Interface Standards as an Enabler for Operational Responsive Space

Brian Davis
Space/Ground System Solutions, Inc.
In Support of
ORS/NRL/APL

ORS Interface Standards – Overview (1 of 2)

- **Interface Standards Have Played A Key and Enabling Role For Phase 3 Of The Operationally Responsive Space (ORS) Effort.**
- **The ORS Sponsored Government And Industry Integrated System Engineering Team (ISET) Has Worked To Establish Specifications For Spacecraft Bus Requirements And Bus/Payload Interface Definitions.**
- **These Specifications Will Be Used To Procure And Establish A Depot Of Standardized Spacecraft Buses That Can Support A Variety Of Tactical Payloads.**
  - In Response To An Emerging Situation, A Bus And Payload Would Be Integrated, Prepared For Launch, Launched, Maneuvered, And Ready For Operations Within Seven Days.

ORS Interface Standards – Overview (2 of 2)

- **The Bus/Payload Interface Standard Is A Crucial Element To Enable Fast Integration Of A Variety Of Payloads For A Responsive Mission.**
  - By extending this approach …
- **The ORS Office Is Promoting Interface Standards For the Spacecraft/Mission Operations Center (SOC/MOC) External Interfaces.**
  - A Fast Integration Effort for the SOC/MOC will Enable a Responsive Operations Approach for Tactical Spacecraft Missions.

Background

Operationally Responsive Space

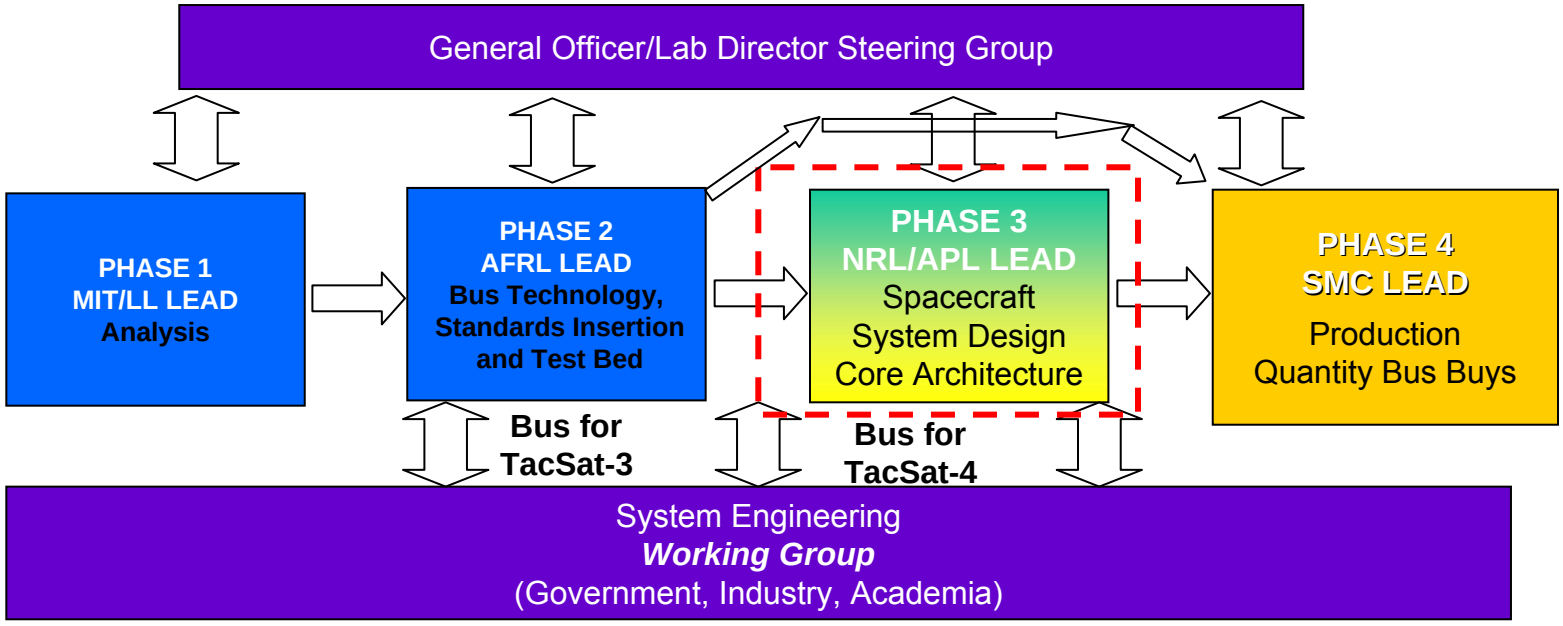
- Vision
  - Enhance and Assure the Space Contribution to Joint Warfare
- Definition
  - Assured Space Power Focused on the Urgent* Needs of the JFCs
    * Expect Will Change to “Timely Satisfaction of” Per OSD-Policy
- Attributes
  - Primary
    - Responsive − Addressing the Need and Delivered Within an Operationally Relevant Timeframe
  - Supporting
    - Agile*
    - Adaptable/Tailorable*
    - Networked*
    - Integrated/Interoperable*
    - Affordable

Operationally Responsive Space Goals

- Connect Space to the User:
  - Make Space Capabilities More Relevant to Joint Force Commanders and More Adaptable to Future Joint Force Needs
- Respond to the Urgent Need:
  - Deliver Effects to Joint Warfare In Response to an Urgent or Previously Unanticipated Need
- Reduce Development/Deployment Time and Cost:
  - Complement NSS Architecture With an Element Focused on Increased Value and Timely Delivery
- Capitalize Upon Emerging/Innovative Capabilities:
  - Motivate and Adopt New Capabilities From Advanced Technologies, Innovative Operational Concepts, and Benefits From Data Integration, Information Sharing, and Net-Centricity

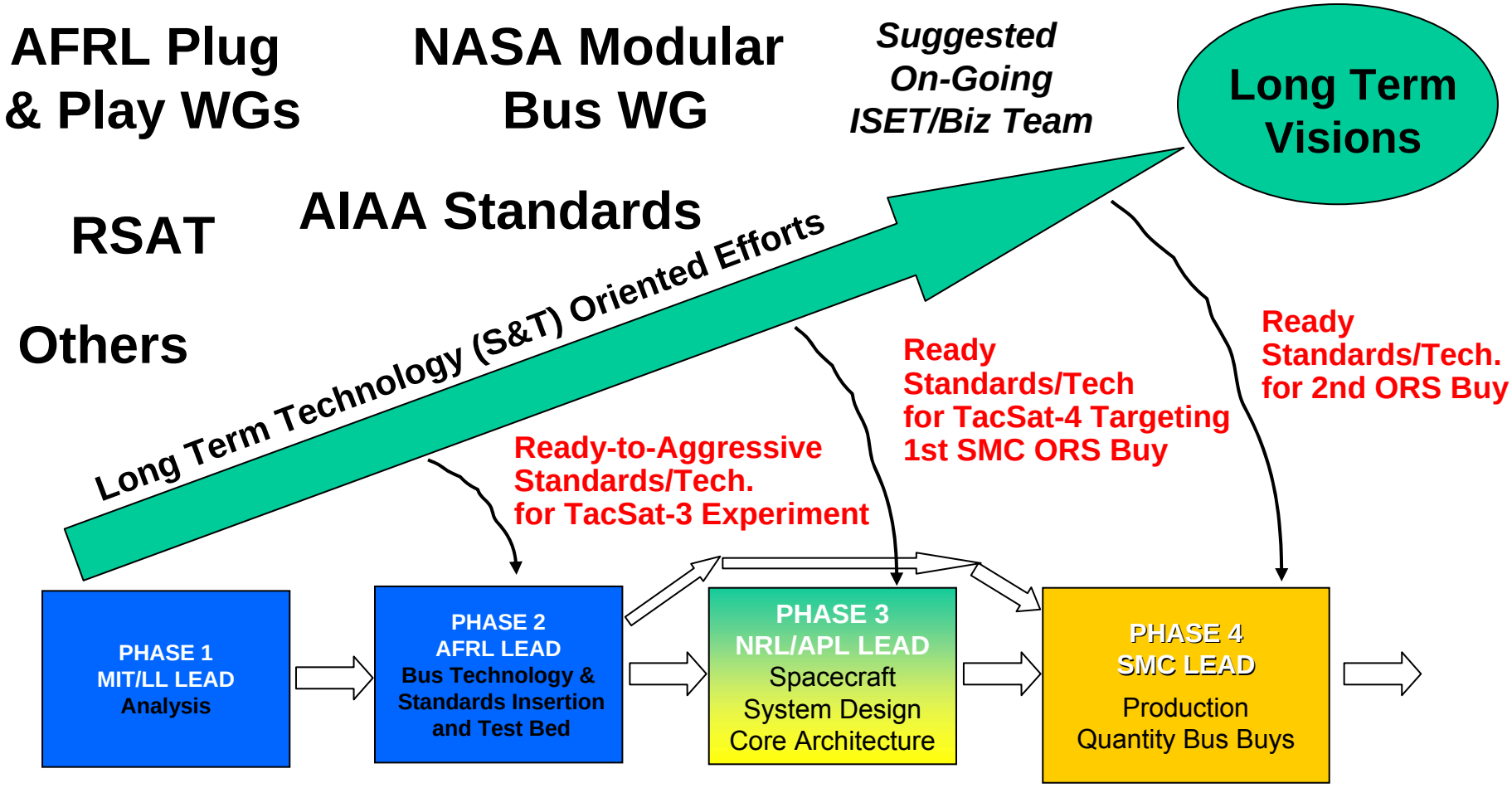
OFT/SMC Four Phase Standard Bus (TACSAT-4 Bus is Undergoing Env Testing)

- Phase 1 – Analysis and Team Building (MIT/LL Led)
- Phase 2 – Test Bed and Standard Avionics (AFRL Led)
- **Phase 3 – Gov't / Industry Prototype Standard Bus System Development**
  - **Naval Research Lab (NRL) and JHU Applied Physics Lab (APL) Led**
- Phase 4 – Production Phase (SMC Led)
  - Leaderships Coordinated, Working Level Coordination Starting



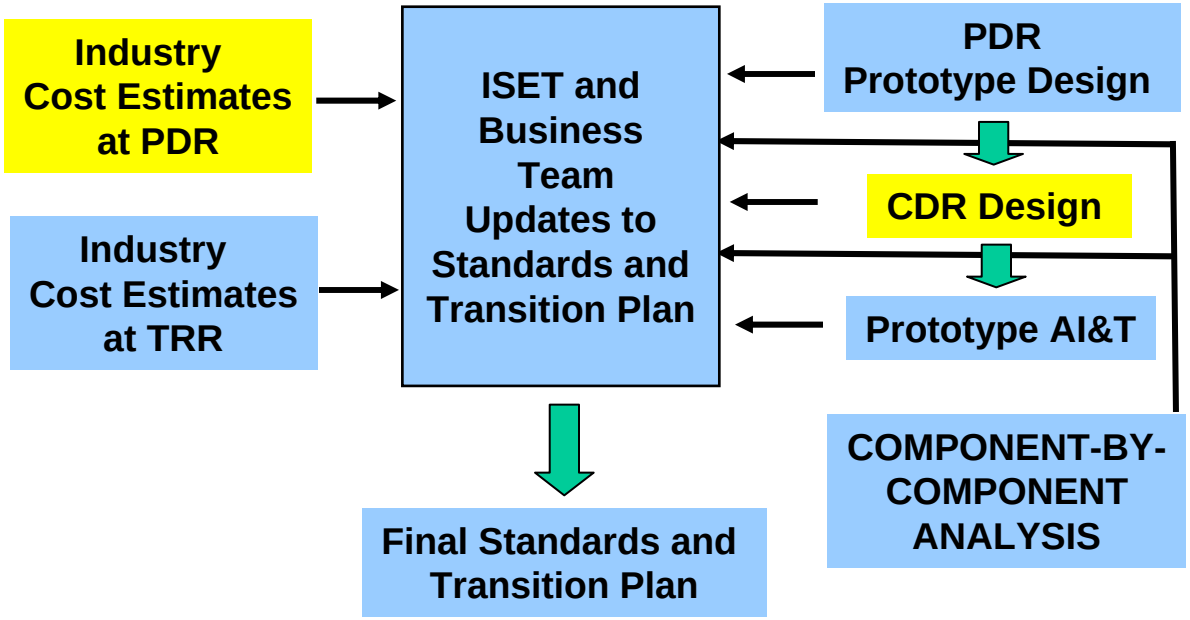
All Phases Supported by the Nation's Collective System Engineering Expertise

Relationship to Other Standards Working Groups



Bus Standards Development and Iteration

Integrated System Engineering Team (ISET)



- **Use Prototype Design to Iterate the Standards With the ISET**
  - **Technical Iteration in Full Swing through TACSAT-4 Bus PDR, CDR, Build, and System Test**
- **Use Cost and Business Team Input to Iterate the Standards**
  - **First Cost Information Received From Industry September 2007**
  - **This Initiated the Business/ Cost Standards Iteration**

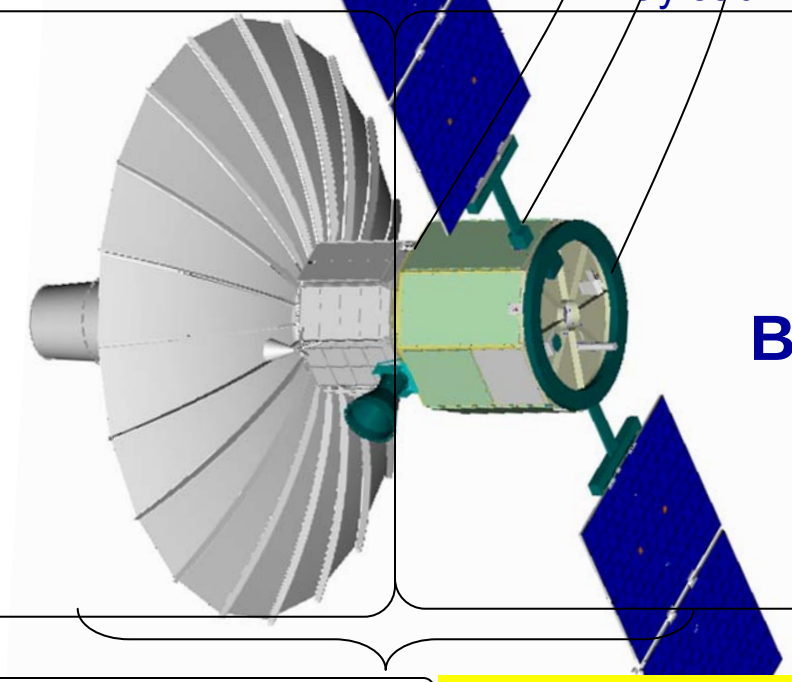
ORS Bus and Payload Relationship

Bus Standards Documents

- ISET Developed

- Launch Vehicle I/F
- General Bus Requirements
- Payload Development Guide

COMMx Payload



Phase 3 Bus Prototype

TacSat-4 Space Vehicle

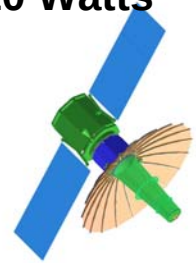
Discussion Is Focused on Business and ISET Team Activities for Bus Standards Development

TacSat-4 Mission Summary

Navy Led for Joint Community

Spacecraft and Payload Highlights

- Satellite [Space Vehicle]:
  - 425 kg
  - Payload Power: 200 - 610 Watts
  - Low HEO (4 hr) Orbit
  - 1 Year Life
- Payload Capability:
  - Data-X and BFT
  - COTM
    - Legacy Radio & IP Netted Support
    - MOUS-Like Wideband Capability



Objectives

- Demo High Dwell ORS Capability via a HEO Orbit
  - Augment Poor/No Coverage Areas
- Evaluate & Mature Phase 3, System Level Bus Standards in Realistic I&T, Launch, and Flight Operations Environment
- Provide TACSAT/ORS Comms-on-the-Move Capability (Legacy, Netted, and MOUS-Like)
- Collect BFT Devices in Underserved Areas
- Perform Buoy/Sensor Data-X on Moderate-to-High Power Transmissions

Ground Equipment

- BFT Devices: MTX, Grenadier Brat, Others
- COTM: Legacy Radios and MOUS Compatible UHF Wideband Radios
- Data-X Buoys and Gnd SensORS
- Ground Terminal: One Per 2000 nm Theater Spacecraft Cmd & Cntrl: Blossom Point, Maryland
  - Additional Coverage From AFSCN
  - Payload Tasking on SIPRNET VMOC

Programmatics

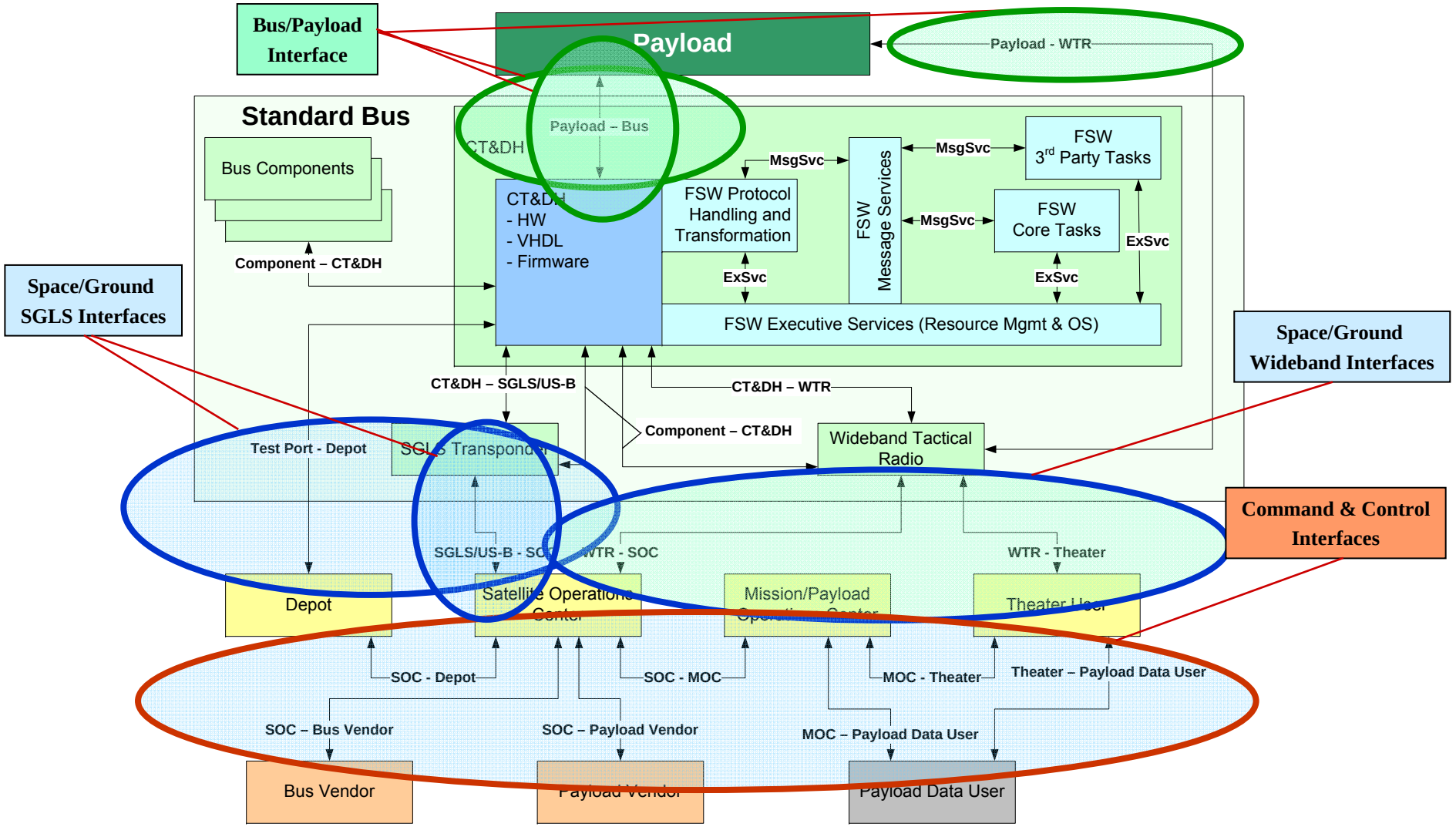
- ONR Payload, Flt Ops, Test Bed Sponsor
- OFT Bus Sponsor – “Phase 3” Bus
- AFSPC, SMC-12 Provided Launch
  - Minotaur-IV
  - Launch Targeting October of 2008
- NRL Program Manager
- STRATCOM to Assign Lead COCOMs as Experiments and Exercises Mature
- Multi-Service Participation

ORS Phase 3

Data Exchange Interface Standards

Interface Standards - Overview

Int[illegible]ured



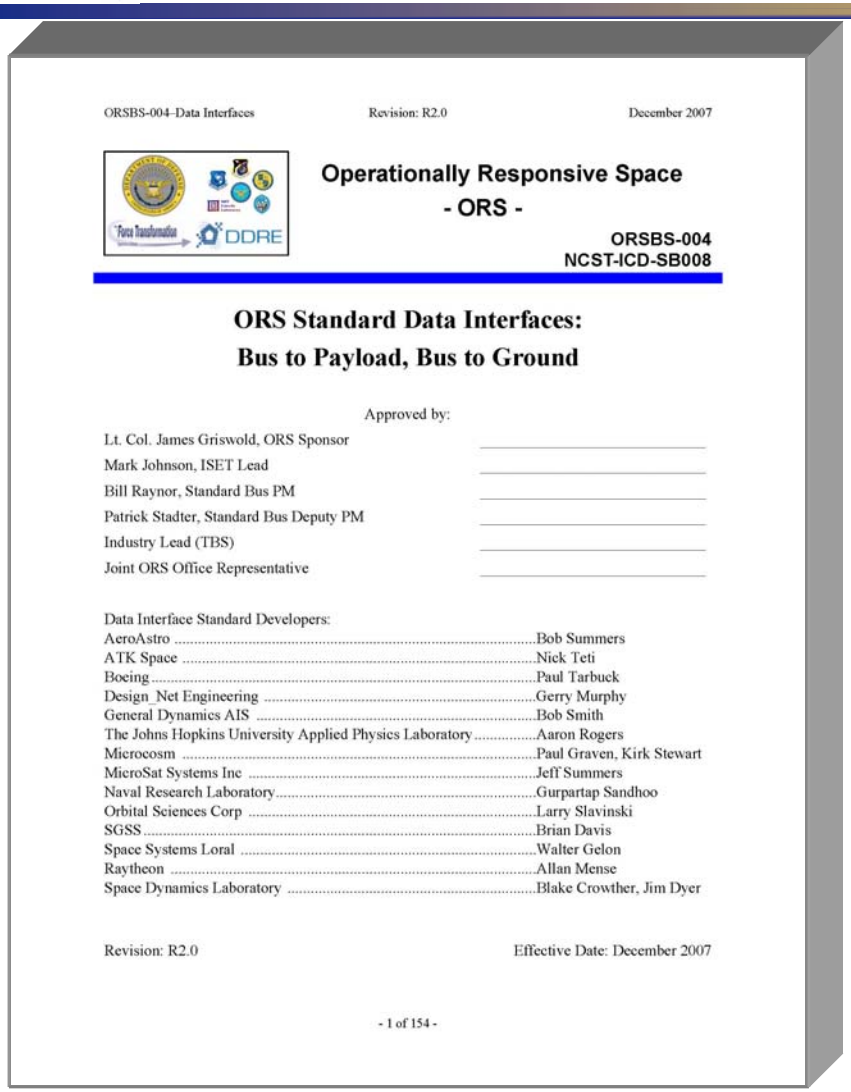
ORS Phase 3 Bus/Payload Interface Standards Top-Level Requirements

- Define an Operationally Responsive Space (ORS) Standard for the Bus/Payload Interface, Spacecraft/Ground Interface, and Spacecraft/Depot Interface
- Conform to CCSDS Recommended Standards - Formats and Protocols
- 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)
  - Both the Bus and the Payload Shall Be Ready for Bus/Payload Communications When in an Operational Mode
  - When The Bus or the Payload Are Not in an Operational Mode and Not Ready to Respond to Messages, the Other Device Will Utilize Response Timeouts to Determine Communications Status
  - Communications Can Be Established by the Bus or the Payload With the Issuance of Any Valid Telecommand or Telemetry Message

References

Document #	Revision	Title	Source
CCSDS 131.0-B-1	September 2003	TM Synchronization and Channel Coding	CCSDS
CCSDS 231.0-B-1	September 2003	TC Synchronization and Channel Coding	CCSDS
CCSDS 732.0-B-1	September 2003	AOS Space Data Link Protocol	CCSDS
CCSDS 232.0-B-1	September 2003	TC Space Data Link Protocol	CCSDS
CCSDS 133.0-B-1	September 2003	Space Packet protocol	CCSDS
CCSDS 301.0-B-3	January 2002	Time Code Formats	CCSDS
CCSDS 135.0-B-2	November 2005	Space Link Identifiers	CCSDS

Bus/Payload & Space/Ground SGLS Interface Standards – Status



ORSBS-004–Data Interfaces Revision: R2.0 December 2007

Operationally Responsive Space
- ORS -

ORSBS-004
NCST-ICD-SB008

ORS Standard Data Interfaces:
Bus to Payload, Bus to Ground

Approved by:

Lt. Col. James Griswold, ORS Sponsor _____
Mark Johnson, ISET Lead _____
Bill Raynor, Standard Bus PM _____
Patrick Stadter, Standard Bus Deputy PM _____
Industry Lead (TBS) _____
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Data Interface Standard Developers:

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SGSS	Brian Davis
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Space Dynamics Laboratory	Blake Crowther, Jim Dyer

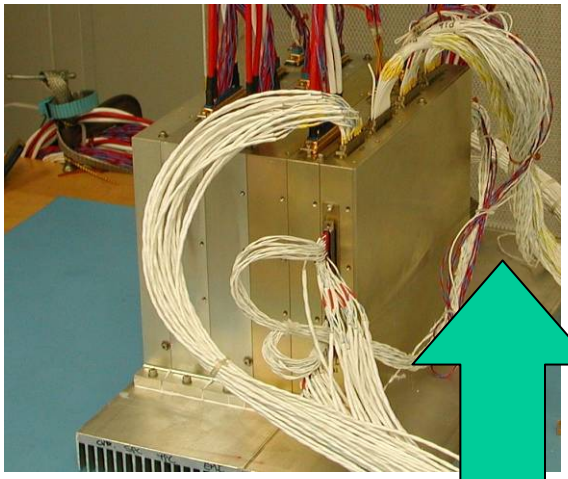
Revision: R2.0 Effective Date: December 2007

- 1 of 154 -

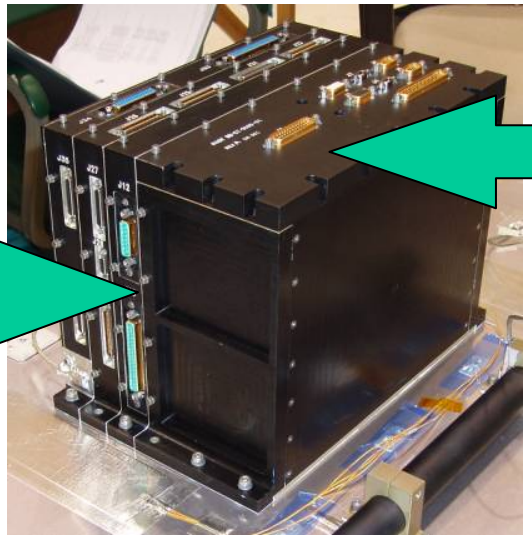
- The ORS Bus/Payload and Space/Ground SGLS Interface Standard Specification was Initiated as Part of the ORS Phase 3 Effort in February 2006
- The ORS Bus/Payload and Space/Ground Interface SGLS Standard Specification is Stable (Revision 2.0) and is Available as Part of the ORS Phase 3 Documentation Set
- These interface standards include:
  - Bus/Payload
    - Transport Protocol, Packet Structure, Published Message Exchange
  - Space/Ground
    - Transport Protocol, Packet Structure
- ORS Phase 3 (TACSAT-4) Bus and the COMMx payload have successfully implemented and tested this interface

ORS Phase 3 (TacSat-4) Interface Standards Implementation

COMMx Payload Interface Unit



ORS Phase 3 Bus SGLS Transponder



Bus/Payload IF

Space/Ground IF

ORS Phase 3 Bus CT&DH

ORS Bus/Payload and Space/Ground Interface Standardization - Status

- The Bus Vendor shall conform to the ORS Space/Ground Interface Control Document
- The Bus Vendor shall conform to the ORS Space/Ground Interface Control Document
- Interface Standardization
  - **Bus/Payload Transport:** **Defined by the ORS Bus Standards**
  - **Bus/Payload Published Message Exchange:** **Defined by the ORS Bus Standards**
  - **Bus/Payload Forward and Return Link Conduit:** **Defined by the ORS Bus Standards**
  - **Bus/Ground SGLS Transport:** **Defined by the ORS Bus Standards**
  - **Bus/Ground WTR Transport:** **Not Yet Defined – req Trade/Analysis**
  - **Payload/Ground SGLS Transport:** **Defined by the ORS Bus Standards**
  - **Payload/Ground WTR Transport:** **Not Yet Defined – req Trade/Analysis**
  - **Bus/Ground Standard Command Set:** **Concept Presented to ISET**
  - **Bus/Ground Standard Telemetry Set:** **Not Yet Defined – req Trade/Analysis**
  - **Bus/Ground Tasking Definition:** **Options Available – req Trade/Analysis**
  - **Bus/Ground Parameter Table Definitions:** **Not Yet Defined – req Trade/Analysis**
  - **Bus/Ground Log Content/Downlink ICD:** **Not Yet Defined – req Trade/Analysis**
  - **Bus/Ground Memory Load/Dump ICD:** **Not Yet Defined – req Trade/Analysis**
  - **Bus/Depot Forward and Return Link Interface:** **Not Yet Defined – req Trade/Analysis**
  - **Bus/Theater Forward and Return Link Interface:** **Not Yet Defined – req Trade/Analysis**

ORS Strategy

Expanding the Role of

Interface and Functional Standards

Spacecraft and Payload Characterization Historical Approach

- **Vendor Delivers Space Qualified HW With Build Acceptance Documentation, Operational Handbooks And Interface Control Documents.**
  - Data Products, When Available, Are Usually Limited To Command And Telemetry Packet And Field Definitions
- **SOC/MOC Develops The Additional Data Products And The Mission Unique Software Pertinent For The Operational C^2 System.**
  - This Approach Introduces Inefficiencies (I.E. Budget, Schedule, Risks) Due To The Need For Organizational Transfer of the Detailed Bus/Payload Technical Characteristics from the vendor to the operational organization
  - This is done by Reviewing Specifications and when Data Products are available they often require interpretation and transformation to operational formats

Spacecraft and Payload Characterization Recommended Approach

- **The Vendor *Still* Delivers Space Qualified HW With Build Acceptance Documentation, Operational Handbooks And Interface Control Documents.**

- ***In Addition,* the Vendor Provides Data And Procedural Deliverables Compliant With SOC/MOC External Interface Standards**

  – This Approach Will Minimize Inefficiencies And Promote The Use Of C^2 Budget For Enhancing Core Capabilities As Opposed To The Budget Being Applied To The Integration Efforts For New Missions.

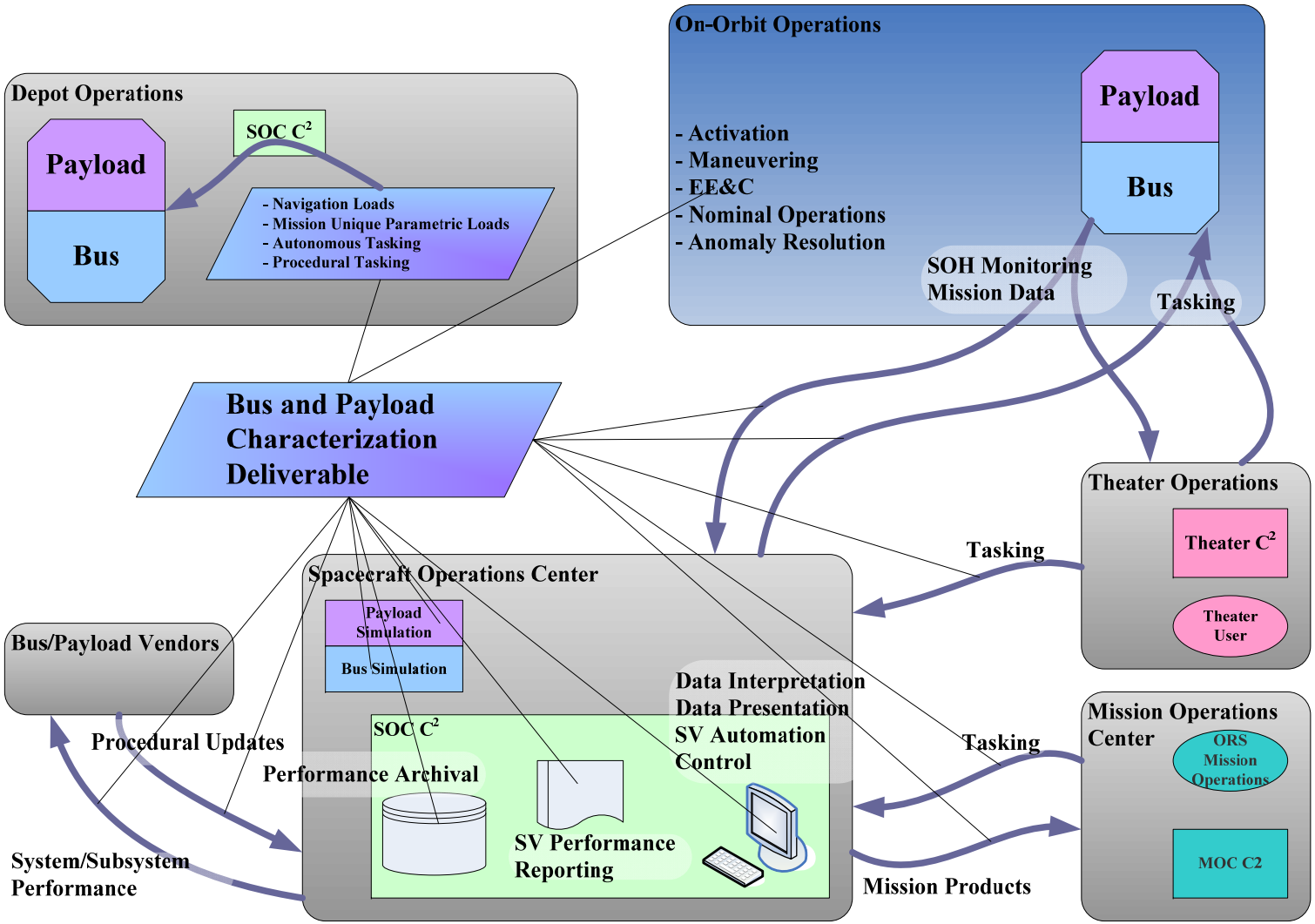
ORS Bus and Payload Vendor to SOC Interfaces Characterization Deliverables (1 of 3)

- The Characterization Deliverables Shall Fully Describe the Bus and Payload Interfaces, Control Methods and Behavior to the Spacecraft Operations Center and Mission Operations Center
- The Bus Vendor shall conform to the deliverable requirements in both content and format
- The Payload Vendor shall conform to the deliverable requirements in both content and format
- Formats
  - XML based deliverables is a viable format option for all data, procedural and documentation content deliverables
  - Simulation Deliverable could be HWIL or SW only

ORS Bus and Payload Vendor to SOC Interfaces Characterization Deliverables (2 of 3)

- **Data**
  - Command Packet Templates, Field Definitions, Field Constraints, and Instantiations
  - Telemetry Packet, Field Definitions and Field Constraints
  - Parametric Load Templates, Field Definitions, Field Constraints, and Instantiations
  - Spacecraft Component/Subsystem/System Hierarchy
  - Alphanumeric Displays
  - Trend Definitions
  - Reactive Graphics
  - Data Storage, Reduction and Analysis Requirements
- **Procedural**
  - Functional Command Verification
  - Derived Telemetry Processing
  - Vehicle state and mission phase dependent State of Health (SOH) checks
  - Configuration Audit
  - Codified Standard Operating Procedures
    - Pre-launch, Activation, Navigation & Stationkeeping, EE&C, Nominal Operations
  - Codified Anomaly Resolution Procedures
- **Models/Simulation**
  - Power, Thermal, and Control Models
  - Behavioral and Interface Simulation
- **Documentation**
  - Subsystem User Guides
  - Standard Operating Procedures
  - Mission Rules and Operational Constraints

ORS Bus and Payload Vendor to SOC Interfaces Characterization Deliverables (3 of 3)



C² (SOC) Architecture (1 of 3)

- **Open and Scalable Architecture**
  - Software Bus and Standardized Internal Interfaces
  - Distributed Architecture – Quickly adapts to changes in HW resources
  - Simultaneous Supports/Contacts, limited only by available HW resources (data path and processing limitations only - no software limitations)
  - Tiered Access – SOC, MOC, Theater, Vendor, Observer
    - Full Control Authority
    - Limited Control Authority
    - Full Monitoring Capability
    - Limited Monitoring Capability
  - Dedicated Client and Web Client Support – compliant with tiered access
  - Data Centric Driven and Dynamic Configuration Support for Constellation Configuration, Spacecraft Attributes, Payload Configurations, Ground System Software Configuration, Ground System Equipment Control, and External Interface Configuration

- **Emphasize Conformity to Interface Standards**
  - Bus/Ground
  - Payload/Ground
  - Bus & Payload Vendor/SOC – Vendor Deliverables, SOC Product Deliverables
  - SOC/MOC – MOC Tasking, Tasking Result Deliverables
  - SOC Theater - Theater Tasking, Tasking Result Deliverables
  - SOC Internals – Conform to Existing and/or Develop SOC Internal SW/SW and SW/HW interfaces

C² (SOC) Architecture (2 of 3)

- **Modular Functions**
  - Telemetry Acquisition, Decom, Distribution, Constraint Checks and Archival
  - Command Request, Formatting and Transmission
  - Efficient, Highly Reliable and Standardized Spacecraft Data Load and Download Protocol and associated standardized formats
  - Procedural Language autonomous ground control, operator initiated ops procedures and test procedures
  - Graphical User Interface
  - Ground Resource Management
  - Space Asset Contact Management
  - Autonomous Ground Operations
    - All nominal spacecraft operations handled automatically
    - Anticipated and Recoverable Anomalies handled automatically
    - Unanticipated or Non-recoverable anomalies generated tiered notifications
  - Spacecraft Navigation Tools (e.g. STK)
    - Orbit Determination
    - Orbit Maneuvering
  - Spacecraft Modeling
    - Power, Thermal, Delta-V, Reactive Attitude Control, Momentum Management, Payload Utilization, Payload FOV, ACS Sensor FOV

C² (SOC) Architecture (3 of 3)

- **Software Development Approach**
  - **Evolutionary Builds**
    - Continual Commitment to improving capabilities and responsiveness of the system
      - Build and Expand on generic and standarized capabilities
      - Minimize mission specific development
    - Incorporate Feedback from Program Office and End Users (Procurement, Mission Planners, Spacecraft Engineers, Operations Staff, Theater Users)
  - **Agile Software Development Approach – The Software Development Team Should:**
    - Have Extensive domain experience
    - Have A Supportive Program Office
    - Be motivated to provide cost effective and innovative solutions
    - Be committed to open and non-proprietary solutions and interface standards
  - **Broad Coverage and Automated Regression Testing**
    - Start the test program early and continually evolve the test program with the system
  - **Software Development Tools**
    - CM (e.g. Clearcase-Multisitge, CVS)
    - Actions/Defect Tracking (e.g. Clearquest, Bugzilla)
    - Static Analysis (e.g. Coverity)
    - Dynamic Analysis (e.g. Purify)
    - Performance Analysis (e.g. Quantify)
    - Test Analysis (e.g. PureCoverage)
    - Open Source Compilers/Debuggers
    - GUI Builders (e.g. QT)
    - SQL Database

SOC Interface and Component Standards (1 of 2)

- **ORS Phase 3 Bus/Payload and Bus/Ground Interface Control Document**
- **Spacecraft Definition**
  - XTCE (XML Telemetry and Command Exchange)
  - ORS Defined Vendor Deliverable as previously listed
- **Standardized C2 Components for ground equipment interfaces**
  - An example … Ground Equipment Monitoring Service (GEMS)
    - Proposal by Space Object Technology Ground to standardize the model for device control
    - GEMS – XML or ASCII
- **Spacecraft Operations C^2 Language – Some Example Trade Options:**
  - Metamodel As Proposed by Space Object Technology Group
  - Spacecraft Command Language - SCL
  - CGA Command Language – CCL

SOC Interface and Component Standards (2 of 2)

- **Standardized Tasking Definition**
  - Spacecraft Command Language – SCL

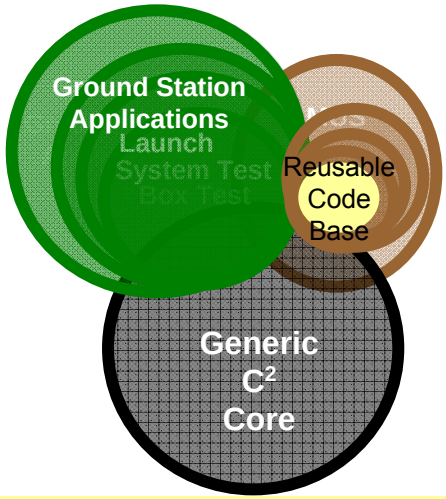
- **Standardized Modular Spacecraft C2 Systems**
  - Government Off-the-Shelf (GOTS)
    - Common Ground Architecture (CGA)
    - NASA ITOS – GOTS / Hammers ITOS COTS
  - Commercial Off-the-Shelf - examples
    - Remote Intelligent Monitoring System (RIMS)
    - Harris OS/COMET ®
    - Integral Systems – Epoch™
    - L-3 InControl ™
  - Reference Architecture (CORBA/IDL model) proposed by Space Object Technology Group in 2001
  - Well Established Domain Tools (e.g. Satellite Toolkit)
  - Open Source Operating System (e.g. Linux)

NRL's Blossom Point Tracking Facility Utilizes a Generic and Open C² System Development Approach is both Evolutionary and Agile

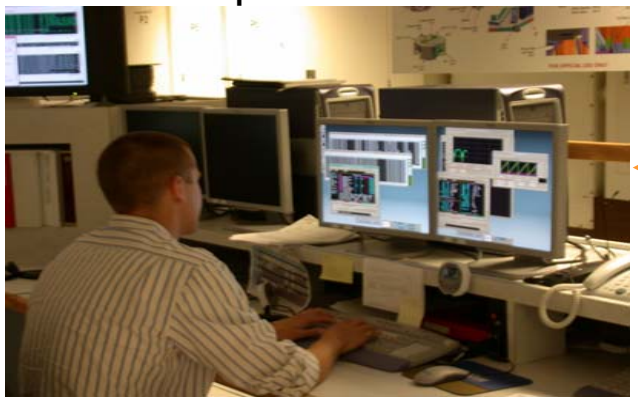
Box Level I&T

Satellite I&T

Launch Support



Operations



Blossom Point has a long standing and proven record as a Highly Responsive and Reliable SOC

ORS Simulation Approach

- **High Fidelity Bus Simulator from Bus Vendor**
  - Software Only and/or Hardware in the Loop (HWIL)
  - Mission Ops Procedure Development, Spacecraft Ops Procedure Development, Training, SOC Compatibility Testing, Anomaly Resolution Procedure Development
- **High Fidelity Payload Simulator from Payload Vendor**
  - Software Only and/or HWIL
  - Mission Ops Procedure Development, Spacecraft Ops Procedure Development, Training, SOC Compatibility Testing, Anomaly Resolution Procedure Development
- **ORS Bus Simulator, ORS GFE to Payload Vendors**
  - Flight Equivalent Mechanical, Electrical and Data Interfaces
  - "Gold" Standard for Payload to Bus Interface Validation and Acceptance
- **ORS Payload Simulator, ORS GFE to Bus Vendors**
  - Flight Equivalent Mechanical, Electrical and Data Interfaces
  - "Gold" Standard for Payload to Bus Interface Validation and Acceptance
- **High Fidelity SOC Ground Equipment Simulation**
  - Provide high fidelity simulation for SOC development, test, and training activities

ORS Concept

Introducing an Integrated

ORS / Vendor Build Approch

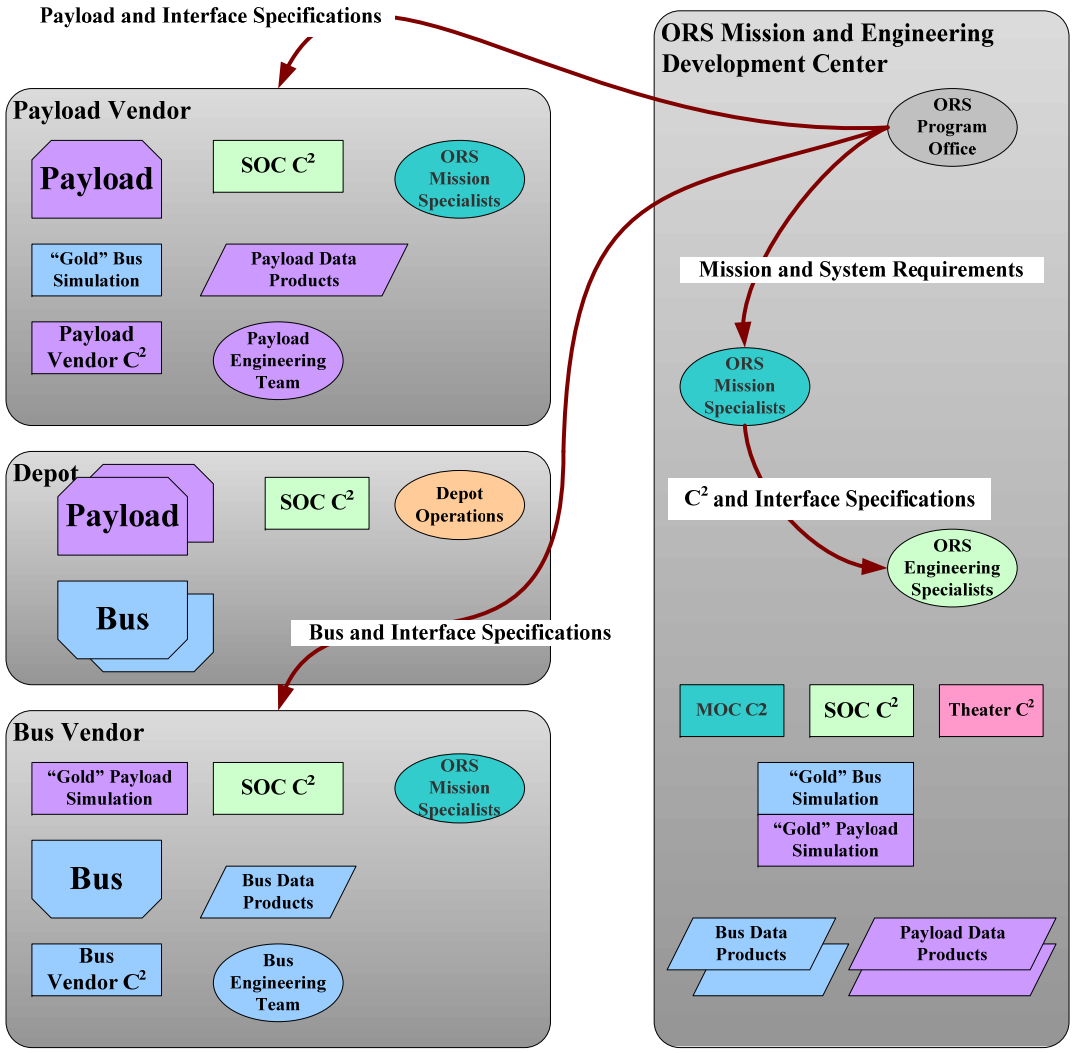
Integrated Bus, Payload and C² Build Approach

- **Continue The Government/Industry Integrated and Iterative Approach for Specification Flow Down and Specification Feedback**

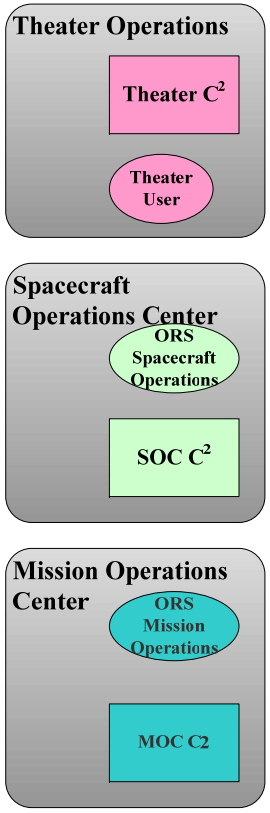
- **Sponsor and Promote "Mission Specialists" Cadre**
  - Programmatic, System Engineering and Engineering Specialists
    - Application and Assessment of Bus and Payload Specifications
    - Vendor Onsite Support – Parallel Efforts with the Build
      - Requirements and Interface Compliance Verification
      - Aides and Contributes to Bus & Payload Data Product Deliverables
      - Confirms ORS C² System Integration
      - Develops Engineering and Mission Operations Procedures
      - Specification Feedback
    - ORS C² Specification Compliance and Build Oversight
    - ORS "Gold" Standard Simulation Build Oversight
    - Mission Design, Implementation and Deployment

- **Utilize Highly Automated C² Systems**
  - Operations Cadre can Focus on
    - Improving Tactical Mission Operations
    - Anomaly Resolution
    - C2 Specification Feedback

Specification Flow Down

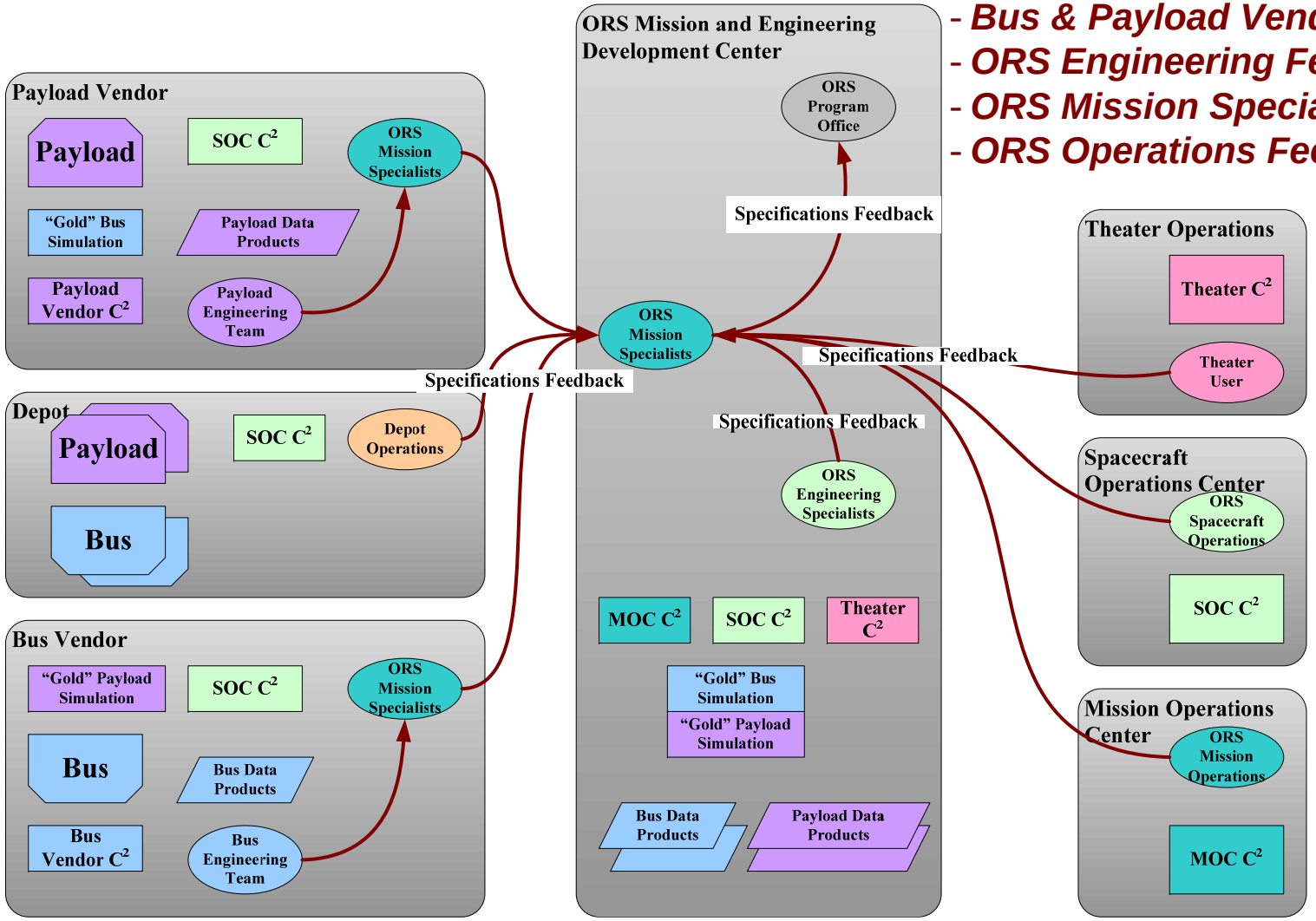


- *Payload Specifications*
- *Bus Specifications*
- *Interface Specifications*
- *C2 Specifications*

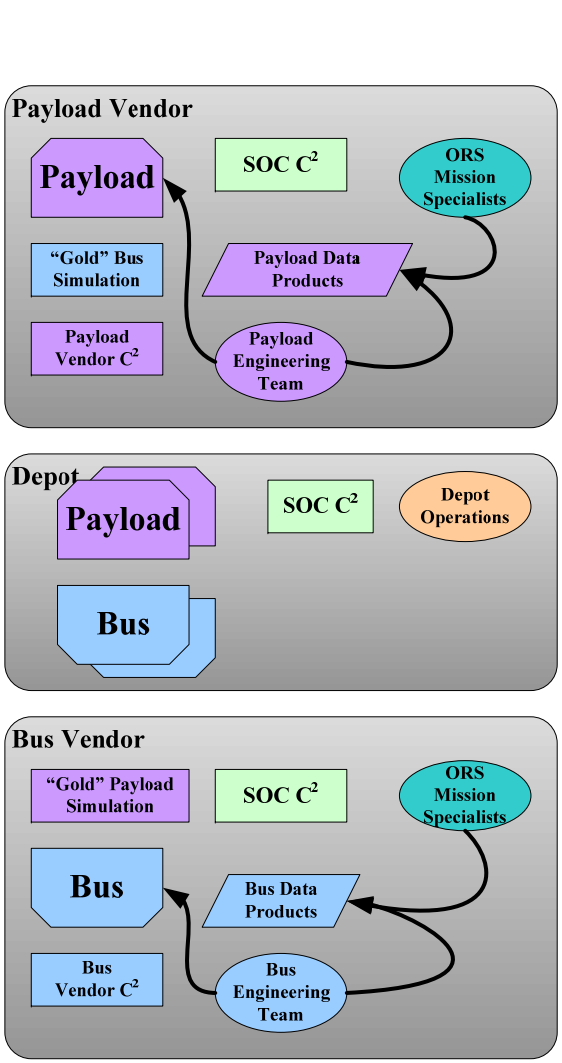


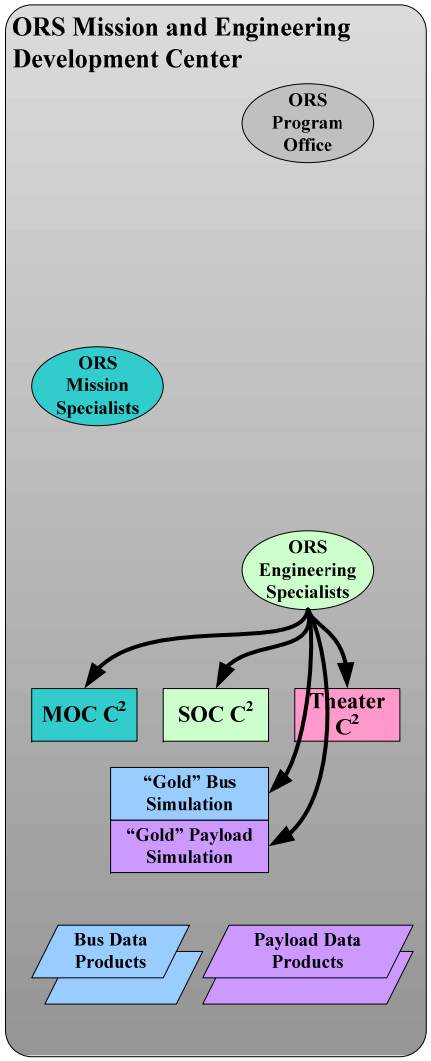
Specification Feedback

- *Bus & Payload Vendor Feedback*
- *ORS Engineering Feedback*
- *ORS Mission Specialists Feedback*
- *ORS Operations Feedback*

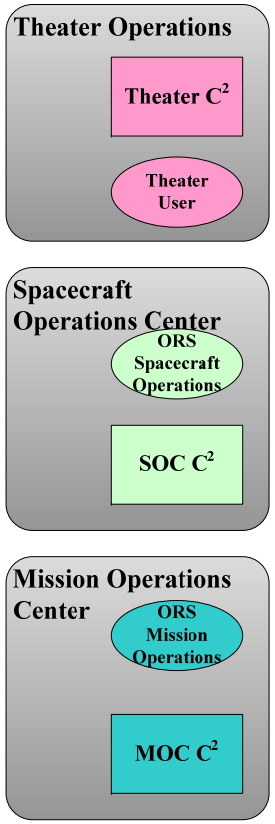


Component Builds

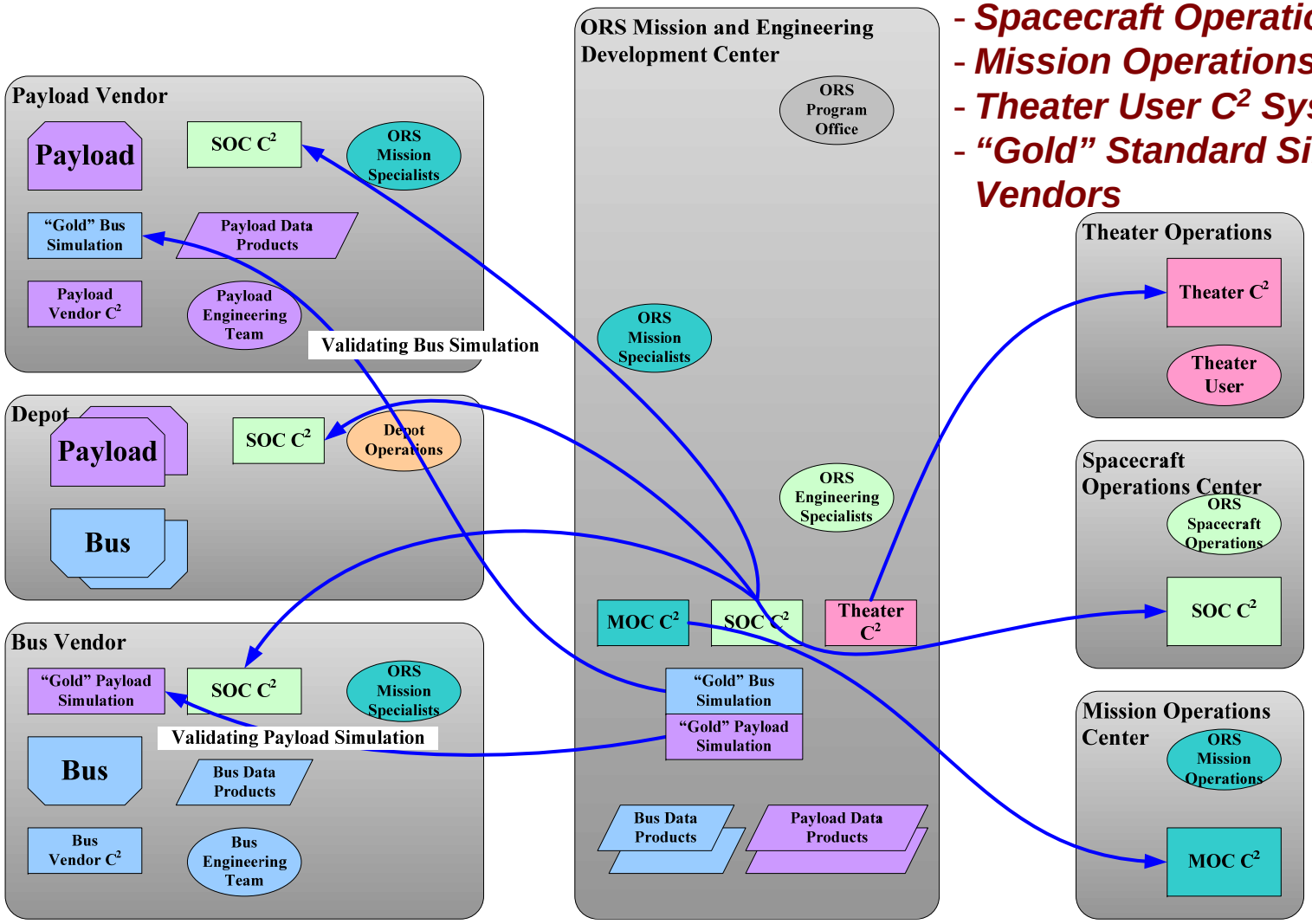




- *Payload and Buses*
- *Joint ORS/Vendor Data Products*
- *ORS C² Systems*
- *"Gold" Phase 3 Bus/Payload SimulatORS*



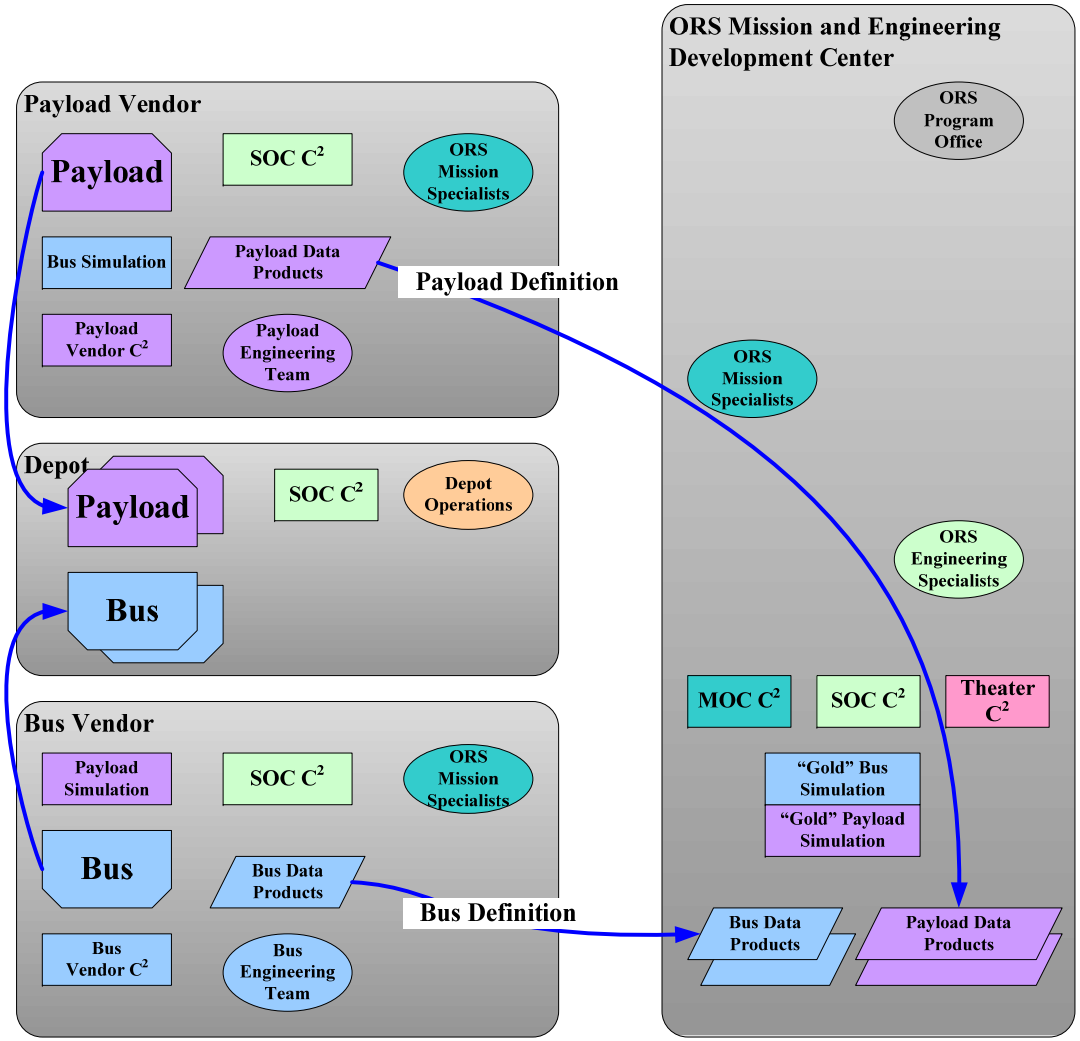
Development Center Deliverables

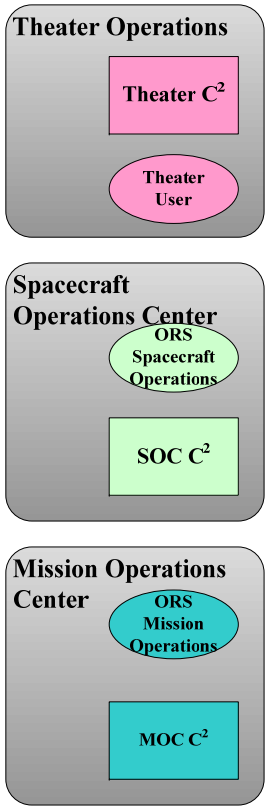


- *Spacecraft Operations C² System*
- *Mission Operations C² System*
- *Theater User C² System*
- *"Gold" Standard SimulatORS to Vendors*

Vendor Deliverables

- *Spacecraft Buses to Depot*
- *Payloads to Depot*
- *S/C Bus Definition Data Products*
- *Payload Definition Data Products*





Recommendations

Integrated Approach – Recommendations (1 of 3)

- **Invest In Selecting And/Or Developing Interface Standards**
  - **These Are Key Enabling Activities For ORS**
  - **Prioritize On Establishing Interface Standards**
    - **Processing (I.E. C^2) Must Conform**
    - **Reduces Proprietary Lock-ins**
    - **Fosters Competition, Options, And Modularity**
    - **Enables Interoperability, Responsiveness, And Adaptability**

Integrated Approach – Recommendations (2 of 3)

- **Specifications Are Now Available For Bus Procurement And Payload Conformance**
  - Follow-up By Investing The Effort To Define The Specifications For Standardized Characterization Deliverables
  - Levy These Requirements On Both The Bus And Payload Vendors

- **Adopt Standardized External Interfaces for the SOC/MOC C^2 System**
  - Take full advantage of the Standardized Characteristics from the Bus and Payload Vendors
  - Improve the Portability and Scalability of the C^2 System

- **Establish a non-Proprietary, Generic and Open Architecture C^2 Based SOC and MOC**
  - Minimize the Development of Mission Unique Software
  - Foster and evolutionary, modular, and agile development approach to enhance core capabilities while reducing mission integration cost and schedule requirements

Integrated Approach – Recommendations (3 of 3)

- **Establish And Enforce Early And Hands-on Activities For ORS Mission Specialists**
- **Introduction Of SOC Integration At The Bus And Payload Factories**
- **Establish a Process for a Joint Technical Effort Between the Vendor and ORS Office for the Build Of Characterization Deliverables**
  - **This Will Help Ensure Vendor Compliance With Specifications**
  - **This will Enable a Parallel Build Of Engineering And Mission Tasking**
    - **For Both Autonomous And User Specified Tasking**
  - **This Will Introduce An Early And Continual Integration With SOC**
  - **This Will Enable Close Coordination Between the Vendors And The ORS Program Office And ORS Based Engineering Efforts**
    - **Enables An Iterative, Responsive And Adaptive Environment**