NASA’s Exploration Initiative: Retooling the Approach to Mission Systems

Ground Systems Architecture Workshop 2007

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Exploration’s Constellation Evolution

♦ **Initial ISS Capability**
  - Ares Crew Launch Vehicles (CLV)
  - Orion Crew Exploration Vehicles (CEV)
  - International Space Station (ISS)

♦ **Lunar Sortie & Outpost Buildup**
  - Cargo Launch Vehicles (CaLV)
  - Earth Departure Stage (EDS)
  - Lunar Surface Access Module (LSAM)
  - EVA crewmembers
  - Unpressurized rovers
  - Habitation modules
  - Robotic rovers
  - Power Stations
  - Science instruments
  - Logistics carriers
  - Communications relay satellites terminals
  - Regolith Movers
  - Pressurized rovers
  - In-Situ Resource Units (O2 from Regolith)
Exploration Challenges

♦ Initial ISS Capability
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♦ Key Challenges for Exploration
  • Ever Growing Complexity
  • Operations Costs
  • Life Cycle Costs
  • Flexibility to Support Broad Scope of Activities

♦ Key Focus Areas
  • Commonality
  • Interoperability
  • Flexibility
  • Evolvability

♦ Retooling Mission Systems
  • Support simultaneous operations of multiple, diverse systems
  • Support increasing automation
  • Support migration of functions from ground to lunar base
C3I Overview
Command, Control, Communications, & Information

♦ Network-Centric Architecture
  • **IP based** network throughout.
  • Leverage wide range of tools, software, hardware, protocols.
  • **Open standards** & established interfaces.
  • Very flexible & extensible.
  • Enables open architecture that can evolve.
  • Requires architecture be established **across all Cx systems**.

Wide area network connections can be via terrestrial infrastructure, umbilical hard-lines, or wireless (RF) links. Systems act as network nodes that route and relay traffic (as in a mesh network).

♦ C3I Approach
  • C3I fundamentally **cuts across all systems** and must function as a “single system” (different from most systems which partition more along physical lines).
  • Historically, communications, networks, command and control, security, and information systems were **designed and developed separately**.
  • Legacy systems optimized for given vehicle/mission vs. Cx systems which must **accommodate multiple systems/vehicles** AND be flexible to exploration style operations.
C3I Overview

♦ Layered approach
  - Isolates change impacts (enabling evolution)
  - Based on industry standards.
  - Includes publish & subscribe messaging framework (enabling plug-n-play applications by establishing well defined data interfaces).

♦ Interoperability
  - Focus on standards and approaches that enable interoperability between systems.
  - Establish small set of interface standards & reduce possible number of interface combinations.
  - Requires interoperability at all layers: communications, networks, security, C2, and information.

Publish & subscribe based framework abstracts communications and inter-application interfaces. It also enforces a consistent data model, any required security, and limited application interfaces.
C3I Interoperability Specification Scope

- Interoperability Specification only deals with the interfaces and protocols at the element interface, NOT the internal (application, API) interfaces.

Note: For future Cx configurations, the C3I architecture will evolve to include increased C2 interoperability.
C3I Architecture Phasing Summary

- **Orion to ISS** (common interfaces)
  - Common communications frequencies, formats, & protocols
  - IP network based command, telemetry, voice, video, and files.
  - Static network routing.

- **Lunar Sortie** (common systems)
  - Common ground control systems based on common C3I Framework and Cmd/Ctrl components (software)
  - Common communications adapter product line
  - Limited dynamic network routing.
  - Limited C3I Framework based flight software.

- **Lunar Outpost** (common adaptive systems)
  - C3I Framework based flight software.
  - Dynamic network routing.
  - Adaptive, demand-driven communications.
  - Disruption/Delay Tolerant Networking (DTN)
Constellation C3I Activities

♦ Constellation C3I Architecture activities are led out of the Computing Systems & Interoperability (CSI) Systems Integration Group as part of the program’s Systems Engineering & Integration team.

- Multi-Center team
- Includes involvement of all projects (Orion Crew Exploration Vehicle (CEV), Ares Crew Launch Vehicle (CLV), etc.)
- Developing products to support architecture buildup
  - Architecture definition
  - Requirements & Standards
  - Ops Concept development
  - Trades & Analysis

♦ Currently working towards the Program SDR.

♦ Work is starting on Lunar Architecture.
Questions?
### Acronyms

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<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>API</td>
<td>Application Programming Interface</td>
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<tr>
<td>C2</td>
<td>Command and Control</td>
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<tr>
<td>C3I</td>
<td>Communications, Command, Control and Information</td>
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<td>CaLV</td>
<td>Cargo Launch Vehicle</td>
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<td>CEV</td>
<td>Crew Exploration Vehicle</td>
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<td>CSI</td>
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<td>Cx</td>
<td>NASA's Constellation Program</td>
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<td>DTN</td>
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<td>EDS</td>
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<td>EVA</td>
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<td>Goddard Space Flight Center</td>
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<td>IP</td>
<td>Internet Protocol</td>
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<td>ISS</td>
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<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
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<td>O2</td>
<td>Oxygen</td>
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<tr>
<td>TCP</td>
<td>Transmission Control Protocol</td>
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<td>RF</td>
<td>Radio Frequency</td>
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<td>Space Communications Protocol Standards</td>
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<td>SDR</td>
<td>System Design Review</td>
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