.23.4 Wire Wrap Posts

Wire wrap terminal posts shall conform to NASA-STD-8739.4.

3.4.24 Bus Bars

Bus bars shall be made of copper conforming to ASTM B 152.

3.4.25 Shielded Modular Enclosures

Modular enclosures and accessories shall be shielded against RF interference in accordance with KSC-SPEC-E-0002.

3.4.25.1 Ignitionproofing

When required, enclosures shall be ignitionproofed in accordance with KSC-STD-E-0002.

3.4.25.2 Finishing

Enclosures shall be finished in accordance with KSC-E-165.

3.4.26 Panels

Panels shall be either standard 483-mm or 610-mm (19-inch or 24-inch), with mounting-hole dimensions and spacing conforming to universal spacing in accordance with EIA/ECA-310.

3.4.26.1 Finishing

Panels shall be finished in accordance with KSC-SPEC-E-0002.

3.4.26.2 Materials

Materials shall be as specified in KSC-SPEC-E-0002.

3.4.26.3 Handles

Handles of panels shall be bail type and shall have a bright chromium finish.

3.4.26.4 Slides

Slides used to mount chassis assemblies to enclosure frames shall allow for the following:

a. minimum 460-mm (18-inch) extension of the chassis assembly from enclosure (panel face in normal position to panel face in extended position),

b. latching the extended position,

c. quick detachment of the chassis assembly from the enclosure,

d. dead-load application of 450 newtons (100 pounds) (rated for continuous service) at the centerline of the panel face when each pair of installed slides is fully extended.

3.4.26.5 Marking

Lettering for panels shall be in accordance with KSC-STD-E-0015.

3.4.27 Identification Plates

Identification plates shall be in accordance with 75M50393.

3.4.28 Wire

3.4.28.1 Magnet Wire

Magnet wire shall be in accordance with NEMA MW 1000.

3.4.28.2 Uninsulated Wire

Uninsulated wire shall conform to A-A-59551.

3.4.28.3 Insulated Wire

Conductors 1.25 mm (16 AWG) and smaller shall be in accordance with NEMA HP 3 or NEMA HP 4, 19-strand minimum. Conductors 1.60 mm (14 AWG) and larger shall conform to SAE AS50861, Type I or Type II. No outer jacket shall be applied over the primary insulation of NEMA HP 3 or NEMA HP 4 conductors, except where individual or overall shields are employed.

3.4.28.4 Shielded Wire

Shielded wire shall be in accordance with NEMA HP 3 or NEMA HP 4, with 19 strands minimum.

3.4.29 Cables

Cable design shall consider growth and versatility. A 20-percent growth factor should be considered so that additions or changes may be effected without major cable redesign.

3.4.29.1 Coaxial Cable

Coaxial cables used for RF transmission shall conform to MIL-C-17. Coaxial cable should be selected from MIL-C-17, MIL-DTL-3890, MIL-C-22931, or MIL-C-28830.

3.4.29.2 Multiconductor Cable

Cables used for interconnecting units of interior-exterior ground-network systems where voltages do not exceed 600 V rms shall conform to KSC-SPEC-E-0031.

3.4.29.3 Fiber-Optic Cable

Fiber-optic cable shall be in accordance with 79K28125 or MIL-PRF-49291.

3.4.29.4 Cable Identification

Cable identification markers shall be in accordance with 75M11300; 75M11300-1 (green) shall be used for flight cables, and 75M11300-2 (red) shall be used for test cables. Unless otherwise specified, cable markers shall be hot-stamped with white in 3.2-mm (0.125-inch), minimum, Gothic uppercase characters, in accordance with KSC-STD-E-0015.

3.4.29.5 Environmental Protection

All cables shall be capped or suitably sealed and stowed when not connected to equipment.

3.4.30 Termination

Wiring systems and terminals shall meet the requirements dictated by the environment in which they are installed and shall be capable of using wires up to 14 AWG.

3.4.31 Isolation

The input/output (I/O) components shall provide immunity and isolation from noise and electrical surges. The following are basic requirements:

a. fast transients: 2 kV;

b. transient-surge-withstand capability: 1 kV common mode, 0.5 kV differential mode;

c. common mode rejection: 120 decibels (dB) at 60 Hz;

d. input impedance: >10 megohms (MΩ) for voltage ranges, 249 Ω for current ranges.

3.4.32 Output Condition During Failure Modes

The operation of PLC software and hardware shall allow for various levels of health monitoring and permit configuration of failure modes. The following requirements shall be met:

a. The processor executive shall recognize nonfatal faults and perform predefined tasks to alert the operator.

b. The hardware shall recognize fatal errors and respond by placing outputs in the predefined failed-safe mode.

c. The processor executive shall recognize faults with system components and perform defined tasks to safe the failed component and alert operators.

3.4.33 Standard Hardware

3.4.33.1 Flathead Screws

Flathead screws used for flush-mounting hardware on panels or on chassis shall conform to NAS24693.

3.4.33.2 Panhead Screws

Panhead screws shall conform to NASM35206 or NASM35207.

3.4.33.3 Self-Locking Nuts

Self-locking nuts shall conform to NASM21042, NASM21045, NASM21046, NASM21083, and NASM21245.

3.4.33.4 Stationary Nuts

Stationary nut plates shall conform to NASM256, NASM21047, NASM21048, NASM21049, and NASM21050.

3.4.33.5 Lock Washers

Lock washers, when used, shall be as follows:

a. flat, external tooth, conforming to MS35335;

b. split helical, conforming to NASM35338;

c. flat, internal tooth, conforming to NASM35333.

3.4.33.6 Flat Washers

Plain flat washers shall conform to ASTM F 844.

4. QUALITY ASSURANCE PROVISIONS

Quality assurance provisions are contained in the appropriate referenced specifications.

5. PREPARATION FOR DELIVERY

Items to be shipped shall be securely packaged and packed in appropriate shipping containers that will provide adequate protection against damage or degradation of any kind during shipment. All applicable carrier rules shall be complied with. Containers shall be marked to conform to MIL-STD-2073.

6. NOTES

6.1 Intended Use

This standard is intended to be used in the establishment of uniform engineering practices and methods to ensure the inclusion of essential requirements in the design of electrical control and monitoring equipment used to support the test, checkout, service, and launch of space vehicles and payloads at KSC.

6.2 Definitions

For the purpose of this standard, the following definitions shall apply.

a. **commercial off-the-shelf (COTS):** equipment, including hardware and associated software/procedures, that is commercially available from current industry inventory

b. **contact racing:** condition that results when the particular order in which events are specified to occur cannot be guaranteed in practice (The term comes from the idea of two signals racing each other to influence the output first.)

c. **control and monitoring equipment:** electrical ground support equipment used in the control and monitoring of launch-related equipment

d. **firmware:** the combination of hardware device, computer instructions, and/or computer data that reside as read-only software on the hardware device

e. **ground support equipment (GSE):** nonflight equipment, systems, or devices specifically designed and developed for a direct physical or functional interface with flight hardware

f. **hazardous area:** an area in which flammable gases or vapors are or may be present in sufficient quantity to establish an air-to-gas ratio that would produce an ignitable or explosive mixture

g. **panel:** the metal plate upon which displays, monitoring components, controls, and test points may be mounted

h. **programmable electronics:** devices based on computer technology which may comprise hardware, software, and input and/or output units

i. **trip-free circuit breaker:** a circuit breaker that will open and remain open under fault or overload conditions

Custodian:

NASA – John F. Kennedy Space Center
Kennedy Space Center, Florida 32899

Preparing Activity:

John F. Kennedy Space Center
Electrical Design Branch
Electrical Division
Engineering Directorate

This page intentionally left blank.

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of the form.

NOTE: This form may not be used to request copies of documents, nor to request waivers or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document or to amend contractual requirements.

I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER KSC-STD-E-0001C	2. DOCUMENT DATE August 12, 2008

3. DOCUMENT TITLE
Design of Electrical Control and Monitoring Systems, Equipment (GSE), and Panels, Standard for

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*	b. ORGANIZATION	
c. ADDRESS *(Include Zip Code)*	d. TELEPHONE *(Include Area Code)*	7. DATE SUBMITTED

8. PREPARING ACTIVITY

a. NAME Electrical Design Branch, Electrical Division, Engineering Directorate	b. ORGANIZATION 321-867-6537

c. ADDRESS *(Include Zip Code)*
Kennedy Space Center, Florida 32899