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 Standardized Modular Power Interfaces

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

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

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

Input Selector Modules

Controller

SC Data Network

Energy Storage

Main Bus Cross-Tie

Primary Channel [B] Main Bus Switching

Bi-Directional Converter

Internal Data & Power Bus

Cooling Fluids

Power Distribution

Power Distribution

Power Distribution
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 120 Volt and 28 Volts

120/28 V Converter

Main Bus A

Input Selector

120 Volt RPC Modules

High Current 120V RPCs

Data & Power Bus Extension

Interconnect Module

28V RPC Modules

28 V Bus

Cooling Fluids

Cooling Fluids

Housekeeping Power

Spacecraft Command & Data Network

Main Bus B

28V Input

120 V Bus

120 Volt RPC Modules
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
Spacecraft Level Data System 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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