



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

Ground Systems Architecture Workshop 2007

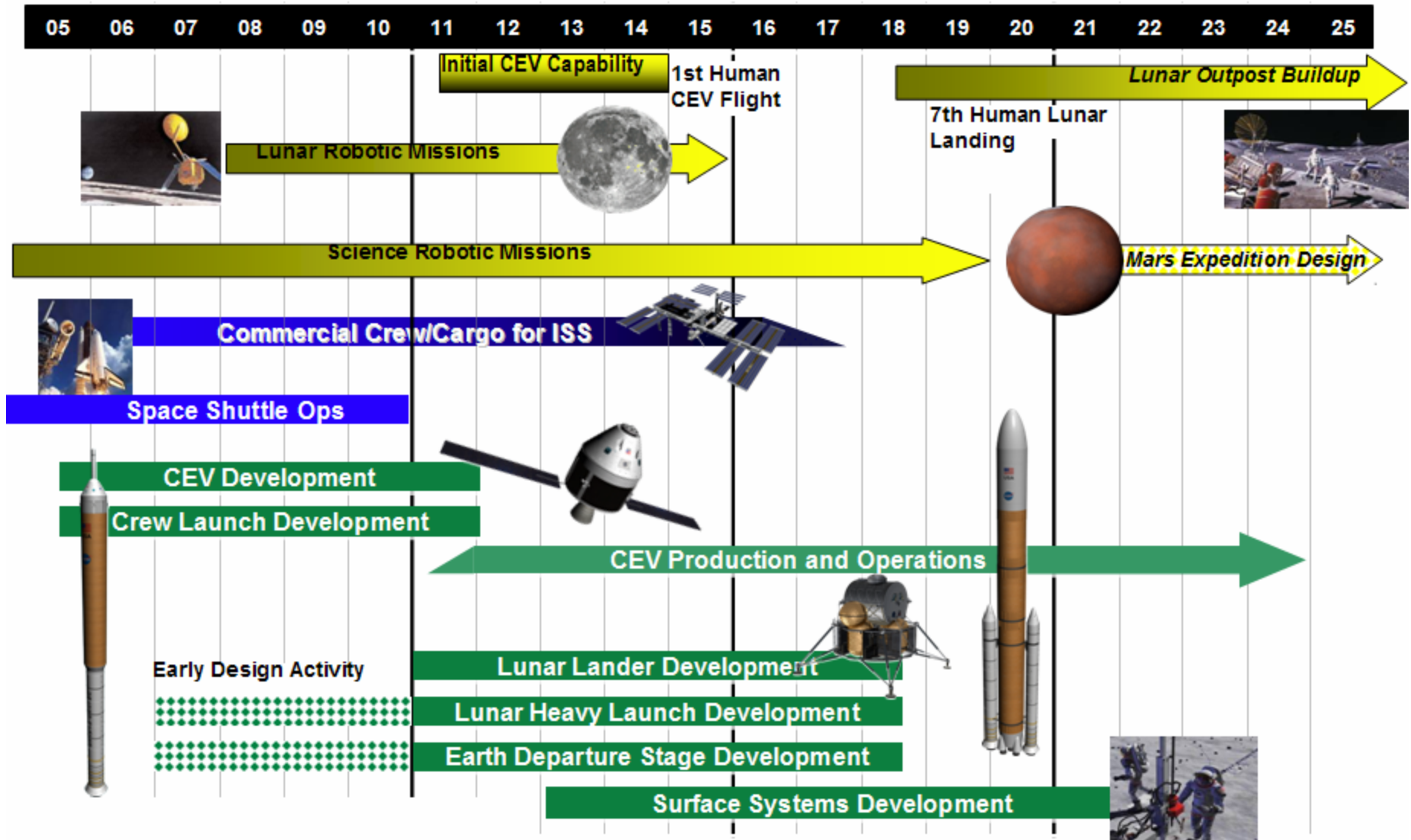
February 28, 2007



**JSC/Steve Rader
GSFC/Dan Smith**

CONSTELLATION

NASA's Exploration Roadmap



Exploration's Constellation Evolution

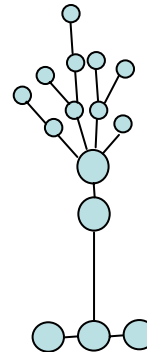
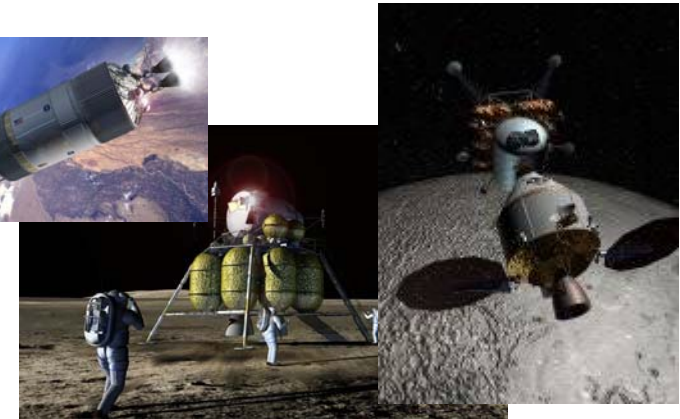
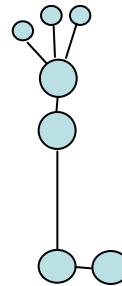
◆ Initial ISS Capability

- 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

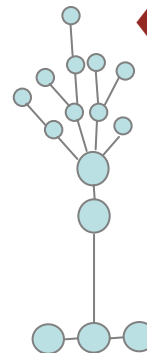
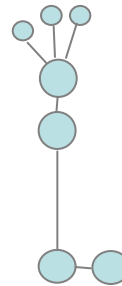
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◆ Key Challenges for Exploration

- 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

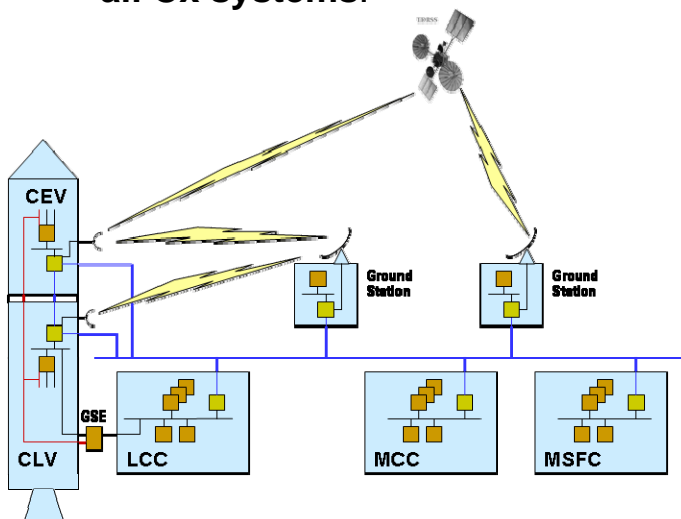
- Support simultaneous operations of multiple, diverse systems
- Support increasing automation
- Support migration of functions from ground to lunar base

C3I Overview

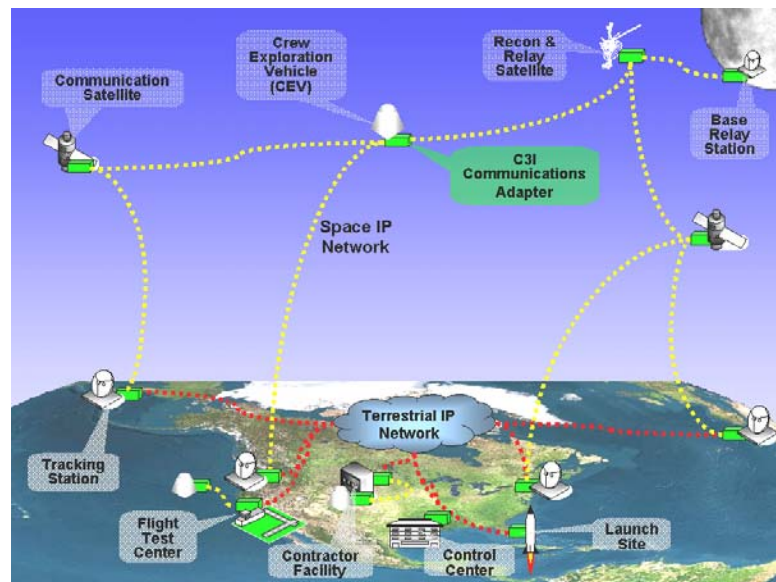
Command, Control, Communications, & Information

◆ 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**.

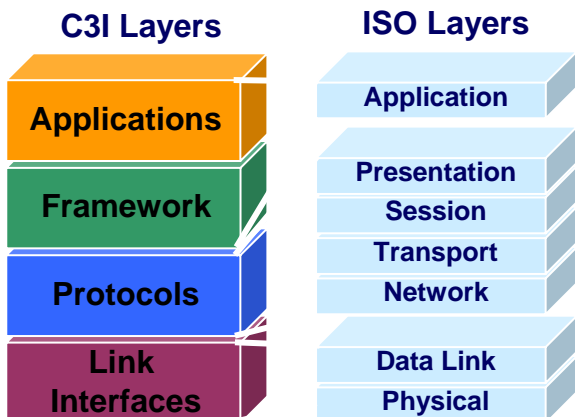


Wide area network connections can be via terrestrial infrastructure, umbilical hard-lines, or wireless (RF) links. Systems act as network nodes that route and relay traffic (as in a mesh network).



◆ 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**.

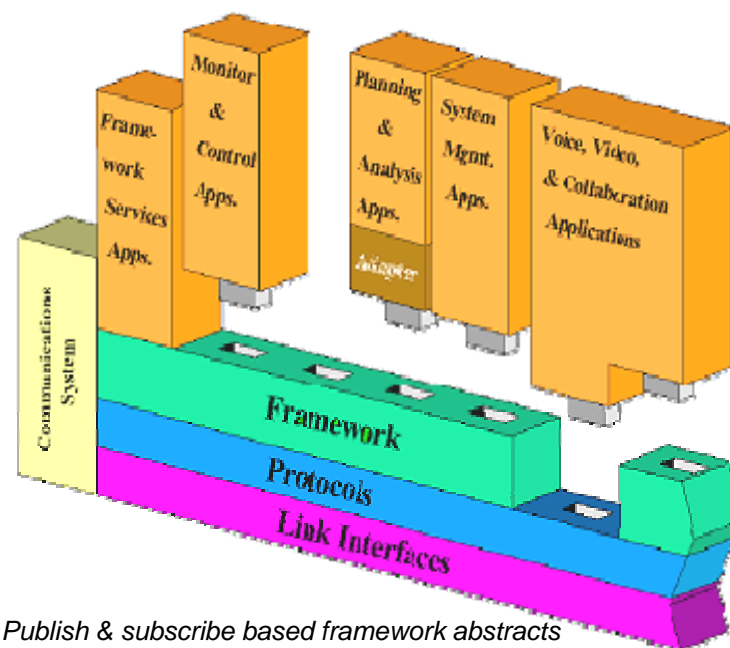


◆ Layered approach

- 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

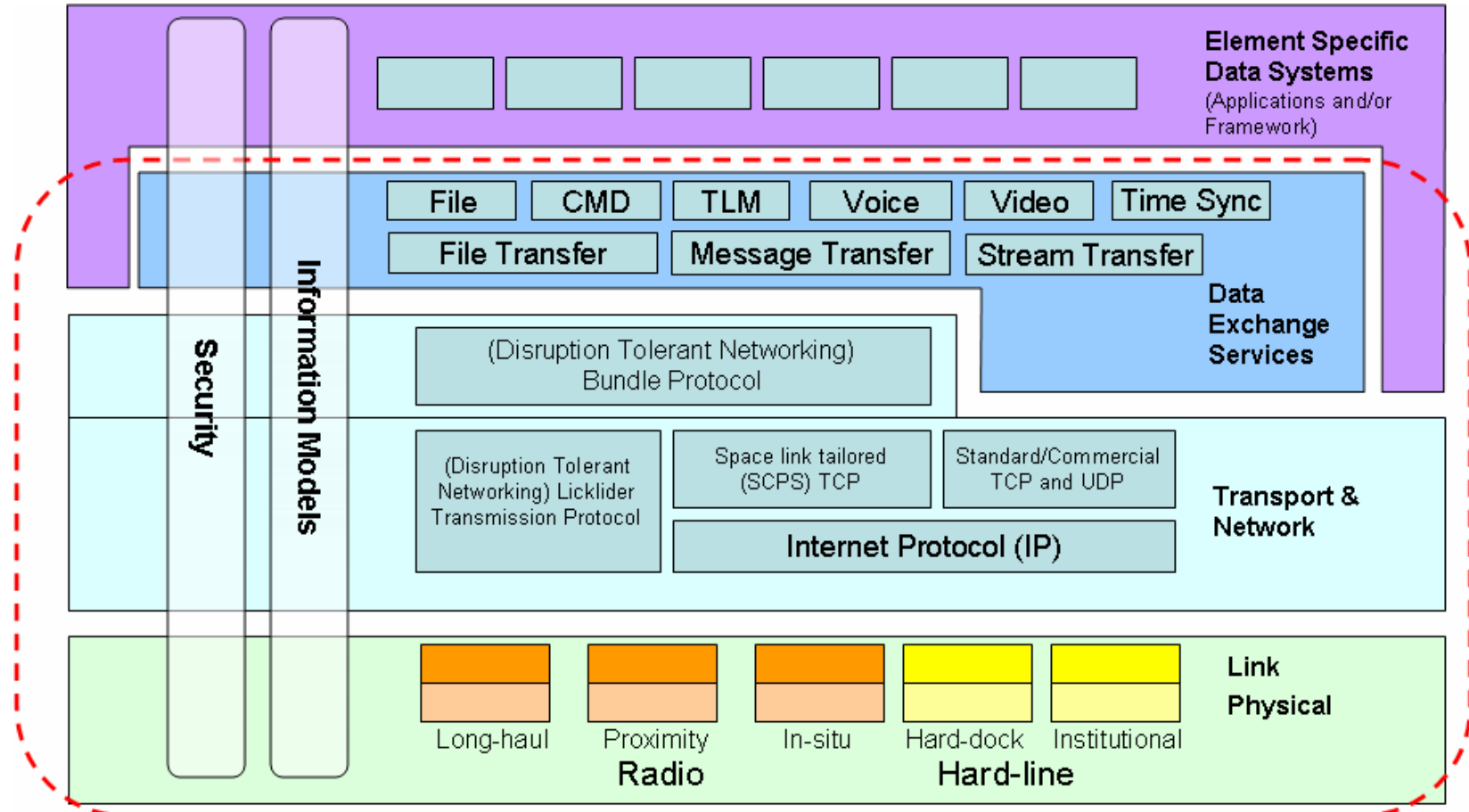
- Focus on standards and approaches that enable interoperability between systems.
- Establish small set of interface standards & reduce possible number of interface combinations.
- Requires interoperability at all layers: communications, networks, security, C2, and information.



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.

Scope of the C3I Interoperability Specification

C3I Architecture Phasing Summary

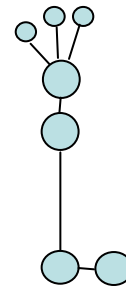
- **Orion to ISS (common interfaces)**

- Common communications frequencies, formats, & protocols
- IP network based command, telemetry, voice, video, and files.
- Static network routing.



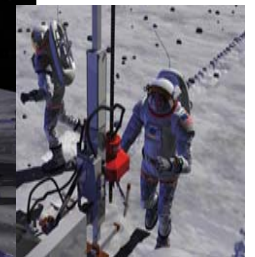
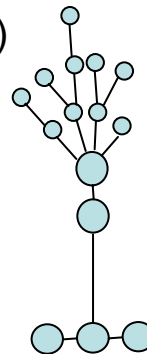
- **Lunar Sortie (common systems)**

- 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.**

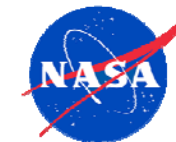
- ◆ **Work is starting on Lunar Architecture.**



Questions?



Acronyms



API	Application Programming Interface
C2	Command and Control
C3I	Communications, Command, Control and Information
CaLV	Cargo Launch Vehicle
CEV	Crew Exploration Vehicle
CLV	Crew Launch Vehicle
CMD	Command
CSI	Computing Systems & Interoperability
Cx	NASA's Constellation Program
DTN	Disruption/Delay Tolerant Networking
EDS	Earth Departure Stage
EVA	Extra-Vehicular Activity
GSAW	Ground System Architectures Workshop
GSFC	Goddard Space Flight Center
IP	Internet Protocol
ISS	International Space Station
JSC	Johnson Space Center
LCC	Launch Control Center
LSAM	Lunar Surface Access Module
MCC	Mission Control Center
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
O2	Oxygen
TCP	Transmission Control Protocol
RF	Radio Frequency
SCPS	Space Communications Protocol Standards
SDR	System Design Review
TLM	Telemetry
UDP	User Datagram Protocol