TacSat-4 Prototype Bus & ORS Phase III Bus Standards Update

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SmallSat 2008
Outline

• Background and Concept of Operations

• Operationally Responsive Space (ORS) Phase III Overview

• Bus Standards Development

• Status of Implementation of the Standards
What is Operationally Responsive Space?

Operationally Responsive Space is using spaceborne assets to act and react quickly to emerging challenges by empowering operational users.

- **Tier-1** On-demand with existing assets *(minutes/hours)*
  - Command It

- **Tier-2** On-call with ready-to-field assets *(days/weeks)*
  - Launch It / Deploy It

- **Tier-3** Emergent technologies with rapid transition from development to delivery of new or modified capabilities *(months)*
  - Develop It

Focus of Phase III efforts
Operationally Responsive Space: Tier-2

- The idea is to preposition launchers, spacecraft buses, and payloads for quick deployment when needed.

- This should allow for mass production and bulk buys, perhaps by coalitions of countries, to reduce costs.

- One or two common bus designs should be able to support about a dozen payload types to satisfy different missions.

- Spacecraft buses and payloads must necessarily support a standard interface to be interchangeable.
National Security Space Missions targeted by ORS

- Electro-Optical Imaging / Spectral Imaging
- Synthetic Aperture Radar (SAR) Imaging
- Signal Collection
- Blue Force Tracking (BFT) / Joint Blue Force Situational Awareness (JBFSA) / Data Exfiltration
- Communications
- Navigation
- Space Surveillance / Space Control
- Weather Monitoring
- Other Science
Two components are combined to make the complete spacecraft:
- the bus
- the payload

Known, well characterized national security missions are addressed.
# Mission Requirements and CONOPS

## High-level Timeline

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<thead>
<tr>
<th>Integration and Launch Insertion</th>
<th>Mission Operations</th>
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<tr>
<td><strong>Day 1</strong></td>
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Some Historical Responsive Space

adapted to reconnaissance. Of the basic spacecraft, whatever its mission, Johnson observed: “You’re talking about assembly-line techniques. There’s nothing fancy about them. We know that simply from the hard data we have on the manned spacecraft. The French have flown on it and the Soviets released a lot of data when we had the Apollo-Soyuz mission back in ’75. We know a lot about it. It’s very simple, and rugged, and mission-effective. It does what it needs to do.” So do Soyuz’s boosters, which also roll off assembly lines at frequent intervals.

Large-scale photoreconnaissance satellite production has at least two advantages. It allows the Russians to respond quickly and repeatedly to emergencies or to any situation in which imagery is useful, and it also increases the odds that they will keep at least some reconnaissance capability in the event that those of their spacecraft in orbit are attacked by anti-satellite (ASAT) weapons.

“They’re very reactive,” Nicholas Johnson observed. “We’ve seen many times that they put up a new satellite within twenty-four hours of a world crisis.” A U.S. reconnaissance satellite launch, by comparison, can take weeks or even months to prepare because of the complex logistics. The Russians, on the other hand, stock both reconnaissance satellites and their boosters, and keep some of each ready to go on short notice. “When the rocket comes out,” Johnson added, “the upper stage is already fueled, the payload is already on, it’s already been checked out, so they erect the thing, fuel the main booster, and it goes.” During the Arab-Israeli war in 1973, that kind of capability allowed the U.S.S.R. to send up seven reconnaissance satellites in one three-week period. And rather than keep them up...
Experiment To:

- Establish a national systems engineering working group comprised of government, academia and U.S. small satellite industrial partners
- Use the national systems engineering working group to develop and maintain bus standards
- Design, build, and test a prototype bus demonstrating the use of the bus standards
  - Validate selected bus standards
  - Update bus standards based on lessons learned
  - Retire selected non-recurring engineering costs future system
- Bridge the Gap Between S&T Experiments and Operational Bus Capability
  - Shorten the development cycle with the prototype bus that has clearly identified elements of the operational bus
- Develop an ORS Phase IV Transition plan with the ORS office and SMC
The ISET efforts have been ongoing since 2005.

Industry and user perspectives on bus standards and interfaces were sought early to ensure the production of practical, implementable, and palatable standards and a subsequent smooth transition to Phase IV.
ORS Phase III Overview
Standard Bus vs. Bus Standards

• Standard Bus
  - Implies that standard applies to only a single spacecraft bus
  - One spacecraft bus and configuration for all missions or mission classes
  - Design must meet all stated requirements and specifications
  - Approach has been tried in the past
    - Rigid performance
    - Leads to “least common denominator” approach
    - System overdesigned in many areas

• Bus Standards
  - Provides a set of requirements that can be used to satisfy range of mission performance
    - Tailor-able/selectable for mission specific capability
    - Framework for overall spacecraft design approach and philosophy
    - Allows for procurement flexibility
    - Allows for a “family” of spacecraft

Terminology Makes a Difference
ISET Focused on Development of Spacecraft Bus Standards

The efforts of the ISET has focused on standards (i.e., requirements) for interfaces, performance and procurement of spacecraft buses in support of operationally responsive space.
ISET Mission Requirements and CONOPS Assessment Process

Survey Representative Payloads and Missions

- General Master Mission “Flysheet”
  - Payload Details
  - Operations Details

- Started with the initial analysis and utility study performed by MIT Lincoln Labs

- Distilled information into representative mission classes

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Review and Selection of “80%” Levels
ORS Phase III Documents

Core ISET Products

ORS Mission Requirements CONOPS
ORSBS-001
NCST-D-SB001

ORS Bus Standards Transition Plan
ORSBS-005
NCST-D-SB030

Payload Developer Guide (PDG)
ORSBS-003
NCST-IDS-SB001

ORS Standard Data Interfaces:
Bus to Payload, Bus to Ground
ORSBS-004
NCST-IDS-SB002

General Bus Standard (GBS)
ORSBS-002
NCST-S-SB001

• Accommodation Provisions
  • Mass
  • Power
  • ADCS
  • Thermal
• Mechanical Envelops
  • Volume/COM
  • Inertias
• Interfaces

• Bus-to-Payload and -Ground Interfaces
  • Data protocols
  • Message formats

• Total SV compliance requirements
• Interface requirements
• LEO and HEO classes
• Test program specs
• Launch vehicle
  • Environments
  • Performance
  • Range
Data Interface Standards

• Defines an Operationally Responsive Space (ORS) Standard for the Bus/Payload Interface and Spacecraft/Ground Interface.

• Take advantage of existing standards:
  – CCSDS Formats and Protocols – already widely accepted
  – SpaceWire – developed by ESA and has a large user base
  – RS-422 & HDLC – very lightweight, pervasive in the industry

• Minimize Dependencies on Link and Hardware Characteristics

• Provide Conduit Services for Payload Data

• Publish a Minimal Message Exchange Protocol Between the Bus and Payload Processing Elements

• Pursue a Balanced Approach for the Interface Between the Bus and the Payload (i.e. Not a Master/Slave Interface Approach)
The False Trichotomy of ORS standards vs. SPA standards vs. SIV standards

- They serve different needs:
  
  - ORS standards
    - Up to 175 kg payloads
    - Interface by
      - RS-422, up to 1 Mbit/sec
      - SpaceWire, up to 100’s of Mbit/sec
    - Already know the missions
    - Mate the payload and bus, then launch it – 2 pieces
    - Comprehensive, detailed standards documentation exists
  
  - SPA standards
    - No mass limit defined for SPA PnP devices
      - Interface by SPA-S (SpaceWire), up to 100’s of Mbit/sec
      - Future: SPA-U, SPA-E, etc.
    - Use the mission design tools to generate a design
    - Tailor build using stocked plug & play satellite components – arbitrary number of pieces
    - Detailed standard documentation in progress
  
  - SIV standards
    - Up to 60 kg payloads
    - Interface by RS-422, up to 2 Mbit/sec
    - Not currently intended for stocking for depot operations
    - Comprehensive, detailed standards documentation exists
Implementation Team Mission

• Build to the ORS Phase III Bus Standards, to mature the standards

• Provide a bus for the COMM-X payload.

• One Year of Flight Operations

• Proto-flight Test and Verification Approach

• Space Segment Implementation

• APL/NRL Team Designed and Built the Prototype Bus

• Launch via GFE Launch Vehicle (Minotaur – IV +) With ILC in September 2009
TacSat-4
Bus and Payload Relationship

Bus Standards Documents
• ISET Developed

COMMx Payload
• SRDR Jan 2006
• PDR Apr 2006
• CDR Aug 2006
• TRR May 2008
• Payload Complete September 2008

Phase 3
Bus Prototype
• CoDR Feb 2006
• PDR Jul 2006
• CDR Dec 2006
• Bus Complete April 2008

TacSat-4
Space Vehicle
• SV TRR July 2008
• PSR July 2009
• ILC/Launch Sept 2009

Presentation is on Implementation Team Activities
Bus Standards Development and Iteration

Integrated System Engineering Team (ISET)

- Experience gleaned during the prototype development was used to iterate the standards with the ISET.
Bus Development

Structure Frame Received

Wire Harness

Electrical I&T

Alignments & CMM Prep

Solar Array Flash Test

EMI Testing

Vibration & Acoustic Testing

Thermal Vacuum Testing
Upcoming Events

- The bus prototype is complete and in storage
- Pending Space Vehicle (SV) level testing
  - Payload delivery 2008 Q4
  - SV level EMI EMC
  - Magnetic Dipole Testing
- Storage Through July 2009

LV Orbit Injection:
- Insertion Orbit: 185 x 12050 @ 63.4 Deg Inclination
- Final Orbit: 700x12050 km @ 63.4 Deg Inclination
Other Implementations of the ORS Bus Standards

- MicroSat Systems Universal Interface Electronics (UIE)

- Design_Net Engineering Flight Software Standards Testbed (FSST)
Final Notes

• The efforts of the ISET have successfully produced extensive trades and a well-documented set of standards and interfaces for cost-effective spacecraft buses for the class of missions considered.
  – The documents are freely downloadable from http://projects.nrl.navy.mil/standardbus/

• Initial validation of a subset of these standards was done by building a prototype bus in an open manner that allows government and industry insight into successful implementation approaches and challenging issues that have arisen. Subsequent separate implementations of the electrical and data interface standards have also been accomplished.

• No proprietary claims have been exercised and any design aspects and techniques are available to the government sponsor for future consideration in industry-supplied operational builds.

• The prototype build of ORS Phase III spacecraft bus to support the TacSat-4 mission is complete and the bus is in storage.