Onboard Plug and Play Standardization Effort

Software System Engineering & Technology Infusion Group Overview

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Introduction

This work introduces "Onboard Plug and Play Standardization".

This work is a study of the role of plug and play services for spacecraft.

Idea:

- **There exist use cases where plug and play services would give system engineers greater leverage in spacecraft development and automation.**
- **A standard Plug and Play architecture is envisaged as mission complexity grows (Mars surface ops/Constellation missions etc).**

Agenda

- **Task Summary**
- **Task Overview**
- **Success Criteria**
- **Planned Products**
- **Technical Approach**
- **Issues and Concerns**

Task Summary

Objectives:
- **Explore uses for Plug and Play in space operations and identify possible JPL based. contributions, to support standards creation.**
- **Recommend set of standards after a thorough search of the solution space (desktop, commercial).**
- **An abstract representation of the solution using a modeling language (UML, IDL).**

Approach:
- Study commercial standards (WDM, Fieldbus, UPnP)
- Review current JPL practices and develop SOIS use cases.
- Develop JPL Mission specific and broader requirements – generate device attribute list.
- Develop recommendations to CCSDS WG.

Team:
- Amalaye Oyake, Lead Engineer

Schedule:

Task Overview: Importance of this Work

This is work is important for several reasons:

• Spacecraft complexity is increasing with new missions and goals.

• Lack of interoperability standards is an obstacle to future inter-agency cooperation.

• A Plug and Play standard will benefit other services such as Monitor and Control.

Task Overview: Impetus or this Task

1. The growing need (for NASA) to facilitate spacecraft interoperability with software standards that leverage current industry trend.
2. The goals of today's space and Earth science programs call for many scientifically compelling, exciting missions, however much of the effort and cost for these missions is slowed down by increased complexity in software design, legacy hardware, and software hardware integration.
3. Plug and Play will help onboard services interoperate (missions/test/integration/verification/validation).

Task Overview: Importance of this Work

- **Decouple the user application (software) from the spacecraft hardware**
  - **At device level (sensors/actuators) ~ Device proxy patterns.**
  - ***At application layer ~ Other proxy patterns (separate emphasis)***
- **Use hardware with different data bus types**
  - **Changing the data bus should only affect the interface, and not the application.**
- **Plug and Play at the device level will facilitate the migration of engineering sensors and actuators from dedicated wires onto a data bus.**

Success Criteria

- **A Proposal - Well defined device level Plug and Play use cases for SOIS.**
- **Commitment from several sectors of JPL. Early adopters.**
- **Positive acceptance from CCSDS, with follow-on work for a prototype implementation. International Standard (CCSDS).**

Planned Products

- An abstract specification/reference design (UML/XML Schema). It should be represented conceptually without any hard software bindings – Peter Gluck

  This conceptual representation should the model is
  - Distributed points of control
  - Allowed associations
  - Roles and responsibilities
  - Definition of all the actors (see UML)

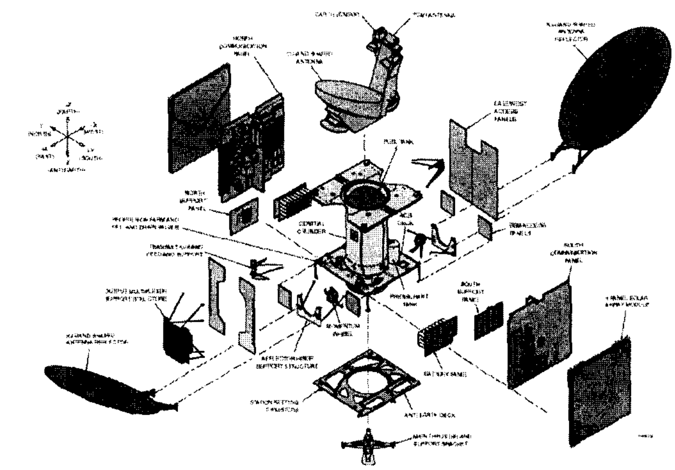
- A generic device attributes list, with prototype attributes for some instruments (star tracker, camera etc).

- Definition of device classes and device proxy types.

- Prototype and further funding.

Task Overview: Spacecraft Hardware Complexity

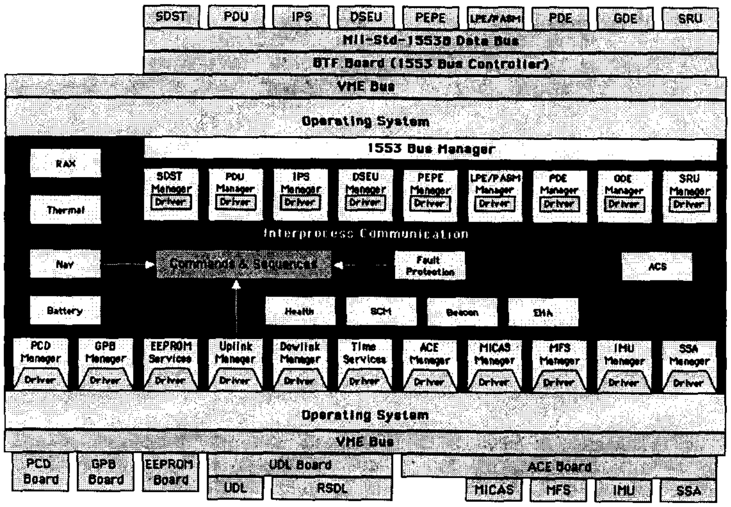
Many instruments ~ many buses ~ many challenges
- 1553
- RS232
- RS485
- VME
- Compact PCI
- Custom designs



Spacecraft Software Complexity, DS-1

DS1 FSW Layered View

Peter Glück, 2 March 2000

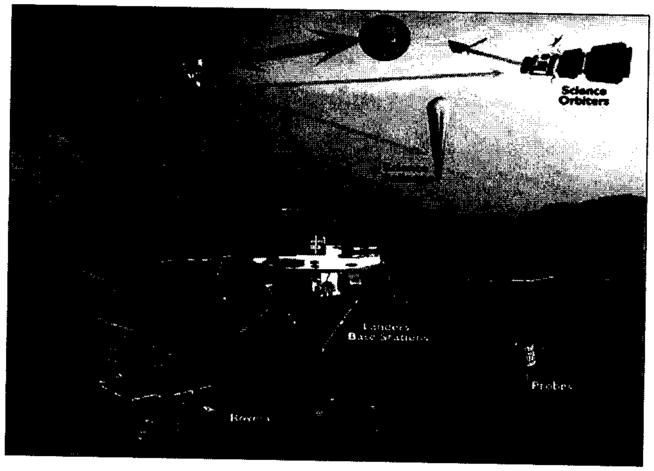


Use Cases

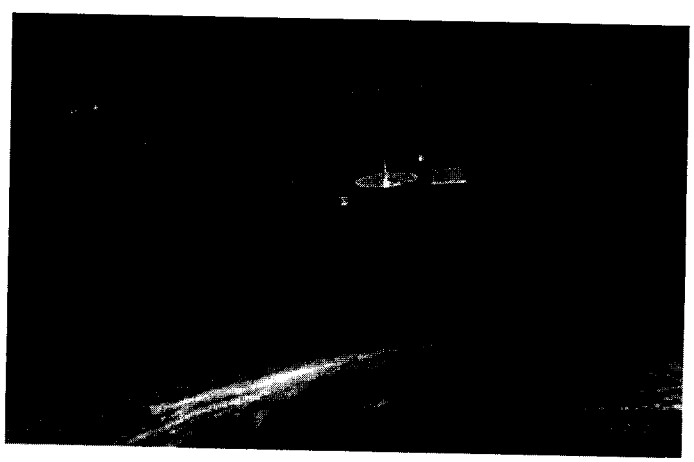
Ongoing discussion on plug and play concepts for both hardware devices and software applications:

- **Test and integration**
- **Instrument coming alive**
- **Application level plug & play**
- **Device level plug and play**
- **Cooperating space craft**
- **Rovers Interacting**
- **Sensor networks**
- **Spacecraft networks**

Use Cases: Surface Operations



Use Cases: Formation Flying



Technical Approach: Previous Efforts at JPL

- **SuperMoca – Demo used Fieldbus FMS**
  JPL - sponsored task aimed at developing an architecture and a set of technologies and associated open system specifications for the monitor and control of remote space vehicles and supporting remote ground networks.
  Status: No longer ongoing ~ Michael K. Jones.

- **SIM/MAM/FIT Testbed – Uses CORBA (ACE-TAO) as the orb,** a CORBA centric solution. **Robust device proxy implementation with devices supported as C++ Objects.**
  Status: Fully implemented, ground based.
  Actually a <u>good</u> reference model.

Technical Approach: External Initiatives

Standard	Description	Organization	Age	Physical Layer	Speed	Plug and Play
IEEE 1451	Transducer interface standard	IEEE	1997	NCAP dependent		YES
Foundation Fieldbus	Field device interface standard	Fieldbus Foundation	1991	Ethernet		YES
UPnP	Universal Plug and Play Standard	UPnP Forum/Microsoft	1999	Ethernet	Ethernet Speeds	YES
ARINC 653	Aviation Standard - Aeronautical Radio, Inc	ARINC	197	1553	1553 Speeds	
SensorML	Sensor Markup Language	OpenGIS		No Bus Architecture		NO
AADL	Avionics Architecture Description Language	Society of Automotive Engineers (SAE)/Honeywell	1991, Based on MetaH + UML-RT	Not bound to any Bus Architecture		UNKNOWN
Jini	Sun device communication protocol.	Sun Microsystems	1996		Ethernet Speeds	YES
Blue Tooth				Bluetooth Wireless		YES

Technical Approach – Opinions

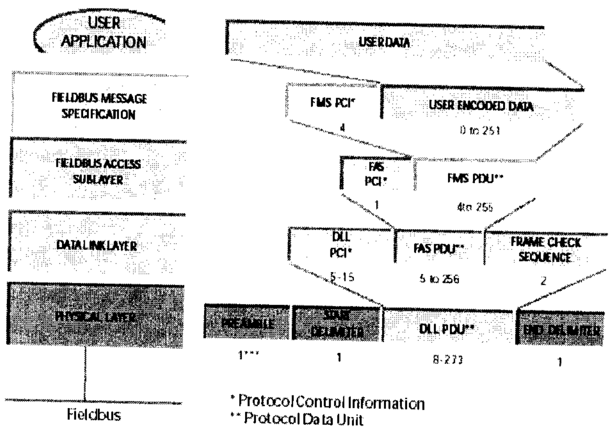
- Peter Glück – Make framework abstract
- Kim Gostelo – Hardware Abstraction Layer
- Roger Klemm – Model a real system (DS1) with UML
- Vince Randolph – Take note of REAL technical obstacles
- Lee Eccles – Advice on Electronic Datasheets

Technical Approach: The Need for Standards

- The OSI model defines 7 layers and provides a good reference point for an Onboard Spacecraft Monitor and Control Standards model.
- Using this as a reference, our work will focus on the Presentation and Application layers only. Need compatibility across various physical and datalink layers.

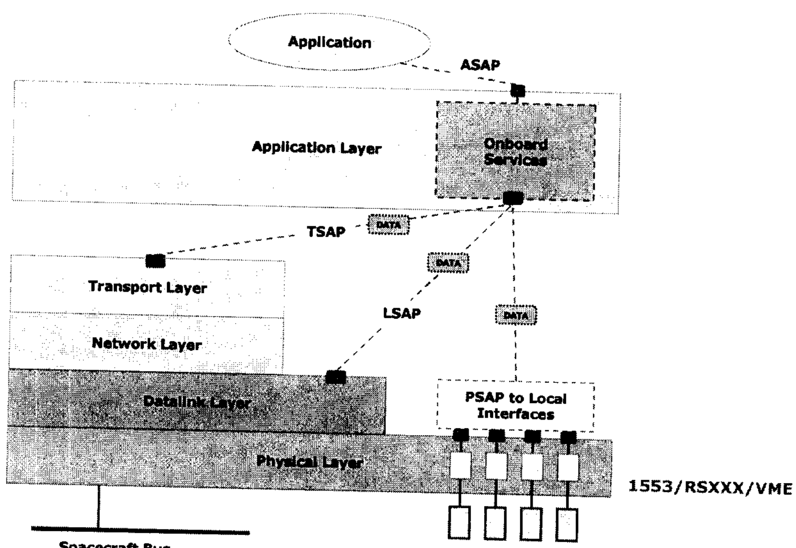
7	Application	Provides the User with Network Capable Applications
6	Presentation	Converts Application Data Between Network and Local Machine Formats
5	Session	Connection Management Services for Applications
4	Transport	Provides Network Independent, Transparent Message Transfer
3	Network	End to End Routing of Packets. Resolving Network Addresses
2	Data Link	Establishes Data Packet Structure, Framing, Error Detection, Bus Arbitration
1	Physical	Mechanical / Electrical Connection. Transmits Raw Bit Stream

Technical Approach: Case Study ~ Fieldbus Messages



* Protocol Control Information
** Protocol Data Unit
*** There may be more than one octet of preamble if repeaters are used

Engineering View



Technical Approach: SOIS Hardware Support Wish List

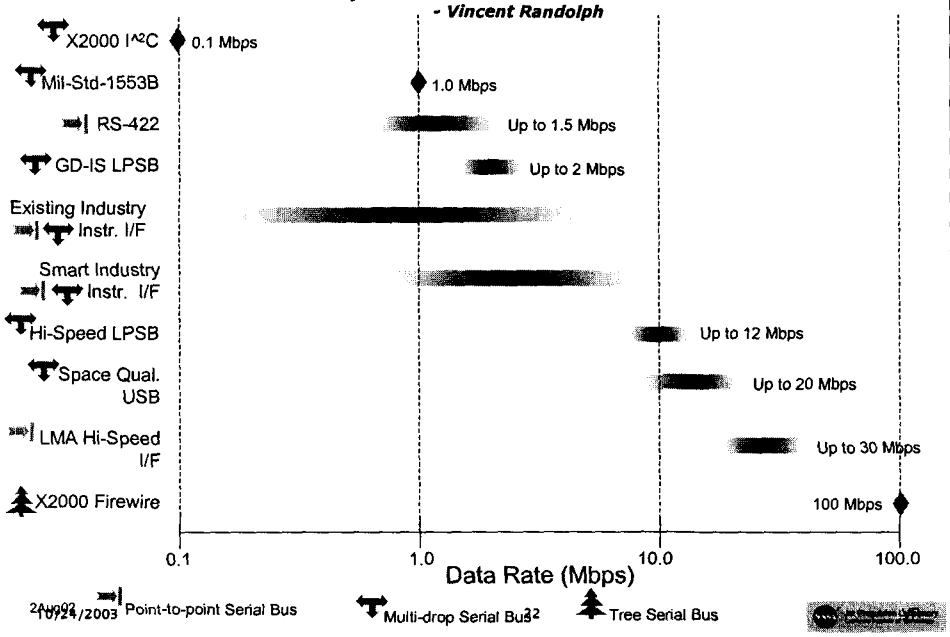
Data / Control Bus
- **MIL-1553B Data Bus** (from NASA-GSFC; NASA-JPL, Honeywell, CNES)
- **4-255 Data Bus** (from ESA)
- **MIL-1773 Data Bus** (from NASA-JPL)
- **(10/100/Gigabit) Ethernet** (from NASA-JPL, Fisher-Rosemount, SRI International)
- **VME/Compact-PCI** (from NASA)

Serial Link
- Spacewire (JPL/ESA)
- **Liaisons Numeriques Rapides (LNR)** (from CNES)
- **IEEE-1394** (from NASA-JPL, NASAGSFC, Honeywell)
- **Packet Wire** (from Saab Ericsson Space)
- **Inter-IC (I2C) Bus** (from NASA-JPL, NASA-GSFC, Honeywell))
- **Foundation H1 Fieldbus** (Boeing, Fisher-Rosemount, SRI International)
- **RS232, RS4XX** (Legacy applications)

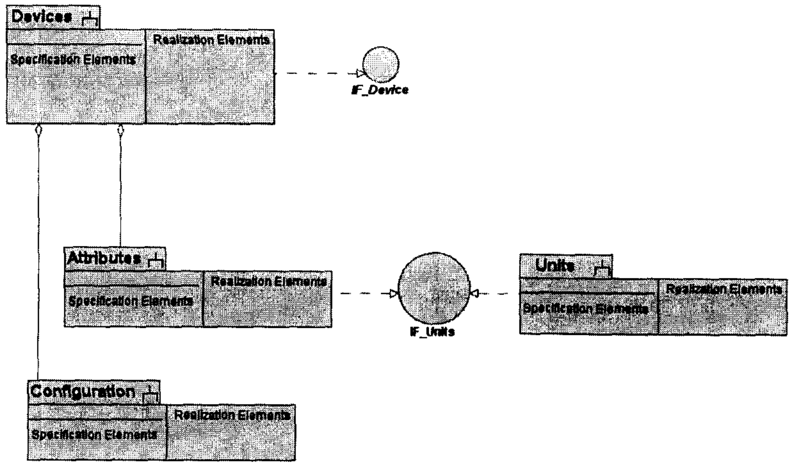
Discrete Interfaces
- **16-bit Serial Digital Output Interface**
- **16-bit Serial Digital Input Interface**
- **16-bit Bi-directional Serial Digital I/F**
- **Bi-level Discrete Input Interface**
- **Analogue Signal Interface**
- **On/Off & High Power Pulse CMD I/F**
- **Switch Status Interface**
- **Timing and Clock Output Interface** (All Discrete I/Fs from ESA)

SOIS Hardware Support Wish List
Spacecraft Internal Data Rates

- Vincent Randolph



Technical Approach: Represent Layers With UML Subsystem Diagrams



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Technical Approach

- **Study the CCSDS requirements and M&C Layers** - Done
- **Case studies - Study current ESA/JPL practices** - Done
- **Hardware Abstract Layers, device driver models, design patterns of device drivers** - Done
- **Study WDM Model/Apple IO Kit/Fieldbus ... as a reference point** - Done
- **Current hardware standards/trends (JPL/Industry)** - Done
- **Consult domain experts and tabulate a device attribute list** - Done
- **Develop abstract representation for the concepts (UML)** – Ongoing/Refinement
- **Write a proposal for an actual implementation** – In progress.

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Issues and Concerns

• The level of buy-in by JPL and related agencies needs to be discovered and the solution space within JPL needs to be defined.

• These concepts need to be marketed, within JPL. CCSDS must address the propagation through SOIS, MOIMS, NASA, ESA/etc - ONGOING

• Once interest is generated, there need to be "birds of a feather" meetings, working groups - ONGOING

• Besides NASA/ESA adoption, SHOULD these ideas need to introduced to the commercial vendor domain?

Conclusions

• Need to work in the domain of space qualified systems*.

• Most space devices are dumb
  - The device layer needs to implement good device proxy architecture that exposes device metadata and fully encapsulates concepts.

• Formalize data "on-the-wire"
  - Need to learn about PUS ...
  - Onboard data formats
  - OMG/CCSDS/ESA
  - Proprietary
  - Fieldbus
  - XTCE

• For device driver layer
  - Need mature design patterns that.
  - Driver models that can be layered.

Conclusions

- Depict high-level overview of requirements
- Formalize onboard subsystem software interfaces.
- Depict high-level overview of design
  - Use UML package/subsystem diagrams
- Logically factor the complete systems into subsystems
  - Use UML subsystem diagrams
  - Use UML interfaces to specify interconnects

Conclusions

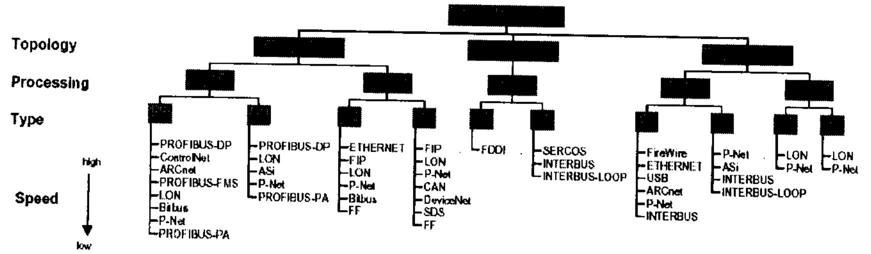
Monitor and Control is fundamentally about data-representation.

We are primarily concerned with Metadata. Specifically and extensible metadata model, to represent commands, events, units and other interesting data.

Propose: Prototype model using JPL ALAB, RTC Framework (XML - Specifically SensorML, and capturing IEEE 1451 type data attributes which has been proposed before - Micah Clark/R&TD/2002, MTS over Spacewire).

BACKUP

Technical Approach: SOIS Hardware Support Wish List



What Do These Technologies Buy JPL?

- A Device Attribute List that we can reference
- A Device Messaging Specification
- A Pattern for device commanding
- A successful framework implementation

Device Description Attributes

MANUFACTURER	Identifies the device manufacturer.
DEVICE_TYPE	Identifies the specific device.
DEVICE_REVISION	Revision of the device.
REVISION	Revision of the Device Description.
VARIABLES	An item of data.
MENU	A menu, listing other menus or displays for selection.
CHANGEABLE VARS	A display for the operator to edit variables.
METHODS	An operational procedure for interaction with the field device.
ARRAYS	An array of variables of similar type.
RECORDS	A data structure of variables of mixed type.
ITEM_ARRAY	An array of items of similar type.
COLLECTION_OF	A collection of items of similar type.
VARIABLE_LIST	A list of variables, arrays or records.
BLOCK	Defines a Function Block (or other block) by listing its contents.
REFRESH	A set of variables whose values must be re-read whenever other specified variables are changed.
UNIT	Defines which variables use a particular engineering unit.
WRITE_AS_ONE	A set of variables which must always be written as a group.
PROGRAMS	An executable program in the field device.
DOMAIN	A memory area in the field device.
RESPONSE_CODES	A set of possible response code values and their meanings.

Attributes of Interest

- Classes
  - Sensors, Actuators
- Subsystem
  - ACS
  - TEL
  - CDS
- Types (Smart, Board, I/F)
  - IMU, SRU, SS, CAM, SDST
- List of OUPUTS/INPUTS - TLM/CMD
  - Value
  - Expected Range
  - Units
  - Freq/Async Messages
  - Transmit Method
  - Jitter (max)
- List of OUPUTS/INPUTS
  - Max Latency
  - Data Size
  - Data Format
  - Data Type
  - Data Rates
  - Precision
  - Accuracy
  - Cycle Sync.
  - "Start Now"
- Start/Stop Talk
- Uncertainty
  - Jitter
- Calibration
- Sequencing
  - How
  - What
  - Procedure

Attributes of Interest

- Delay Between Commands (min/max)/TLM
  - Heartbeat
- Time Synchronization
  - Freq FWD/REV
  - Precision
  - Accuracy
  - Format
- Status Messages
  - On/Off
  - Standby/Operate
  - Offline/Online
  - Busy/Ready
  - Loading (SW)
  - Boot/Recycle
- Performance Metrics
  - Made/Missed Deadline
  - Excess Processing Available
  - Avg. or Expected processing duration estimate
  - Timestamp
  - Dump
- Dependencies/Associations
- Resource Requirement
- Resource Availability
  - Power
  - Memory
  - Processing Cycles
  - Mass Properties
  - Thermal Properties
  - Vibration/Dynamics
  - Radiation Tolerance
  - Bright Body Constraints

Attributes of Interest

- Resource Availability (Cont)
  - **FOV**
    - **Exclusion**
    - **Zone**
    - **Duration**
    - **Rate**
  - **Consumables/Consumability**
  - **Max Operating Time**
  - **Warm-Up Time**
- Data Buses
  - **1553**
  - **RS422**
  - **I2C**
  - **Wi-Fi (802.11a/b/g)**
  - **Bluetooth**
  - **1394a/b**
  - **USB**
- Protocols
  - **TCP/IP**
  - **UDP**
  - **Proximity-1**
  - **CCSDS**
  - **Plug and Play**
- Care & Feeding Instructions
  - **Procedures for Resetting DEV**
  - **Flight Rules**
  - **Fault Recovery**
  - **Handling Instructions**
  - **Requests (Responses) Def.**
  - **Recovery Instructions**
- Data Types
  - **SI Units *****
  - **Science**
  - **Health**
  - **Engineering**
  - **Status**
  - **Warnings/Errors**