Plug-and-Sense: Enabling Onboard Networking Technology for Modular Spacecraft

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What Is SMARTBus?

- A set of Mechanical, Electrical, and Logical standards
- These standards define how spacecraft modules interact to create a complete vehicle
- Each module shares its functional abilities, physical characteristics, and mass properties
- This modularity allows implementation independence

  - A module implements a given function
  - Other modules access that function in the ways defined by the standards
  - How a given module provides the function is transparent
What Is SMARTBus?

- Each module performs a specific function: e.g. solar power generation, attitude control, communications
- Plug-and-Sense request/response architecture allows modules to allocate and manage resources as needed
- Modules stack together to form an electrically and structurally complete spacecraft
- Alternative mechanical, electrical, and logical technologies can be incorporated smoothly
AeroAstro’s AstroLogic is a particular set of electrical and logical interface requirements to enable:
- Plug-and-Play (PnP) integration
- Device self discovery
- Autonomous operations

“Plug-and-Sense” expands PnP to include identification of the device’s physical characteristics: mass, size, shape, center of gravity, position in vehicle, etc.

Allows a stack of SMARTBus modules to autonomously understand how it is configured and what it can do, and governs the request and allocation of resources for the stack.

AstroLogic builds upon ideas already established within the aerospace industry and in the commercial marketplace.
The SMARTBus™ modular spacecraft architecture defines three types of interaction among spacecraft devices.

Each layer interfaces with the layers above and below, and with the corresponding layer on another device.

<table>
<thead>
<tr>
<th>Logical</th>
<th>Mathematical</th>
<th>Electrical</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPLICATION</td>
<td>TRANSPORT</td>
<td>NETWORK</td>
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The Logical, Electrical, and Mechanical specifications support, but do not require, each other.
Implementation Independence

- Module Designers work in isolation from other module designers – there is no need for close coordination.
- Final Vehicle Configuration does not need to be known when module is designed.
- Pre-launch test can be reduced to a go/no-go decision based on feedback from simple tools.
- Ability for two devices (modules) to work together even if they were never designed to work with each other.
Astrologic – Compatibility with SPA Standards 1

- Sensor components – star tracker, Sun sensors, magnetometer – attach and self-configure to the CEB according to SPA Standards
- CEBs interact, using the same SPA Standard data dictionary, to share information among modules
- Modules provide quick mechanical assembly; SPA Standards provide Plug-and-Play functionality

Core Electronics Block (CEB) common to all SMARTBus modules – performs IEEE1451 function of Network Capable Application Processor
Astrologic – Compatibility with SPA Standards 2

SPA: Governs all interactions between components and computing devices to make them intelligent and Plug-and-Play

IEEE 1451 (called for by SPA): Adds peer-to-peer networking via Internet Protocol

SMARTbus: Adds mechanical and thermal interface standards to achieve a complete responsive spacecraft
AstroLogic is designed around resources (logic view)

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rather than equipment and principal functions that components provide (physical view)
AstroLogic™ is a Plug-and-Sense architecture, meaning it recognizes both the functional and physical aspects of a device.

UDP is an extremely simple port-based transport layer; sessions, if needed, are handled at the application layer. Also provides top-level packet checksum.

Internet Protocol (IP) is the common layer between the Logical and Electrical interfaces. The Logical interface needs only know that it wishes to talk to a given IP address; the Electrical interface needs only know how to send a packet to a given IP address.

AstroLogic is a client/server architecture where devices request and provide resources.

On a spacecraft, these resources include Power, Attitude Knowledge, Communications, Memory storage, and so forth.
Plug-and-Sense uses a Request/Response system taken from well-understood Client/Server designs.

- **Single-Server**
  - Clients
  - Server
  - Invocation
  - Results

- **Multiple-Server**
  - Clients
  - Service
  - invocation
  - Results
Application Requesting a Resource – Messaging implemented using XML

Once Requester/Responder connection is established…. 

Requester/Responder Interaction
Subsystem Modules Developed In Advance of Need

Establish Standards
- Data
- Elec.
- Mech.
- Test
- ...

Package & Ship to Field Location

Supplier Manufacture & Test

War Reserve Materiel:
Modules in Inventory
Achieving the 6-Day Spacecraft

Operational Need

Mission Design Tool (defines stack needed)

Responsive Space Operations

Rapid LV Integration & Launch

Assembly from Inventory

Automated Checkout & Go/No-Go

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AeroAstro

2005 AIAA/USU Conference on Small Satellites
SMARTBus builds on government-industry standards efforts
   • Pathfinder for a 6-day (or less!) microspacecraft

Stacked architecture enables field customization

Funded by DARPA & AFRL
   • System and Enabling Technologies

SMARTBus Standards v1.0 published 1 July 2004;
v2.0 will be published 1 September 2005
   • Incorporates existing standards, avoids creating new ones
   • Available upon request – Feedback desired!

Next big steps are expanding module catalog, flight readiness