Standardized Modular Power Interfaces for Future Space Explorations Missions

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AMPS: Advanced Exploration Systems
Modular Power Systems

• Introduction to AMPS
• Need for Standardized Modular Power Interfaces
• AMPS Approach Standard
  • Levels of Assembly
  • Common Framework
• Electrical Interfaces
  • Primary Power Backplane/Module
  • Secondary Power Backplane/Module
• Command and Data Interfaces
  • Spacecraft Data Interface
  • Internal Data Bus
• Summary
AMPS: AES Modular Power Systems

AMPS seeks to develop a common set of Modular Power Building Blocks for future Exploration missions

- Long distances, long durations
- No logistics support
- Missions composed of multiple vehicles, multiple power architectures

Improve Operational Supportability:
- Reduced Logistics with Common Spares
- Spare at lower levels of assembly
- Common Maintenance Processes
- Common Diagnostics

Preserve Power Architecture Flexibility

*Opportunity:* Salvage power hardware from spent stages to exploit hardware as Spares or reuse in new mission applications.
AMPS is drafting a proposed standard that is:

- Applicable to NASA exploration,
- Accommodates variations in power architecture
- Supports mission flexibility (configuration changes)
- Defines the common infrastructure needed to support the modular design
- Standardizes Data, Electrical and Mechanical Interfaces

The intent is to guide power system developers without restricting design or technology options.

- Adopts existing standards where applicable
- Emphasize Interchangeability and Interoperability
AMPS Standardized Modular Power Interfaces

**AMPS Modular Approach**

- Extend the modularity of International Space Station to lower Levels-of-Assembly
- AMPS defines modules as “encapsulated units” that are accessible, replaceable, and interchangeable,

<table>
<thead>
<tr>
<th>Levels of Assembly</th>
<th>Example</th>
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</thead>
<tbody>
<tr>
<td><strong>Assembly:</strong> Composed of sub assemblies and component parts [typical Avionics LRU or ISS ORU]</td>
<td>Battery Charge Discharge Unit Main Bus Switching Unit Power Distribution Unit</td>
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<tr>
<td><strong>Sub Assembly:</strong> replaceable grouping of components on a substrate or support frame</td>
<td>Circuit Cards that may support lower level modules.</td>
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<tr>
<td><strong>Component:</strong> lowest level of encapsulated replaceable hardware</td>
<td>Point of Load Converters, Switching Units, Battery Cell, (as plug in modules or mezzanine Cards)</td>
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AMPS Standardized Modular Power Interfaces

- Establish a common framework for Data, Electrical, Mechanical interfaces.
- Apply the Standards to 3 segments of a Power Architecture
  - Define interfaces between modules and internal to modules
  - Create Interface Specs for
    - Assemblies,
    - Subassemblies
    - Components

Module Interface Specifications

Spacecraft Modular Power Standards
- Command & Data
- Electrical
- Mechanical

Power Distribution
- Primary Power: Main Bus Regulation
  - Bus Switching
- Secondary Power: Distribution & Conversion

Power Generation

Energy Storage
Generic Power Architecture

Power Generation
- Solar Arrays
- Fuel Cells
- Nuclear

Primary Power Bus
- Bus Regulation
- Main Bus Switching
- Vehicle Bi-Directional Converter

Secondary Power Distribution
- 120V Power Distribution
- Power Loads
- Voltage Conversion
- Low Voltage Distribution
- Power Loads

Energy Storage
- Batteries
- Fly-Wheel
- Ultra Capacitors
- Regenerative Fuel Cells

External Vehicle Interface

Distributed Energy Storage
- C&D Management
- Storage
Standardization Frameworks

**Electrical Interface** section addresses modular approach that is flexible, configurable, and supportable
- Breaking an architecture into functional blocks
- Grouping functions as common modular elements
- Creating an interconnection framework of Common Backplanes
- Defining the characteristics that make up Modular Interface Specs

**Command & Data Interface** section addresses the Communication protocols and Software with emphasis on interoperability standards.
- Power modules will support automatic ID, Digital Configuration and Integration. (i.e. Plug-and-Play)
- Internally, modules adopt protocols suited power applications but must support the higher level Interoperability requirements.

**Mechanical Interface** section addresses the mechanical needs in terms of structural support, encapsulation and thermal control.
- Modules and backplanes must support static and dynamic loads while providing a means of transferring thermal loads.
- Mechanical interfaces must assure ease of access and interchangeability.
Electrical Interface Standards
Electrical Power Standard

Primary Power:
- Main Bus Voltage Regulation, Switching, Directional Conversion
- Follows SAE AS5698 Power Quality Spec

Primary Power Channel A
- Power Generation
- Main Bus Regulation
- Main Bus Switching
- Bi-Directional Converter
- Power Distribution
- Energy Storage
- External Spacecraft

Lines crossing dashed envelopes must meet the Power Quality Spec
Primary Power Regulation Backplane-Module

Modules mounted on a Assembly Level Backplane.
Unregulated & Regulated Power, Data and Structural and Thermal Interfaces
Modules: Switching, Regulation, Unit Control
Primary Power Assembly Backplanes-Modules

Main Bus Regulation

Primary Channel [A] Main Bus Switching

Controller

Input Selector Modules

SC Data Network

Main Bus Cross-Tie

Energy Storage

Bi-Directional Converter

Internal Data & Power Bus

Cooling Fluids

Power Distribution

Primary Channel [B] Main Bus Switching
Secondary Power:

- Power Distribution Units transfer Main Bus power to loads.
- May involve voltage conversion (120V to 28V) and distribution.
- May allow switching to an Alternate Main Bus.
- Output channels controlled by a Remote Power Controllers (RPC):
  - Switching, Automatic Fault Interruption, Current Limiting.
  - Covered by SAE AS5698.
Secondary Power Assembly Backplane-Modules

Secondary Power Distribution with dual main bus inputs

- Main Bus A
  - Spacecraft Command & Data Network
  - Housekeeping Power
  - Input Selector
  - Backplane Controller
  - Sub Assembly Controller

- Main Bus B
  - 120V RPC Modules
  - High Current 120V RPCs

- Sub Assembly Level Backplane
- Expansion Slots
- Common Backplane
- Cooling Fluids
- Internal Data & Power Bus
Secondary Power Assembly Backplane-Modules

Secondary Power Distribution with 120 Volt and 28 Volts

Main Bus A

Spacecraft Command & Data Network

Housekeeping Power

Input Selector

Main Bus B

120/28 V Converter

120 V Bus

Cooling Fluids

Data & Power Bus Extension

Interconnect Module

Cooling Fluids

28 V Input

28 V RPC Modules

28 V Bus

120 Volt RPC Modules

High Current 120V RPCs
Subassembly Backplane-Module

Subassembly level backplanes support component level modules.

- Provides an intermediate *layer of accommodation*
- Common Input Power, Internal Data Bus and Housekeeping power
- Mounting and Thermal loads transfer into Assembly Level Backplane

Subassembly Inputs/Outputs

- Inputs from to Assembly Level Backplane
- Output channels conducted via Multilayer Backplane
- Connector Module gathers outputs to loads
- Connector Module is replaceable to allow alternate distribution and connector options
Command and Data Interface
Exploration spacecraft C&DH networks are expected to employ the “DDS” (Data Distribution System) Interoperability standard

• DDS is for reliable real-time (low latency) data communications for safety critical distributed systems.
• Originally for DoD systems, DDS is currently used on SLS and Orion
• Employs a Publish/Subscribe scheme
• Encompasses Automated Integration (Plug and Play capabilities).
• Independent of network protocols
  • Time-Triggered Gigabit Ethernet
  • 1553B
Assembly Level Data Architecture

Internal Data Bus for control of Subassembly Level hardware.

- Currently considering the CAN Bus
- Must be consistent across power system
- Must allow interchangeable spares
- Must support redundancy where needed.
- Must be Visible and Addressable by upper level communications
- Allow Multi-Master control
- Packet Error Checking
- Hardware Based Arbitration

Support Fault Management
- Provide fault detection flags
- Respond to safing actions

Support Health Management
- Diagnostics features
- Prognostics features
Subassembly Level Data Architecture

Local Control Bus: Subassembly to Component Comm
- Common Commands and Data set
- Components Visible and Addressable by upper level communications
- Support Fault Management detection and safing actions
- Support Health Management Diagnostics and Prognostics
- Allow Multi-Master control
- Packet Error Checking
- Hardware Based Arbitration
- Suited for single board or backplane mounted modular components
Subassembly Level Data Architecture

**SMBus Standard:** Based on a PC Industry Standard and derived from I²C a device-to-device serial bus.

- Use a simple address scheme
- Multi-Master/Slave control
- Uses a hardware based bus arbitration scheme
- Packet Error Checking
- Dedicated Host Interrupt line

**PMBus:** SMBus with specific power management features, commands and status.

**Smart Battery System (SBS):** SMBus with specific a battery management features, commands and status

A number of IC manufacturers produce, SMBus, PMBus, and SBS compliant devices
Modular Specification Summary

• **Electrical Interface**
  - Applicable to Primary and Secondary Power
  - Defined Assembly & Subassembly Level Backplanes
    • Provides a common interface for Modules
    • Provides a “layers of accommodation” for more options
    • Replaceable Regulation, Switching, Controller, Input/Output Modules

• **Command and Data Interface**
  - Adopt DDS Interoperability standard
  - Supports Plug and Play features
  - Allows a power specific internal control bus

• **Mechanical Interfaces** (ongoing work)
  - Standardize Structural and Thermal interfaces
  - Define Physical Encapsulation required to create interchangeable modules.
Forward Work

• Work with *Interagency Advanced Power Group* to establish modular standards from a multi-agency perspective
• Compare AMPS Data Standard with other standards
  – AIAA Plug and Play spacecraft avionics standard.
  – Applicable Mil-Standards
• Complete the Electrical Interface definition for distribution
• Develop Mechanical Interfaces Standards for the Backplane
• Build a backplane/module demonstrator.
Thanks for your Attention

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