Spacecraft Onboard Interface Standardization in CCSDS

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Agenda

- CCSDS structure and Strategic Themes
- Purpose and Goals for the Spacecraft Onboard Interface task
- The Subsystem Perspective of SOIF
- The Communications Protocols for SOIF
- Issues

The research described in this presentation was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.
Spacecraft Onboard Interface task for CCSDS

Consultative Committee for Space Data Systems (CCSDS) is an international organization of national space organizations.

- NASA is the U. S. member of CCSDS

The purpose of CCSDS is to create international standards for interoperability of space missions, and to ease dissemination of space derived scientific data.

CCSDS has created standards for:

- Space communications
- Data interchange and archiving
- Standard mission operations services
- Internet type protocols for space missions

These standards are well entrenched in many space programs.

Recent interest has been in new area for standardization of onboard interfaces.

- This is called Spacecraft Onboard Interfaces (SOIF) and is the subject of most of this presentation
CCSDS Strategic Themes

1. Develop Highly Efficient Communications in Resource-Constrained Environments
   - Single Aperture/Multi-User Links
   - Higher Frequency Communications
   - Efficient Modulation
   - High Performance Coding
   - Proximity/In-Situ Communications Links
   - File Transfer Protocols
   - Security and Privacy
   - Advanced Data Compression

2. Develop Standard Data Interchange and Archiving Services
   - Data Management Services
   - Information Architecture for Space Data
   - Space Data Archiving Techniques

3. Develop Standard Mission Operations Services
   - Space Link Access
   - Spacecraft Monitor and Control
   - Ground System Monitor and Control
   - Tracking and Navigation Services
   - Mission Planning Services
   - Telecommunications Services

4. Develop Space Missions as Extensions of the Earth's Internet
   - Interface with Near-Earth Constellations
   - Interface with Commercial Near-Earth Navigation Systems
   - Interface with Public Media Distribution Systems
   - Extension of the Internet into Near-Earth Vicinity
   - Extension of the Internet into Deep Space

5. Develop Interoperable Spacecraft Onboard Interfaces
   - "Network Ready" Space Devices and Subsystems
Purpose of Spacecraft Onboard Interface (SOIF)

- Lack of standards has lead to each new project to redesign its onboard interfaces
  - This leads to use of resources to perform the same work
  - Resources could be better spent on enhancing the functionality and technology of new missions
  - Projects should spend time and resources on making missions better, instead of on the same old interfaces

- Purpose is to standardize the onboard hardware and software interfaces
  - Projects only need to worry about interface implementation, not design
  - Will allow for reuse of interface designs in different missions

- Will be performed by the Consultative Committee for Space Data Systems (CCSDS)
  - CCSDS creates recommendations, which are used by projects as needed
A Future Vision based on SOIF Success

The proposed SOIF recommendation will produce the following benefits:

- Reduce flight system development costs
- Reduce flight system development and integration time
- Reduce flight and test system documentation
- Encourage rapid insertion of new technologies (through layering)
- Increase flight and test system reuse and reliability
- Improve test systems and spacecraft simulators
- Better support secondary and quick-ride payload development
- Encourage development of truly standard spacecraft devices and elements
- Encourage second-source of flight and test system hardware and software

This will allow the use of the standard interfaces for science instruments and subsystems

Spacecraft hardware devices will also be able to use the appropriate interface standard
The Subsystem or Device Perspective

- From the perspective of the instrument or subsystem
  - All external electrical interfaces can be met with the set of standardized interfaces
  - Power standard selected for spacecraft & instrument/subsystem needs
  - Use of high-, medium-, and/or low-speed busses meet all instrument/subsystem needs, using one or more of the three selected busses

- Only standardized interfaces are to be tested during vehicle integration & test, placing all unique I/Fs (if used) inside instrument/subsystem
Communications for Applications & Devices

User Unique Applications & Devices
- Application (e.g., Attitude Control) or Spacecraft Hardware Device

Application Layer Services

Transport
Network
Onboard Link
Onboard Physical

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Application Layer Services

Transport
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Onboard Physical

Communications will be between a pair of applications, or between an application and a spacecraft device
SOIF WEB Site

- ESA Web site address for the Spacecraft Onboard Interface task at:
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Physical Context of the SOIF: Micro/Nano Spacecraft

Micro/Nano spacecraft can use medium- and low-speed busses

- Medium-speed bus for backbone bus to interface to payloads, I/O gateways, and large sensors & effectors
- Low-speed bus to interface to small sensors & effectors

Cartoon of possible Micro/Nano Spacecraft architecture

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Physical Context of the SOIF: Large Spacecraft, Robotic & Inhabited

- Larger spacecraft may need busses with all three speed classes
  - High-speed busses needed for some payloads
  - Medium-speed busses will also need to interface with spacecraft subsystems
  - Low-speed busses still interface with sensors & effectors
- No difference in reqmts of large and small S/C busses

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System Model: Spacecraft Segment

- Spacecraft segment can be modeled with various levels of busses, each with a different level of responsibility for running the spacecraft systems.
- Devices interfacing to the busses vary from high speed payloads and the spacecraft executive processor to sensors and effectors.

[Diagram of spacecraft segment model]
Elements of the SOIF Interface
Reference Model

- Electro-Mechanical Interfaces
  - For electrical power, grounding, mechanical, thermal, and EMC/EMI interfaces and designs
  - Will propose only electrical power interface standards

- The Communications Interfaces
  - Propose an initial three-bus configuration for high-speed, medium-speed, and low-speed busses for API at Link layer
  - New busses to be proposed later to keep up with new technology
  - Will also propose Transport layer API, and Application layer API for messaging service

- The Applications Service Interface
  - Common Applications Objects and Services (CAOS) to be determined for API at Application layer
  - Know that time distribution and synch is one of the CAOS

- Communications is provided to either an application or a S/C device

API = Applications Programming Interface
Interface Reference Model: 99-NOV-12

Onboard Electro-Mechanical Interfaces

Application (e.g.: Attitude Control) or Spacecraft Hardware Device

Common Applications Objects and Services

Messaging
Transport
Network
Onboard Link
Onboard Physical

Communications Interfaces

Spacecraft Hardware Bus or LAN

Space Link

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Electro-Mechanical Interfaces

- Will select and develop three power interfaces
  - +5VDC power for micro/nano spacecraft (such as Nanosat)
  - +28VDC power for medium and large sized spacecraft (such as MIDEX, EO-x, and TRMM)
  - +120VDC power for large, high power spacecraft (as is used on the International Space Station)
- Other electro-mechanical interfaces will be deferred to later, or taken up by other standards organizations
Communications for Applications & Devices

- For this discussion will ignore the differences between communications interfaces and application service interface
- Purpose of the communications interfaces is to provide communications between application and/or devices
  - Can be an application (flight software) running on a processor
  - Can be a hardware device (star tracker, temperature sensor), sometimes called sensor/effector or sensor/actuator
- The application/device can access communications and application interfaces directly
  - Use a Messaging, Transport, or Link layer API; depending on need and capabilities of the application/device
  - The application service interface would be available for applications or devices that would have the sophistication to take advantage of the services
Communications for Applications & Devices

Communications will be between a pair of applications, or between an application and a spacecraft device.
Communications Interfaces: Link Layer API

- The Link layer API is the least sophisticated interface
  - A simple hardware device will usually use the Link layer API
  - Telecommand and telemetry packets will usually use the Link layer API
  - Link layer API will probably be defined first, so will be used by earlier projects
  - Is closest to bus interface used by most flight software today
  - Recommended have three different busses available from Link layer
    - Suggested high-speed bus is IEEE-1394
    - Suggested medium-speed bus is MIL-STD-1553B
    - Suggested low-speed bus is I²C
  - Link layer API would provide identical interface to all three busses, insulating bus design and changes in technology from higher layers
Communications Interfaces: Transport Layer and Messaging APIs

- The Transport layer API will provide access to Transport and Network layer services
  - Network services include routing, congestion control, and internetworking
  - Transport services include multiplexing, segmentation, flow control, and congestion management
  - These services should only be needed for movement of data to another network, or off of the spacecraft (but not telemetry or telecommand)

- The Application layer API provides the messaging service
  - Messaging service provides consistent formats for data and messages
    - Predefined data types and formats for these data types
    - Consistent message formats for moving parameters (data) and defined events
  - Providing messaging services for data/devices or for applications
  - Messaging can support a mechanism to poll and discover devices on bus at initialization
  - The messaging service is provided directly to the Link or Transport layer as required
Application Service Interface

- The application/device can access communications interfaces directly
  - Use a Messaging, Transport, or Link layer API; depending on need
  - Also have Common Applications Objects and Services (CAOS) available for use by applications and devices

- Common Applications Objects and Services (CAOS) will provide common methods for communications between applications and devices
  - These objects and services will need to be defined after an analysis of spacecraft applications needs
  - Time distribution and synchronization is one of these services
Issues

- System Firmware: Automate device initialization and electronic data sheets, but not clear how (or if) this fits into the SOIF work
- Test Port: would like to recommend a test port, however not yet clear how this fits into SOIF work
- Spacecraft Constellations: insufficient time to understand how this subject will effect the SOIF work