Commercial Off The Shelf (COTS) EEE Parts @ KSC

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KSC Programs & Projects

- Exploration Ground Systems Program
  - Orion & Space Launch System (SLS): Vehicle & Payload Processing & Launch
    - Command, Control & Communications - Launch Control System
    - Mobile Launcher – Umbilical & Control Systems
    - Ground Support Equipment
- Commercial Crew Program
- Launch Services Program
- Gateway Deep Space Logistics
- Exploration Research & Technology (ISS & Small Ground & Flight Projects)
- Center Management & Operations

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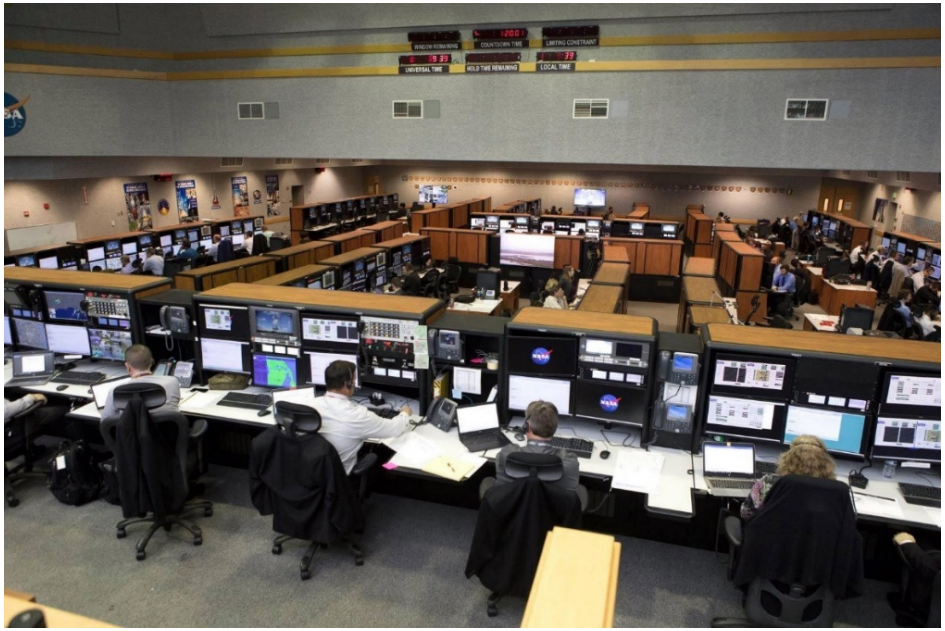
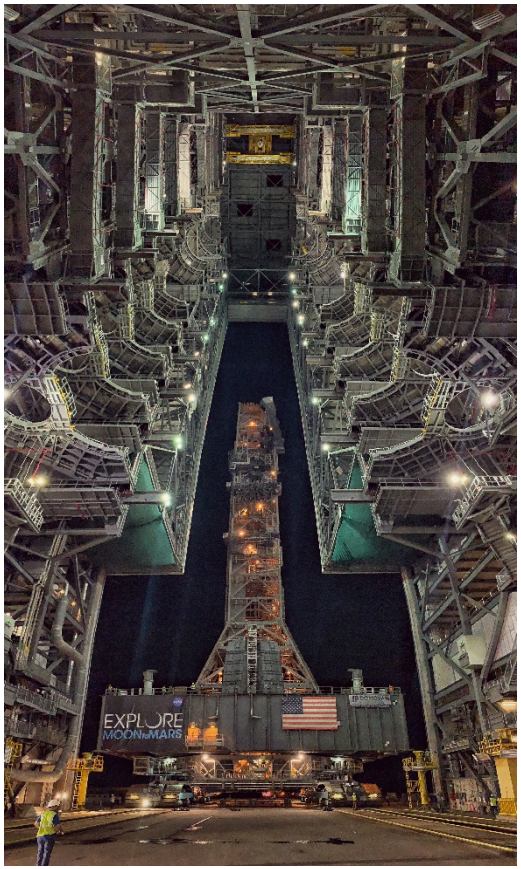
- **Exploration Ground Systems**
  - Orion & SLS: Vehicle and Payload Processing and Launch
  - Command, Control & Communications – Launch Control System

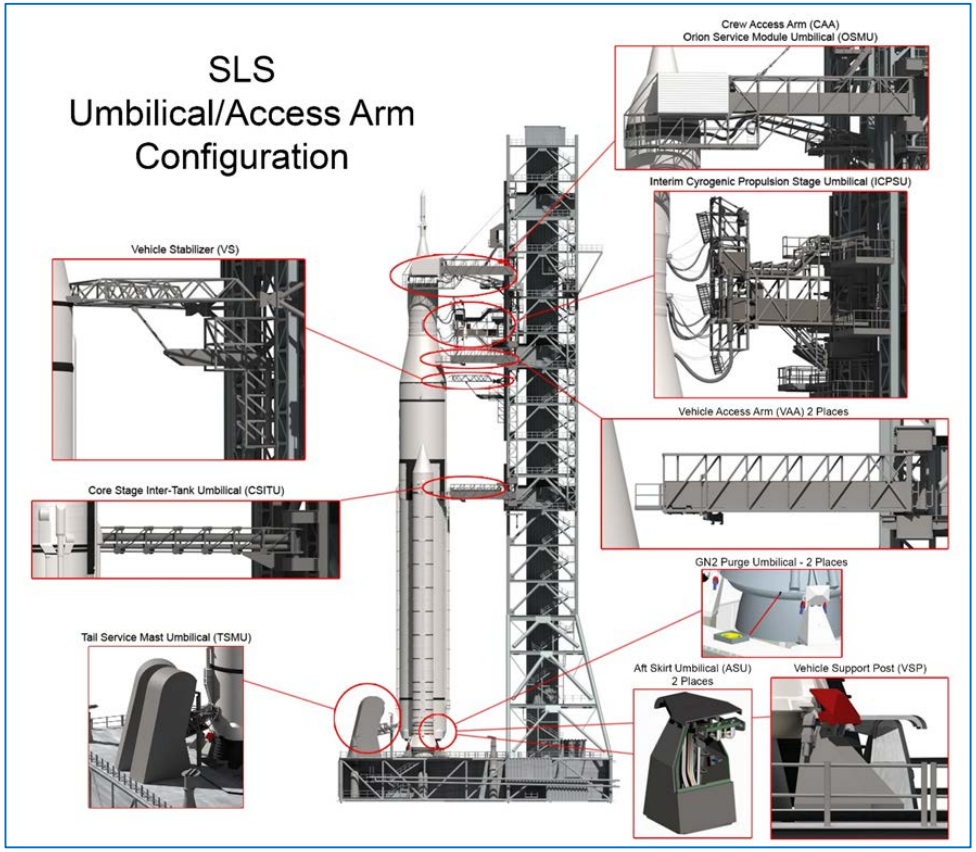


- **Exploration Ground Systems**
  - Mobile Launcher



Exploration Ground Systems

- Controls for SLS/Orion Arms & Umbilicals:
  - Crew Access Arm
  - Orion Service Module Umbilical
  - Interim Cryo Propulsion Stage Umbilical
  - Vehicle Stabilizer
  - Vehicle Access Arms
  - Core Stage Inter-Tank Umbilical
  - GN2 Purge Umbilical
  - Tail Service Mast Umbilical
  - Aft Skirt Umbilical
  - Vehicle Support Post



- **Exploration Ground Systems**
  - Ground Support Equipment & Controls:
    - Hypergolic Servicing Subsystem
    - Cryogenics: Liquid Hydrogen & Liquid Oxygen
    - Ground Cooling Subsystem
    - Thrust Vector Control Hydraulic Servicing Subsystem
    - Hydraulic Arms and Accessories Service Pressure
    - Environmental Control Subsystem
    - Gaseous Helium, Nitrogen, Oxygen, Breathing Air
    - Ground Main Propulsion System
    - Ground Special Power
    - Radio Frequency Telemetry Station
    - Range Safety Checkout Subsystem
    - Launch Release Subsystem
    - Hazardous-Gas Leak Detection Subsystem
    - Sensor Data Acquisition Subsystem
    - Weather Instrumentation
    - Thermal Control Subsystem
    - Kennedy Ground Control System

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- **Guiding KSC Documents**
  - **KSC-DE-512: Ground Systems Development Standard**
  - **KSC-PLN-5406: Design and Development Electrical, Electronic, Electromechanical (EEE) Parts Plan**
  - KSC-NE-10074: Electrical Ground Support Equipment Qualification Plan
  - KSC-NE-9187: Sensors, Transducers and Signal Conditioning Systems Selection Guidelines
  - KSC-STD-164: Standard for Environmental Test Methods for Ground Support Equipment
  - KSC-STD-G-0003: Standard For Qualification of Launch Support and Facility Components
  - KSC-STD-E-0022: Bonding, Grounding, Shielding, Electromagnetic Interference, Lightning and Transient Protection, Design Requirements for Ground Systems
  - K0000283895-SPC: Standard For Mobile Launcher Ground Support Equipment Vibration Qualification

Adobe Acrobat Document

KSC-PLN-5406

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- **Strategy for use of COTS for Critical Ground Support Equipment**
  - Ground Support Equipment is certified to function in their intended operational environment. This requires extensive evaluation, analysis, qualification and testing. COTS equipment is used to the maximum extent possible when (1) it satisfies the intended function, (2) it will not degrade the safety or reliability of the flight or ground system, and (3) it provides a cost savings that exceeds possible cost increases that may result from unique maintenance or logistics requirements, modifications, or an increase in the complexity of the interfacing equipment.

  - EGS is defined as a Category 1 project as defined in NPR-7120.5. The systems are safety critical or mission critical. They are designed for a 20-year lifecycle. The systems are single fault tolerant, they either fail operational or fail safe. Systems are certified to function in their intended operational environment. This requires extensive evaluation, analysis, qualification and testing.

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- **“Keys” for COTS EEE Part Utilization in Ground Systems**
  - Selection, Procurement and Part Pedigree
  - Obsolescence Management
  - Reliability and Maintainability Evaluation
  - Rigorous Design and Development Review Process
  - QUALIFICATION!!!!!
  - Screening & Derating
  - Embedded SW – IT Security Assessments
  - Maintain Qualified Parts List

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Part Type	Federal Stock Class
Capacitors	5910
Circuit Breakers	5925
Connectors	5935
Crystal Oscillators	5955
Diodes and Semiconductors	5961
Electronic Assemblies	5998
Fiber-Optic Accessories	6070
Fiber-Optic Cables	6015
Fiber-Optic Conductors	6010
Fiber-Optic Devices	6030
Fiber-Optic Interconnects	6060
Fiber-Optic Switches	6021
Filters	5915
Fuses	5920
Inductors	5950
Hybrid Microcircuits	5962
Magnetics	5950
Monolithic Microcircuits	5962
Optoelectronics Devices	5980
Pressure, Temperature, and Humidity Measuring and Control Instruments	6685
Relays and Solenoids	5945
Resistors	5905
Switches	5930
Thermistors	5905
Transformers and Coils	5950
Transistors	5961
Wire and Cable	6145

EEE Part Types

- High Level Assemblies
  - Line Replaceable Units
    - Power Supplies
    - Programmable Controllers
  - Subsystem Racks & Enclosures
- Sensors & Transducers
- KSC EEE Parts are defined in KSC-PLN-5406 and includes electronic assemblies. COTS electronic assemblies include Line Replaceable Units (LRUs) such as power supplies and programmable logic controllers (PLCs). High level assembly racks and enclosures contain many LRUs and other COTS components. For this discussion, the term assemblies include LRUs, racks and enclosures. Sensors, transducers, data acquisition and instrumentation are included.

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- **Part Selection**
  - COTS Parts & Assemblies are Selected According to:
    - Operational & Functional Requirements, Operational Environment (Natural & Induced)
    - Pedigree, Quality, Reliability and Maintainability

EEE Parts Grade Description per KSC-PLN-5406

Grade	Summary	Reliability	MTBF	Cost	Typical Use
1	"Space" quality-class qualified parts, or equivalent.	Highest	Longest	Very High	Spaceflight
2	"Full Military" quality-class qualified parts, or equivalent.	Very High	Very Long	High	Spaceflight or critical ground support equipment
3	"Low Military" quality-class parts, and Vendor High Reliability or equivalent. Industrial/High Reliability COTS Automotive grade (AEC) EEE parts	Medium	Variable	Moderate	Spaceflight experiments, aeronautical flight experiments, critical ground support equipment, test demonstrations. Screening and qualification performed as required.
4	"Commercial" quality-class parts. Qualification data at manufacturer's discretion. No government process monitors incorporated during manufacturing.	Variable	Variable	Lowest	Aeronautical flight experiments, test demonstrations, and prototypes. Ground support equipment with appropriate qualification and screening.

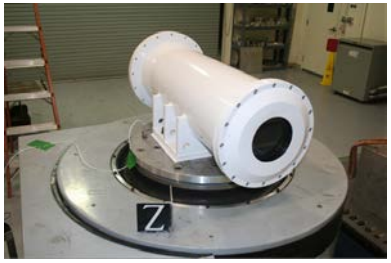
Sample COTS Components & Assemblies

Power Supplies

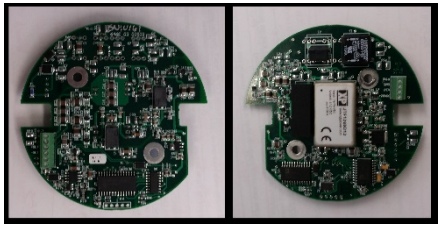
Servers & Switches

DC-DC Converters,
Circuit Breakers

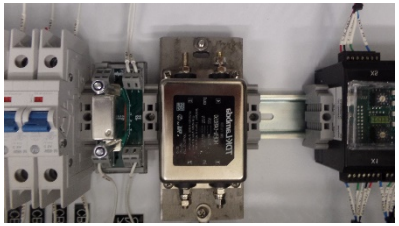
Programmable Logic Controllers (PLC)



Voice, Video, Data

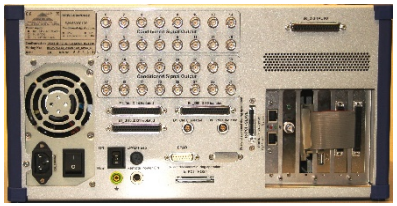


Custom PCBs with COTS



Filters

Temperature Probes & Transducers



Data Acquisition Systems

Flow Meters

Selection, Procurement And Part Pedigree

- Parts and assemblies are procured from the Original Component Manufacturer (OCM), Original Equipment Manufacturer (OEM) or their franchised (authorized) distributors. This assists with counterfeit avoidance.
- Certificate of Conformances along with lot/batch numbers may be requested for critical items.
- Parts and equipment are reviewed for applicable GIDEP Alerts and Advisories.
- Once received, parts are visually inspected for defects before they are put into logistics.
- Once a part or assembly is purchased, it may be traced or tracked for a number of reasons:
  - To readily identify location and usage of parts (serialized, lot/batch, etc.).
  - To trace components to the assembly and the next higher-level assembly.
  - In case of obsolescence, NASA advisory alerts and GIDEP alerts to readily identify the affected parts and application aiding in the implementation of resolution.
  - To assure genuine authentic parts and materials by requesting supplier or manufacturer lot/batch codes, date codes, or serial numbers in conjunction with Certificate of Conformances (CoC).
  - To provide an unbroken supply chain history and part pedigree.
  - To monitor and control critical items.
  - To track limited-life items and monitor maintenance requirements and cycles.
  - For GSE, we have traceability and track the following:
    - Limited-life items (batteries), limited shelf-life items, critical components or assemblies, configuration controlled items and components or assemblies subject to periodic checkout, test, calibration, servicing, maintenance, or inspection, or items under warranty.

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Obsolescence Management

- Projects with extended product life cycles, such as GSE, and those that utilize heritage hardware are exposed to high risk of being affected by parts obsolescence.
- COTS parts and equipment have much shorter life due to technology advancements, vendor support and constant upgrades.
- Parts are assessed prior to selection to ensure part availability meets or exceeds production milestones and mission duration.
- Parts are monitored throughout the system life cycle to identify and mitigate obsolescence issues before they occur. Obsolescence monitoring provides notification of part discontinuance to allow projects with sufficient time to procure spares.
- Lifetime buys may be necessary.
- Logistic Support Analysis (LSA) is developed for every GSE subsystem.
  - Identifies obsolete parts and provides alternative parts & vendors.
  - Identifies lifetime buys when necessary.
  - Plan refreshes.
- Maintain warranties and support (HW & SW).
- Stay away from sole sources.

Reliability and Maintainability Analysis

- EGS GSE subsystems have to meet reliability, maintainability and availability requirements.
- Analysis is performed at the higher assembly and system level.

Configuration	Reliability (@ 24 hours)	Maintainability (hrs)	Availability (A_{inh} @ 24 hrs)
REQUIREMENT	0.999760	15.00	0.999880

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- **Design and Development Review Process**
  - Ground Support Equipment undergo a rigorous technical review process as defined in the Kennedy Documented Procedure KDP-P-2713.
  - This KDP defines required reviews such as System Requirements Review (SRR), 30%-60%-90% Design Reviews, Preliminary Design Reviews (PDR), Critical Design Reviews (CDR) and Test Readiness Reviews (TRR) for verification and validation tests. The KDP also defines the associated products required for each review and milestone.
  - This eventually leads to system Design Certification or System Acceptance.

- **Examples of required products include:**
  - System Requirements
  - Design Verification Matrix
  - Configuration Management Plan (CMP)
  - Quality Assurance Plan (QAP)
  - Acquisition Plan
  - Logistics Support Analysis Development Plan
  - Software Assurance Classification Assessment (SACA)
  - Software Management Plan and NPR 7150.2 Compliance Matrix
  - Risk Matrix
  - Reliability and Safety Assessment Report (RSAR)
  - IT/OT Security Assessment
  - System Assurance Analysis (SAA)
  - Software Safety Analysis (SSA)
  - Engineering Drawings and/or Models
  - Software Maintenance Plan
  - Design Analysis Reports
  - Procurement Specification
  - Reliability, Maintainability, and Availability (RMA) Analysis
  - Operations & Maintenance Requirements Specification Document (OMRSD)
  - Design Data Manual
  - Logistics Support Analysis (LSA)
  - IT/OT System Security Plan
  - Electromagnetic Compatibility Management Plan
  - Component Qualification Plan
  - Verification & Validation Reports

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- **QUALIFICATION!!!!**
  - Functional/Performance – Verify functionality and vendor performance specifications.
  - Electromagnetic Compatibility – Verify functional performance in the specified electromagnetic environment.
  - Vibration - Verify functional performance in the specified launch induced environment.
  - Acoustic - Verify functional performance in the specified launch induced environment.
  - Thermal - Verify functional performance in the natural environment.

  - KSC has a qualification panel and team that is responsible for identifying and performing qualification tasks and tests. KSC has a several labs that support qualification including the Electromagnetics Lab, Cryogenics Lab, Vibration & Acoustic Test Facility, Sensors & Transducers Lab, Engineering Development Lab, Thermal Chamber and the Launch Equipment Test Facility.

Electromagnetic Compatibility Testing

- Electromagnetic Compatibility Testing requirements are specified in KSC-E-STD-E-0022.
- Requirements:
  - Ground systems shall be electromagnetically compatible within themselves such that system operational performance requirements are met.
  - Systems, subsystems, and equipment shall be capable of providing full performance in conjunction with other subsystems and equipment that are required to operate concurrently.
  - Electrical and electronic ground systems shall be designed to perform when exposed to a minimum level of 20 volts per meter (V/m) in the frequency range from 30 Hz to 18 GHz.
- Tests include Conducted Emissions & Susceptibility, Radiated Emissions & Susceptibility. Testing is in accordance with MIL-STD-461. Testing may be performed at the component level, assembly (LRU) level or rack level.

- Mitigations:
  - EMI Shielded Enclosures (min 26 dB attenuation).
  - Shielded Cable, 3600 Termination.
  - EMI Filters.
  - Operational RF Clear Zones.

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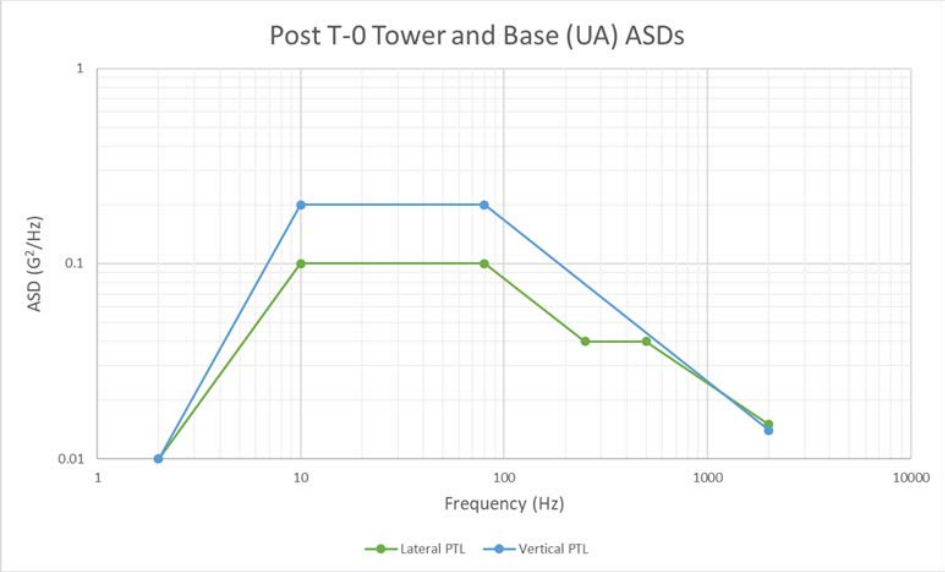
Vibration Testing

- Requirements:
  - Specified GSE shall function during and after exposure to the induced environments specified in K0000132092-ANA, Space Launch System (SLS) Mobile Launcher Rocket Exhaust Plume Induced Environment, Volume I & II: Acoustic and Vibration, Thermal and Pressure.
  - Vibration qualification is performed in accordance with K0000283895-SPC. Levels vary according to location of equipment and use of isolators. Tests represent 10 launches, 30 seconds each axis.
  - Testing may be performed at the component level, assembly (LRU) level or rack level.



FREQ(Hz)	ASD(G2/Hz)	dB	OCT	dB/OCT	AREA	Grms
2	0.0100					
10	0.2000	13.01	2.32	5.60	0.69	0.83
80	0.2000	0.00	3.00	0.00	14.69	3.83
2000	0.0140	-11.55	4.64	-2.49	83.72	9.15

Vibration Testing

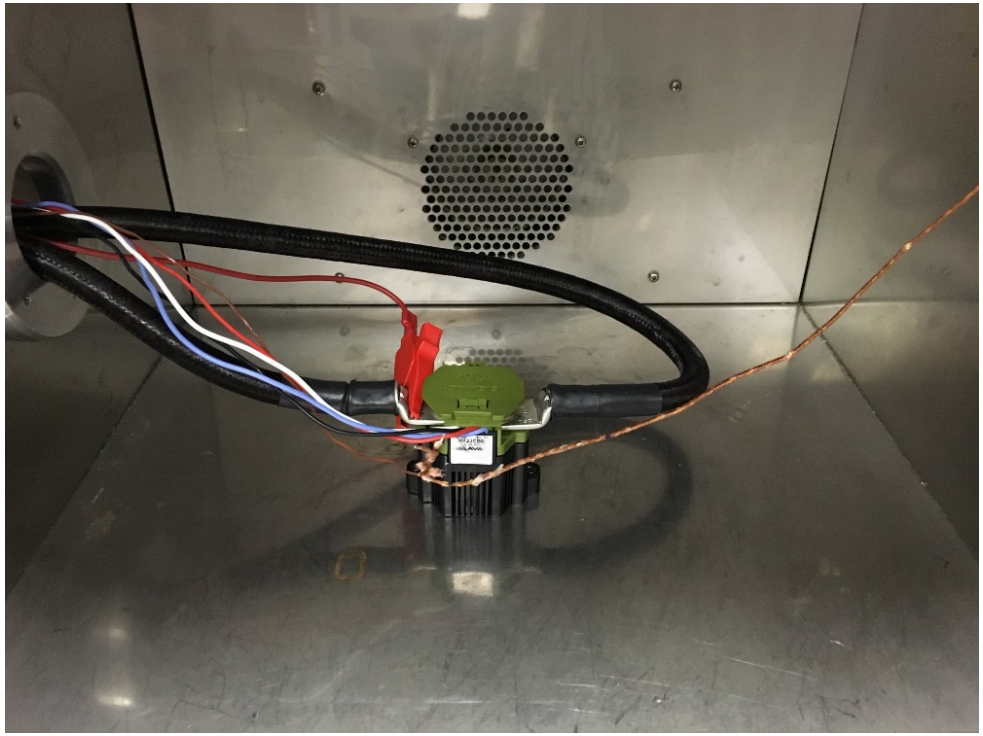
Vibration Testing

Acoustic Testing

- Tests are performed on equipment located outside the electrical rooms along the tower of the Mobile Launcher. Electrical rooms provide 11.63 dB attenuation.
- Tests are conducted at the component/small assembly level.
- Chamber - 35”d x 24”w x 22”h.
- Max Level - 145 dB (11 Hz -11,360 Hz) 30 second duration test.

Thermal Testing

- Requirements:
  - GSE used or stored in an exterior environment shall be designed to function after exposure to the natural environment at its respective geographical location as specified in NASA/TM-2008-215633.
  - GSE designed to function within a controlled interior environment shall be designed to the following temperature and humidity requirements:
    - Temperature: +15 °C (60 °F) to +27 °C (80 °F) and within the extremes of +11 °C (52 °F) to +40 °C (104 °F) for a maximum of 1 hour.
    - Humidity: nominal 55%, within a range of 30% to 70%.



- Analysis may be performed in-lieu of formal testing. This is usually at the box or enclosure level.

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Screening

- Screening is performed on GSE Critical Items as defined in KSC-PLN-5406.
  - Critical Items are identified in the Safety Assurance Analysis (SAA).
- Screening is performed per KSC-PLN-5406.
  - Leveraged GSFC-EEE-INST-002.
- 100% functional tests performed at assembly level.
- Requirements documented on engineering drawings.

Derating

- Derating is performed per KSC-PLN-5406.
  - Leveraged GSFC-EEE-INST-002.
  - Added Ground Systems derating requirements.
- NFPA 70E – National Electric Code.
- Documented in Subsystem Design Analysis Reports.

Embedded SW – IT Security Assessments

- Just about all COTS assemblies contain embedded software. These assemblies may be used in critical Ground Support Equipment applications. Software incorporated into the design of GSE must meet the requirements of NPR 7150.2. This includes firmware and embedded software in COTS assemblies (e.g., the software in PLCs and motor controllers). NPR 7150.2 contains provisions applicable to COTS software in NASA-developed systems. A Software Assurance Classification Assessment (SACA) is performed at the subsystem level. All GSE systems fall under an Information Technology (IT) System Security Plan. IT security assessments are performed at the assembly and system levels. There have been instances where COTS assemblies had to removed from GSE because of IT vulnerabilities. IT security requirements specified in NPR 2810.1 and NPR 7150.2. A Software Safety Analysis is also performed. All subsystems have software management/maintenance plans which includes embedded software and firmware upgrades and configuration management.

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Qualified Parts

- KSC has a qualification team responsible for the qualification of GSE components and assemblies.
- KSC maintains a qualified parts list.
- Over 500 components and assemblies.
- EPARTS has a GSE module and KSC's qualified parts have been uploaded to EPARTS.

Rons PN	Subsys	Item	Assembly # / Subassembly #	Component	Description	Location of Use	Level Haz Loc	Level Vibrat / Acoust	Level Envir Cntrl	Method of Qualification	Qualifying Entity	OK'd by Qualifying Entity	Qualified ?	Date Qualified or Qualification Need Date	Comments
1756-A13	BUIE	6	K0000108158	1756-A13	CHASSIS, 13-SLOT	ML	C,	C,	D	Testing	KGCS	Yes	Yes		EMI=EML-0241-QUL, KGCS-QTR-0052: Thermal=Similar KGCS-QTR-0033: VIBE=KGCS-QTR-0054: ACC=Similar KGCS-QTR-0056 Temp Range: -40°C to +85°C
1756-PB75	BUIE	7	K0000108158	1756-PB75	POWER SUPPLY	ML	C,	C,	D	Testing	KGCS	Yes	Yes		EMI=EML-0241-QUL: KGCS-QTR-0052: THERMAL=KGCS-QTR-0033: VIBE=KGCS-QTR-0054: Acoustic=KGCS-QTR-0056 Temp Range: -40°C to +85°C
1756-EN2F	BUIE	8	K0000108158	1756-EN2F	ETHERNET/IP COMMUNICATION MODULE	ML	C,	C,	D	Testing	KGCS	Yes	Yes		EMI=EML-0241-QUL: KGCS-QTR-0052: Thermal=KGCS-QTR-0018: Vibe=KGCS-QTR-0054: ACC=KGCS-QTR-0056 Temp Range: -25°C to +70°C

Take Aways…

- Understand your Operational Environment.
  - Select parts that fit not only functional requirements, but fit operational and environmental requirements.
- Qualification is Key! Qualify Parts and Assemblies. Do it Early!
- Know your Parts! Understand its Pedigree. Procure from the Original Component Manufacturer (OCM), Original Equipment Manufacturer (OEM) or their Franchised (authorized) Distributors.
- Track Obsolescence Throughout the Project.
  - Perform obsolescence analysis when considering a part.
- Maintain Warranties and Vendor Support (HW & SW).
- Stay Away from Sole Sources, if possible.
- Implement Redundancy.
- Maintain a Qualified Parts List Database.

EXPLORING SPACE **TOGETHER** FOR ALL HUMANITY

KSC ENGINEERING