National Aeronautics and
Space Administration

CxP 70022-01

BASELINE

RELEASE DATE: DECEMBER 18, 2006

CONSTELLATION PROGRAM COMMAND, CONTROL, COMMUNICATION, AND INFORMATION (C3I) INTEROPERABILITY STANDARDS BOOK, VOLUME 1: INTEROPERABILITY SPECIFICATION

ADL: The applicable and reference documents listed in this document may not have been developed from the approved Program ADL listing. Please review the approved ADL before use. (Reference: CxP 70013, Constellation Program Systems Engineering Management Plan, dated 8/31/06.)

Glossary: The terms within this Glossary may not have been developed from the approved Program Glossary. Please review the approved Program Glossary prior to use. (Reference: CxP 70072-ANX01, Constellation Program Management Systems Plan, Annex 1: Common Glossary and Acronyms, December 4, 2006 version dropped for baseline.) These listings will be validated by Program Baseline Re-sync.

Acronyms: The terms within this Acronyms listing may not have been developed from the approved Program Acronym list. Please review the approved Acronym list prior to use. (Reference: CxP 70072-ANX01, December 4, 2006 version dropped for baseline.) These listings will be validated by Program Re-sync.

The electronic version is the official approved document.
Verify this is the correct version before use.

REVISION AND HISTORY PAGE

Status	Revision No.	Change No.	Description	Release Date
Baseline	-		Baseline (Reference CxCBD C000100/1-1, dated 12/14/06)	12/18/06

NOTE: Updates to this document, as released by numbered changes (Change XXX), are identified by a black bar on the right margin.

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1 INTRODUCTION

1.1 PURPOSE

The Command, Control, Communications and Information (C3I) ARCHITECTURE provides the functional and performance requirements necessary to implement Constellation's interoperable Command, Control, Communication, and Information (C3I) vision. This specification states how Constellation SYSTEMS must interface to ensure command and control interoperability between SYSTEMS. This specification also provides a definition of interoperability requirements between Constellation SYSTEMS and other external SYSTEMS, such as the Space Network and other various communications and tracking networks.
The Command, Control, Communications and Information (C3I) ARCHITECTURE intends to provide interoperable information systems focused on the support of Constellation missions. C3I encompasses the technologies of communications, distributed information systems, command and control, decision support, and information operations and includes technology exchange, collaborative development, analysis and evaluation through systems development

1.2 SCOPE

This specification includes the requirements to ensure interoperability between Constellation SYSTEMS for command, control, communications, and information. The following sections define these terms and thus the scope of the specification. The CxP 70072 Management Systems Plan, Annex 02 - Doc, Spec, Product Trees provides the Constellation Program Requirements Document Tree that shows the location of this specification relative to other requirements documents.

1.2.1 Interoperability

Interoperability is defined (based on IEEE 90) as the ability for two or more SYSTEMS to exchange information and to use the information that has been exchanged. For Constellation, C3I interoperability includes the common mechanisms for communicating between SYSTEMS, as well as the common information structure and language necessary for SYSTEMS to perform appropriate COMMAND and control functions using the information exchanged.

1.2.2 Constellation Systems

The Constellation Program consists of multiple SYSTEMS. The SYSTEMS used by the crew consist of the CEV, the Lunar Surface Access Module (LSAM), the Suit Systems (EVA) and Flight Crew Equipment. In the future, the Mars Transfer Vehicle (MTV) and the Mars Descent Ascent Vehicle (DAV) will be added to the active program. The launch vehicles include the Crew Launch Vehicle (CLV) and the Cargo Launch Vehicle (CaLV). The common support SYSTEMS consist of the Mission Operations and Ground Operations SYSTEMS. Finally the destination surface SYSTEMS consist of the habitat, surface mobility, power systems, robotic SYSTEMS and resource utilization. Significant external interfaces to the Program include the Communication and Tracking (C&T) Networks and the International Space Station (ISS).

1.3 CHANGE AUTHORITY/RESPONSIBILITY

This specification will be a configuration controlled document maintained by the Constellation Program Office's Systems Engineering and Integration (SE&I) C3I Systems Integration Group (SIG), which includes membership from each Constellation SYSTEM as well as Constellation Program Office stakeholders. Any changes in the document will be approved by that same group and controlled by revision level. Given the schedule for initial SYSTEMS, the specification is expected to evolve over time, with initial focus on providing very flexible, basic interoperability building blocks. As the architecture, SYSTEMS and new technology mature, it is expected that additions and improvements will be made to the specification.

1.4 APPLICATION OF THE SPECIFICATION

This specification is applicable to all Constellation SYSTEMS. However, not all SYSTEMS require the same functionality due to their role in the larger Constellation ARCHITECTURE. For this reason, the specification is organized such that functional interfaces are applied consistently across many different SYSTEMS. This approach allows Constellation to 1) minimize unique interface definition / implementation and 2) maximize the potential for interoperability.

The application of the specification to the individual Constellation SYSTEMS is captured in the Constellation Architecture Requirements Document (CARD) and Interface Requirement Documents (IRD) by calling out the specific sections of the C3I Interoperability Specification that apply for a given function or interface. This approach ensures that the specification is applied based on required functions and interfaces. For example, the C3I specification defines how hard-line interfaces are consistently provided between SYSTEMS. SYSTEMS not needing hard-line interfaces to other SYSTEMS would not include CARD or IRD callouts to the C3I Interoperability Specification's hard-line section. This process takes into account the need to balance: 1) SYSTEM specific capabilities, 2) Constellation-wide ARCHITECTURE concerns (communications, security, COMMAND and control, etc.), and
3) project phasing and evolution drivers.

Specific applicability for each SYSTEM of the requirements in this specification is captured in the SYSTEM Applicability Matrices in Appendix E. Additionally, program phasing of the specification requirements is noted in Appendix D. These matrices provide high level rationale for why each section of requirements is applicable or not applicable. These tables are developed and maintained at Level 2 by the C3I SIG with participation by each of the projects. CARD and IRD callouts are also developed and managed through the C3I SIG which provides programmatic architecture control to enforce all aspects of the specification that affect multiple SYSTEMS (i.e., ensuring that SYSTEMS on both ends of a long-haul link implement the high data rate or low data rate long-haul portion of the specification). Note that Level 3 projects are responsible for developing the details of their SYSTEM designs and applying this specification via appropriate SRD requirements (or lower) and ICD requirements.

1.5 BACKGROUND AND RATIONALE

NASA's Exploration Systems Mission Directorate (ESMD) is pursuing an aggressive expansion of human space flight beyond low Earth orbit (LEO), including missions to the Moon and eventually to Mars. These missions will be different from previous NASA campaigns, in that the number of simultaneously interacting space and ground systems will be larger, and SYSTEMS will need to coordinate with each other both to achieve their science objectives and to accomplish the 'routine' mechanics of mission operations. The interaction between combinations of these SYSTEMS is important. Since the combinations of n SYSTEMS is governed by $n \times (n - 1) / 2$ interfaces, three SYSTEMS would mean just three interfaces. However, five SYSTEMS would translate into 10 interfaces and 10 SYSTEMS would mean 45 interfaces. For C3I related exchange functions between SYSTEMS, unique interfaces between SYSTEMS would be very expensive to implement, maintain, and operate. Additionally, the complexity of managing and operating large numbers of unique interfaces also increases safety and reliability risks. Use of a common interface specification or approach for implementing the interfaces between SYSTEMS is perhaps the most obvious way to mitigate these risks and reduce costs. This common interface specification must balance the range of potentially unique capabilities required to support the various SYSTEMS and interfaces, with the fewest number of options (since each option adds complexity, cost, and potential for interface incompatibility). Additionally, the common interface specification must allow for the flexibility, evolvability, and scalability requirements that accompany a long term campaign. Note that commonality between communications links does increase the hazard of common mode failure points, and that where redundant communication loops are provided effort should be made to decrease the commonality of the technology used to provide the redundant loop.

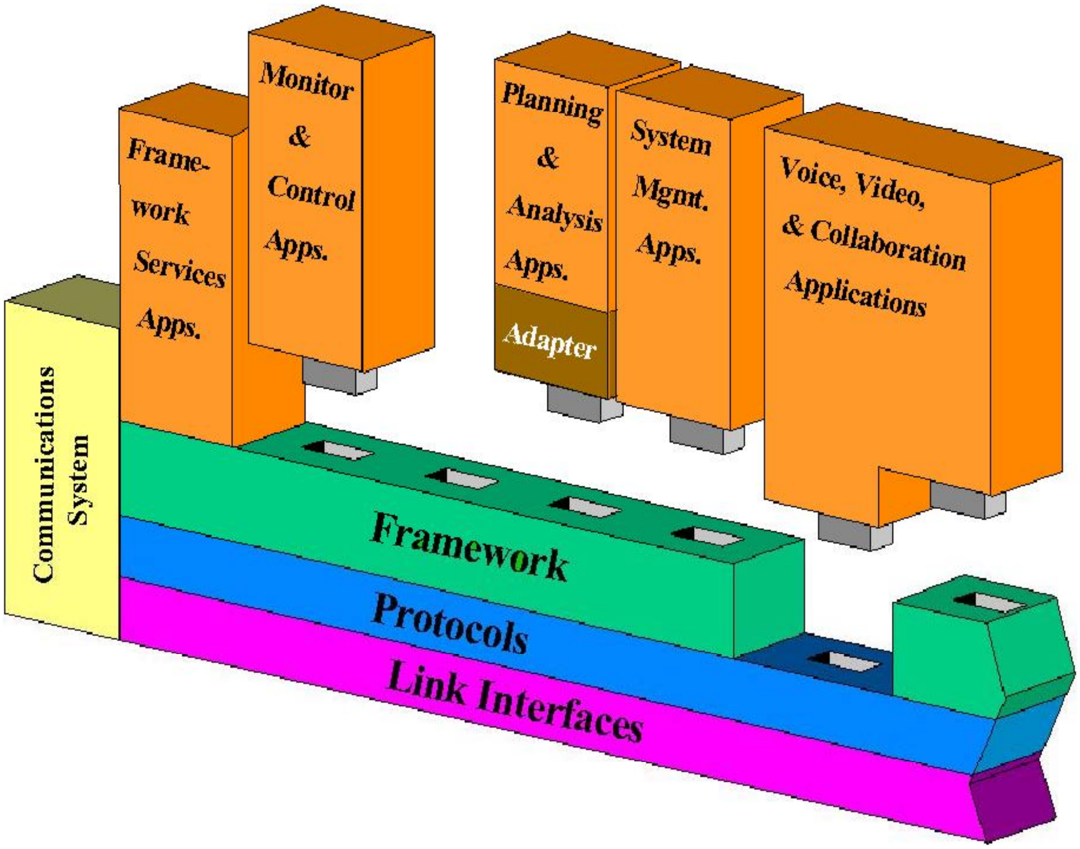

Figure 1.5-1 - C3I Framework Structure

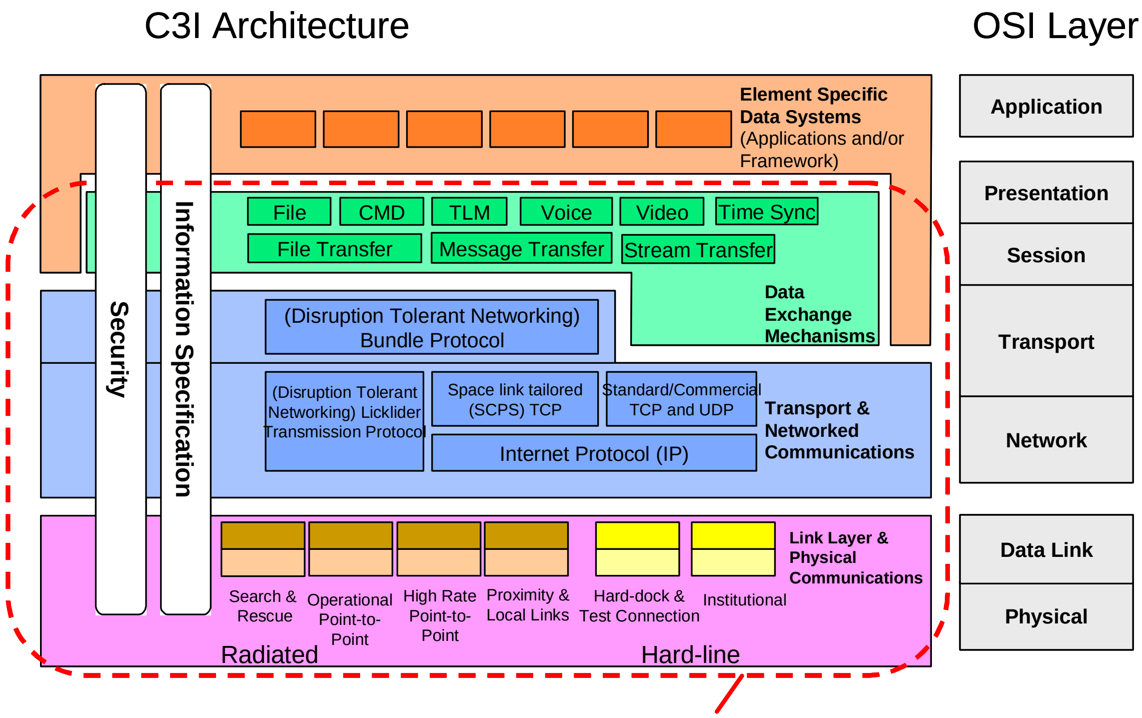

Figure 1.5-2 - Architecture Interoperability Layers and Their Mapping to the OSI Reference Model

1.6 APPROACH

The C3I ARCHITECTURE is based on common communications links and protocols, common COMMAND and TELEMETRY formats, interoperable voice and motion imagery protocols, and common information definitions. The C3I ARCHITECTURE leverages industry advances in network and data systems to address key challenges of the Constellation Program including simultaneous COMMAND and control of multiple systems, use of diverse communications environments, AUTONOMOUS operations support, cost constraints, and configurations and operations concepts which will continue to change over a period of many years. To address these challenges, the C3I ARCHITECTURE defines a loosely coupled, interoperable SYSTEM-of-SYSTEMS ARCHITECTURE based on the use of open, standards-based interfaces and switched/routed end-to-end communications networks. The functionality associated with each of the primary layers (communications / link interfaces, networking / protocols, framework / data exchange, security, and applications) is shown in Figure 1.5-1 and Figure 1.5-2, and is briefly described below. More detailed specifications for each layer are detailed in Section 3 of this document. Layering is used both to isolate functionality and to aggregate commonly-used functions. Each layer provides a set of services to the layer above it by using protocols to exchange information with its peer layer as well as services from the layer below. So long as the interfaces to the layers above and below are maintained, the technology and protocols used to implement the services at a particular layer can be changed with minimal disruption and at relatively low cost. This will allow the Constellation C3I ARCHITECTURE to grow and evolve gracefully as technology changes. Central to the ARCHITECTURE is the use of a framework or data exchange services mechanism that uses publish and subscribe communications over an information bus. The framework allows individual application components to “plug-n-play” by supporting interface standards and facilitating the interactions with the system and between applications. Above the network protocols are the data exchange protocols necessary for command and control, including COMMANDS, TELEMETRY, time synchronization, voice, MOTION IMAGERY, and file transfer. The layered approach also allows for the eventual introduction of a Delay/Disruption Tolerant Networking (DTN) layer in the future to accommodate communications delays and the periodic communications availability associated with Mars and other deep-space missions as well as with some near-term orbiting or surface assets with minimal impact to the architecture. Also included in the ARCHITECTURE is an integrated information model, the platform for a standard, common command and control method for all Constellation SYSTEMS, and an integrated space and ground network. This specification also includes a section on information model definition, which provides standard definitions, schemas, and formats across Constellation SYSTEMS.

1.6.1 Communications

Communications (physical and link layers) comprise the lowest layer of the C3I ARCHITECTURE and ensure that any two SYSTEMS are physically able to communicate. The specifications in this area are designed to provide the maximum capability and flexibility for communicating between SYSTEMS, while maintaining the least number of unique link configurations. In order for any two SYSTEMS to communicate, they must both configure their communications systems exactly the same. For modern communications systems, this includes a large number of variables such as frequency band, channel, data rate, signal design, and coding. These many variables provide designers with many options to optimize communications links for spacecraft. This is especially important for space communications due to the physics of radio signals as a function of distance. However, a goal when designing for flexibility and interoperability for communications between many different SYSTEMS is to reduce the number of possible configurations so as to limit the complexity of operations, test and validation.
This specification selects a minimum set of link configurations to support the various operations of Constellation systems. This small set of links is based on the Space Network (SN) standards that are currently used in human spaceflight. This enables any two systems to communicate in most every operations scenario. It may be possible for systems to provide communications capabilities beyond these minimum specifications. It is also expected that communications systems will evolve over the life of the program. The layered nature of the C3I ARCHITECTURE attempts to minimize the impacts of changing communications systems. As new protocols or links (i.e. laser communications) are introduced, this specification may be updated to include them. Any impacts to the program will be assessed at that time.

1.6.2 Network Communications

The Network/Transport layer defines a set of higher-layer protocols which provide the multi-hop, routed, networked communications architecture needed to support Constellation missions. With a network, data can be addressed to destinations that are not necessarily reachable from the source via a single physical communication link. Constellation SYSTEMS will use the Internet Protocol (IP) as the network layer protocol to provide for a common datagram format and addressing scheme for all SYSTEMS in the network. This will allow Constellation applications to communicate on the network so long as there is a (possibly multi-hop) path between them. The network's job is to get the data to the destination so that applications will not have to manage, or even to be cognizant of, the actual network topology connecting them. From the overall C3I ARCHITECTURE perspective, the standardization on IP can be viewed as the unifying system in the overall layered architecture. An exception to this approach will be required for tracking, when a user may want to use a specific asset to directly track a vehicle, in order to provide a particular geometry that allows for the observation of some component of the state vector.

The IP provides a best-effort packet-switched service as opposed to a circuit-switched one. The best-effort service means that IP datagrams are not guaranteed to arrive at their destinations. Reliability (if desired) must be implemented by a higher-layer protocol such as the Transmission Control Protocol (TCP). Packet switching allows a much more efficient method of handling multiple users on a single data link as compared to a data link that pre-apportions fixed bandwidth among the users. Figure 1.6-1 illustrates the difference between channelized and multiplexed approaches, and the bandwidth recovered by using previously wasted bandwidth from the separate channels. This is particularly useful since voice and MOTION IMAGERY are typically not transmitting continuously, so bandwidth goes unused. So for instance the high bandwidths required for High Definition (HD) MOTION IMAGERY can be used to support other command and control functions when HD MOTION IMAGERY is not needed. Network prioritization and other Quality of Service (QoS) mechanisms provide the system with the tools necessary to ensure that voice and critical COMMANDS and TELEMETRY are reliably transmitted regardless of other network traffic.

For future mission configurations having significant round-trip light time delays, or when no end-to-end path exists, the Delay/Disruption Tolerant Networking (DTN) technology provides secure reliable communications when no end-to-end path exists. Commercial-Off-The-Shelf (COTS) IP implementations will currently discard packets for destinations that are not immediately reachable. The DTN technology provides a store-and-forward overlay that can use IP technology in a hop-by-hop fashion, and allows intermediate nodes to hold on to data before forwarding it.

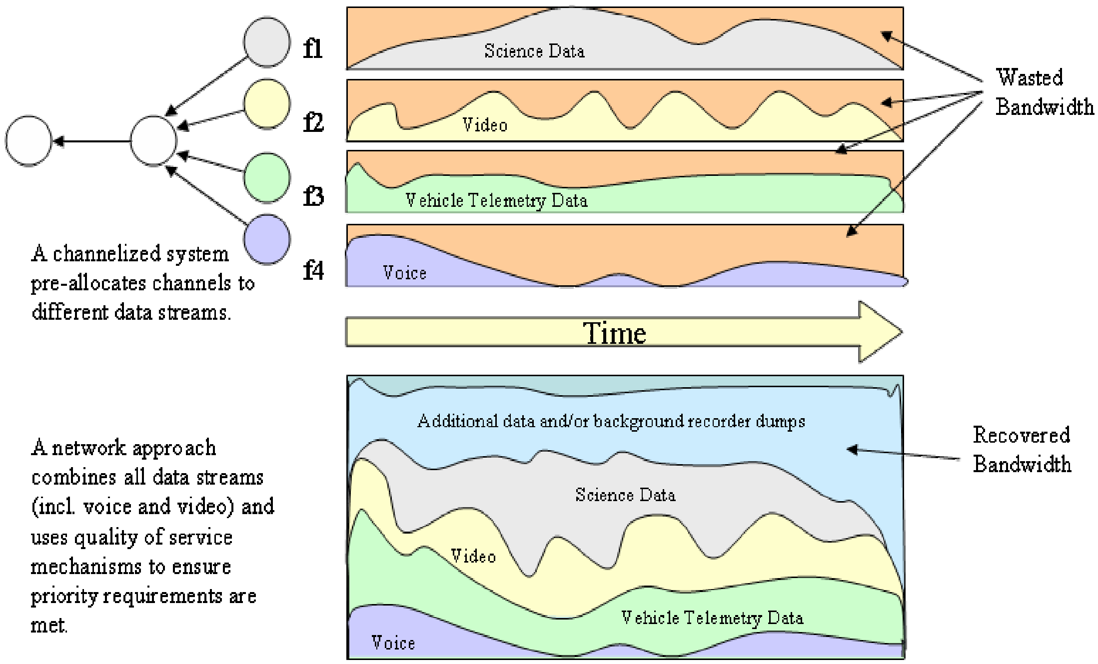

Figure 1.6-1 - Channelized vs. Network Communications

1.6.3 Data Exchange Mechanisms

The Data Exchange Layer defines a set of common data exchange mechanisms which can be used to simplify application development and testing, and improve application performance and interoperability. These "mechanisms" provide Constellation SYSTEMS a standard approach to share COMMAND, control and end-user information with one or more other systems. Data exchange mechanisms have always been present in spaceflight systems, but they have traditionally been defined and implemented in the context of a tightly integrated set of flight and ground components bound by a small set of customized interface definitions. Constellation, on the other hand, is intended as a larger collection of space exploration assets which must interoperate with multiple mission systems and configurations.

1.6.4 Information Specification

A common information specification or model is used to ensure data concurrency and to provide a common language that defines how systems communicate in order to achieve required command and control functions. The information defines the data exchange definitions and data dictionaries needed to ensure that any two systems can effectively "understand" the digital bits that they exchange. This will enable a variety of operational tasks, the most important of which is the interoperable exchange of information among Constellation SYSTEMS. This specification documents the basic information model describing the information passed between SYSTEMS. The detailed data definitions for each SYSTEM will require SYSTEM developer participation for the specific definitions. To accommodate this, the C3I ARCHITECTURE will define a new NASA controlled registry process that will provide and maintain a central repository for data definitions. This will allow SYSTEMS to use a common set of definitions to describe their

SYSTEM information while also providing the process for a SYSTEM to introduce new data definitions required by that SYSTEM.

1.6.5 Security

Constellation SYSTEMS must be interoperable in terms of the security approaches employed to protect the availability, integrity, and confidentiality of the information communicated between SYSTEMS. The actual security controls put into place depend on the outcome of security risk assessments, but it is likely that some or all SYSTEMS will require secure communications capabilities. Interoperability requires that communicating systems employ the same security protocols at the same layer(s) of the communications stack and the same algorithms must be used to perform security functions (e.g., encrypting, decrypting, hashing, signing). An interoperable key management capability is required to establish the keys used for encryption/decryption and AUTHENTICATION. Other security management capabilities may be needed if algorithms are to be updated over time. Security related parameters may be required in metadata models in order to facilitate interoperable security processing at the application layer.

1.7 TERMINOLOGY AND ACRONYMS

This document is a detailed specification that is intended for a technical audience. This specification covers several domains including communications, networking, data exchange protocols, information modeling, and security. Each section is intended for domain knowledgeable readers. For clarity, all acronyms are defined Appendix A and glossary terms are defined in Appendix C. The convention used in this document which indicates requirements, goals, and statements of fact or declaration are as follows: Shall – Used to indicate a requirement which must be implemented and its implementation verified. Should – Used to indicate a goal which must be addressed by the design, but is not formally verified. Will – Used to indicate a statement of fact and is not verified.

2 DOCUMENTS

The following sections specify all applicable and referenced documents used in this specification.

2.1 APPLICABLE DOCUMENTS

The following documents include specifications, models, standards, guidelines, handbooks and other special publications. The documents listed in this paragraph are applicable to the extent specified herein. Only documents specifically referenced in ‘shall statements’ will be listed in Table 2.1-1.

Table 2.1-1 - Applicable Documents

Document Number	Document Title	Rev	Date	Section
IETF STD-0013	Domain Name System (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
ISO/IEC 15444-3	Motion JPEG 2000 (Part 3) (International Standards Organization, (ISO, http://www.iso.ch)) <TBD-ADL-001>			
CCSDS 732.0.B-2	AOS Space Data Link Protocol (Consultative Committee for Space Data Systems, http://www.ccsds.org) <TBD-ADL-001>			
CCSDS 131.0-B-1	TM Synchronization and Channel Coding (Consultative Committee for Space Data Systems, http://www.ccsds.org) <TBD-ADL-001>			
CCSDS 131.1-O-1	Low Density Parity Check Codes for Use in Near-Earth and Deep Space Applications (Consultative Committee for Space Data Systems, http://www.ccsds.org) <TBD-ADL-001>			3
CCSDS 702.1-R-1	IP over CCSDS Space Links (Consultative Committee for Space Data Systems, http://www.ccsds.org) <TBD-ADL-001>			
NTIA	Manual of Regulations and Procedures for Federal Radio Frequency Management (National Telecommunications & Information Administration, (NTIA, http://www.ntia.doc.gov)		Jan. 2006	
STD-0005, RFC-791	Internet Protocol (IP) Specification, Version 4 (Internet Engineering Task Force (IETF, http://www.ietf.org))			
RFC-792	Internet Control Message Protocol (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-3416	Protocol Operations for Version 2 of the Simple Network Management Protocol (SNMPv2) (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-1918	Address Allocation for Private Internets (Internet Engineering Task Force (IETF, http://www.ietf.org))			
RFC-3171	IANA Guidelines for IPv4 Multicast Address Assignments (Internet Engineering Task Force (IETF, http://www.ietf.org))			
RFC-2131	Dynamic Host Configuration Protocol (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-3927	Dynamic Configuration of IPv4 Link-Local Addresses (Internet Engineering Task Force (IETF, http://www.ietf.org))			

Document Number	Document Title	Rev	Date	Section
RFC-4361	Node-specific Client Identifiers for Dynamic Host Configuration Protocol Version Four (DHCPv4) (IETF, http://www.ietf.org) <TBD-ADL-001>			
RFC 2211	Specification of the Controlled-Load Network Element Service (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-2213	Integrated Services Management Information Base using SMIv2 (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC 2460	Internet Protocol, Version 6 (IPv6) Specification (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-4443	Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-1812	Requirements for IP Version 4 Routers (Internet Engineering Task Force (IETF, http://www.ietf.org))			
RFC-2644	Changing the Default for Directed Broadcasts in Routers (IETF, http://www.ietf.org) <TBD-ADL-001>			
STD-0003, RFC-1122	Requirements for Internet Hosts – Communications Layers (Internet Engineering Task Force (IETF, http://www.ietf.org))			
RFC-4271	A Border Gateway Protocol 4 (BGP-4) (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
STD-0056, RFC-2453	RIP Version 2 (Internet Engineering Task Force (IETF, http://www.ietf.org))			
STD-0054, RFC-2328	Open Shortest Path First (OSPF) Version 2 (Internet Engineering Task Force (IETF, http://www.ietf.org))			
RFC-2427	Multiprotocol Interconnect over Frame Relay (IETF, http://www.ietf.org) <TBD-ADL-001>			
RFC-2784	Generic Routing Encapsulation (GRE) (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-3140	Per Hop Behavior Identification Codes (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-3246	An Expedited Forwarding PHB (Per Hop Behavior) (Internet Engineering Task Force (IETF, http://www.ietf.org))			
RFC-3626	Optimized Link State Routing Protocol (OLSR) (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-2080	RIPng for IPv6 (IETF, http://www.ietf.org) <TBD-ADL-001>			
RFC-2740	OSPF for IPv6 (IETF, http://www.ietf.org) <TBD-ADL-001>			
RFC-2473	Generic Packet Tunneling in IPv6 Specification (IETF, http://www.ietf.org) <TBD-ADL-001>			
RFC-2474	Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers (Internet Engineering Task Force (IETF, http://www.ietf.org))			
RFC-2508	Compressing IP/UDP/RTP Headers for Low-Speed Serial Links (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-2205	Resource ReSerVation Protocol (RSVP) – Version 1 Functional Specification (Internet Engineering Task Force (IETF, http://www.ietf.org))			

Document Number	Document Title	Rev	Date	Section
RFC-4292	IP Forwarding Table MIB (IETF, http://www.ietf.org) <TBD-ADL-001>			
RFC-4293	Management Information Base for the Internet Protocol (IP) (IETF, http://www.ietf.org) <TBD-ADL-001>			
RFC-4113	Management Information Base for User Datagram Protocol (UDP). (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-4022	Management Information Base for Transmission Control Protocol (TCP) (Internet Engineering Task Force (IETF, http://www.ietf.org)). <TBD-ADL-001>			
RFC 4301	Security Architecture for the Internet Protocol (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-4302	IP Authentication Header (AH) (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-4303	IP Encapsulating Security Payload (ESP) (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-4305	Cryptographic Algorithm Implementation Requirements for Encapsulating Security Payload (ESP) and Authentication Header (AH) (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-4306	The Internet Key Exchange (IKEv2) (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-4307	Cryptographic Algorithms for Use in the Internet Exchange (IKEv2) (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-4308	Cryptographic Suites for IPsec, Suite VPN-B for use in the Internet Key Exchange Version 2 (IKEv2) (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-4309	Using Advanced Encryption Standard (AES) CCM Mode for IPsec Encapsulating Security Payload (ESP) (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-3289	MIB for the Differentiated Services (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-3747	Differentiated Services Configuration MIB. (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-2959	Real Time Protocol MIB (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
STD-0007, RFC-0793	Transmission Control Protocol (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
STD-0062	Structure of Management Information Version 2 (SMIv2) <TBD-ADL-001>			
RFC-1323	TCP Extensions for High Performance (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
STD-0006, RFC-0768	User Datagram Protocol (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
STD-0064, RFC-3550	RTP: A Transport Protocol for Real-Time Applications (Internet Engineering Task Force (IETF, http://www.ietf.org))			
DTN <**TBD 2-1**>	DTN, Delay/Disruption Tolerant Networking, Specifications, http://www.ietf.orf/internet-drafts/draft-irtf-dtnrg-bundle-spec-05.txt	Draft		

Document Number	Document Title	Rev	Date	Section
	status (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
CCSDS 714.0-B-1	Space Communications Protocol Specification – Transport Protocol (SCPS-TP)	Blue Book, Issue 1	May 1999	
RFC-1305	Network Time Protocol (NTP) Version 3 (http://www.ietf.org/rfc/rfc1305.txt) (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>	Version 3		
CCSDS 727.0-B-3	CCSDS File Delivery Protocol (CFDP) – Recommended Standard (http://public.ccsds.org/publications/SpaceIntServ.aspx) Protocol (Consultative Committee for Space Data Systems, http://www.ccsds.org)		June 2005	
ITU G.729	Coding of speech at 8 kbit/s using conjugate-structure algebraic-code-excited linear prediction (CS-ACELP) (International Telecommunications Union, (ITU, http://www.itu.ch))			
ITU H.264	Advanced Video Coding for Generic Audiovisual Services (http://www.itu.int/rec/recommendation.asp?type=folders&lang=e&parent=T-REC-H.264). (International Telecommunications Union, (ITU, http://www.itu.ch)) <TBD-ADL-001>			
FIPS PUB 197	Advanced Encryption Standard (AES) National Institute for Standards and Technology (NIST, http://www.nist.gov))			
FIPS PUB 180-2	Secure Hash Algorithms (SHA), sections on Secure Hash Algorithms (SHA) SHA-1 and SHA-256 National Institute for Standards and Technology (NIST, http://www.nist.gov)) <TBD-ADL-001>			
FIPS PUB 186-2	Digital Signature Standard (DSS), sections on Digital Signature Algorithm (DSA) National Institute for Standards and Technology (NIST, http://www.nist.gov)) <TBD-ADL-001>			
FIPS PUB 198	Keyed-Hash Message Authentication Code (HMAC) method National Institute for Standards and Technology (NIST, http://www.nist.gov)) <TBD-ADL-001>			
C/S T.001	Specification for Cospas-Sarsat 406 MHz Distress Beacons <TBD-ADL-001>	7	Nov. 2005	
ITU-R M.633	Transmission characteristics of a satellite emergency position-indicating radiobeacon (satellite EPIRB) system operating through a low polar-orbiting satellite system in the 406 MHz band (International Telecommunications Union, (ITU, http://www.itu.ch)) <TBD-ADL-001>			
RFC-2507	IP Header Compression (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
RFC-1631	The IP Network Address Translator (NAT) (Internet Engineering Task Force (IETF, http://www.ietf.org)) <TBD-ADL-001>			
IEEE 802.16e	IEEE Standard for Local and Metropolitan Area Networks (Institute of Electrical and Electronics Engineers, Inc. (IEEE, http://www.ieee.org)) <TBD-ADL-001>			
RFC-3986	Universal Resource Indicators (URI) – W3C Standard (http://www.gbiv.com/protocols/uri/rfc/rfc3986.html) Internet Engineering Task Force (IETF, http://www.ietf.orf)) <TBD-ADL-001>			
RFC-3810	Multicast Listener Discovery Protocol <TBD-ADL-001>	2		
RFC-2858	Multi-protocol Border Gateway Protocol<TBD-ADL-001>			

Document Number	Document Title	Rev	Date	Section
RFC-1584	Multicast Extension to OSPF<TBD-ADL-001>			
RFC-3376	Internet Group Management Protocol (IGMP) <TBD-ADL-001>			
ISO/IEC 13239:2002	Information Technology – Telecommunications and information exchange between systems – High-level data link control (HDLC) procedures (International Standards Organization, (ISO, http://www.iso.ch)) <TBD-ADL-001>			
NPD 2570.5D	NASA Electromagnetic (EM) Spectrum Management <TBD-ADL-001>			
451-PN CODE-SNIP	Space Network PN Code Libraries, Rev 1. <TBD-ADL-001>	1		
MIL-STD-188-181	Interoperability Standard for Dedicated 5 kHz and 25 kHz UHF Satellite Communications Channels <TBD-ADL-001>			
IEEE 802.11g	802.11g <TBD-ADL-001>			

2.2 REFERENCE DOCUMENTS

The following documents listed in Table 2.2-1 contain supplemental information to guide the user in the application of this document.

Table 2.2-1 - Reference Documents

Document Number	Document Title	Rev	Date
CXP-70000	Constellation Architecture Requirements Document (CARD)		
CXP-70007	Constellation Design Reference Missions (DRMs) and Operational Concepts Document		
IRB-TR-03-003	A Delay-Tolerant Network Architecture for Challenged Internets, K. Fall (Intel Research, http:// www.intel-research.net)		Feb., 2003
ACM Queue, Vol. 3 Issue 4, pp. 54—59	You Don't Know Jack About Network Performance, K. Fall and S. McCanne		May 2005
ISO /TU-T ASN.1	Abstract Syntax Notation one (ASN.1), (http://asn1.elibel.tm.fr/en/standards) (International Standards Organization, (ISO, http://www.iso.ch))		1995
OMG/CCSDS XTCE	Object Management Group (OMG) XML Telemetric and Command Exchange (XTCE)		
RDF	http://www.w3.org/RDF (World Wide Web Consortium, (WC3, http://www.wc3.org))		
RuleML	http://www.ruleml.org		
OWL	http://www.w3.org/TR/owl-features/ (World Wide Web Consortium, (WC3, http://www.wc3.org))		
SWRL	http://www.w3.org/Submission/2004/SUBM-SWRL-20040521 (World Wide Web Consortium, (WC3, http://www.wc3.org))		
IEEE 90	IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries		1990

Document Number	Document Title	Rev	Date
GSFC-450-SNUG	Space Network User's Guide (SNUG)	8	June 2002
MIL-STD 1553B	http://snebulos.mit.edu/projects/reference/MIL-STD/MIL-STD-1553B.pdf		

3 Requirements

3.1 RF Communication

This section provides the functional and performance requirements necessary to ensure interoperability between Constellation SYSTEMS at the physical and data link layers, ensuring that a common RF communications path can be easily established. Interoperability at the physical layer includes common definitions of frequency, modulation, and transmit/receive signal polarization. Interoperability at the data link layer includes common definitions of channel error correction coding, data link framing, and information packet structure. Table 3.1-1 provides an overview of the link parameters.

Common link classes include definitions of frequency spectrum, physical and data link layer protocols. Link classes are specified in terms of their use. This specification defines classes of links that may be implemented by the various Constellation SYSTEMS and external SYSTEMS. Links may be used in-space, inter-system, or Direct To Earth (DTE)/ Direct From Earth (DFE) as appropriate. The intent is that if two SYSTEMS must communicate in a similar way (must make use of a common class of link), then those SYSTEMS will both implement that link class in the same manner. Links may exist between Constellation SYSTEMS, or between Constellation SYSTEMS and supporting communication and tracking infrastructure.

For the purpose of this specification, communication and tracking infrastructure refers to the NASA communications and tracking networks including the Space Network (SN), Deep Space Network (DSN), and Ground Network (GN). Future networks including possible lunar relay or lunar in-situ communications and tracking systems are also considered “communication and tracking infrastructure”.

Point-to-point links generally will communicate either through the Space Network (SN) or through a ground or space system that emulates SN. This architecture was selected to minimize flight system RF system operating modes, simplifying flight radio design, test and operations. This architecture is reflected in the requirements below, with many common requirements that are independent of the infrastructure network being used. A point-to-point link is addressed between two end point namely, point A and point B which is shown in Figure 3.1-1. Point A is generally the flight element on one end of the link. Point B is either the infrastructure or another flight element on the other end of the same link. In order to facilitate callouts from SYSTEM Interface Requirements Documents (IRDs), requirements for point-to-point links have been organized into three general categories: Common – requirements that are common to both ends of a communication link. Point A – requirements that apply to one end of a communication link, generally the flight system end. Point B – requirements that apply to the opposite end of Point A links, generally the infrastructure end of the link (SN, GN, DSN, commercial ground stations, Air Force ground stations, etc.). For operational point-to-point links used during RPOD operations, Point B represents either the SN or the target vehicle.

The end of the link being referred to as Point A or Point B will be specified in the IRDs.

Table 3.1-1 - Summary of Link Parameters

	High Rate Point-to-Point	Operational Point-to-Point	Contingency Voice	Multi-point Proximity	Hard Line High Volume	Hard Line Time Critical Control	Recovery / SAR
Data Packet	IP		N/A	IP	IP	N/A	N/A
Data Link Framing	Multiprotocol Interconnect over Frame Relay (Q.922)		N/A	<TBD 3-2>	Ethernet 10BaseT *	<TBD 3-5>	Analog SATCOM SARSAT
Space Link Framing	CCSDS AOS*		N/A	<TBD 3-2>	N/A	N/A	Analog SATCOM SARSAT
Error Correction	CCSDS Rate ½ AR4JA LDPC*		N/A	<TBD 3-2>	N/A	N/A	N/A
Modulation	SQPN* SQPSK* BPSK	SQPN* SQPSK* BPSK*	AM	<TBD 3-2>	N/A	N/A	AM/FM SATCOM COSPAS/ SARSAT
Frequency	Ka-Band	S-Band (CatA) <TBD 3-1>. (Cat B)	UHF	<TBD 3-2>	N/A	N/A	VHF/UHF

Note: (*) indicates value is TBR **<TBR 3-1>**

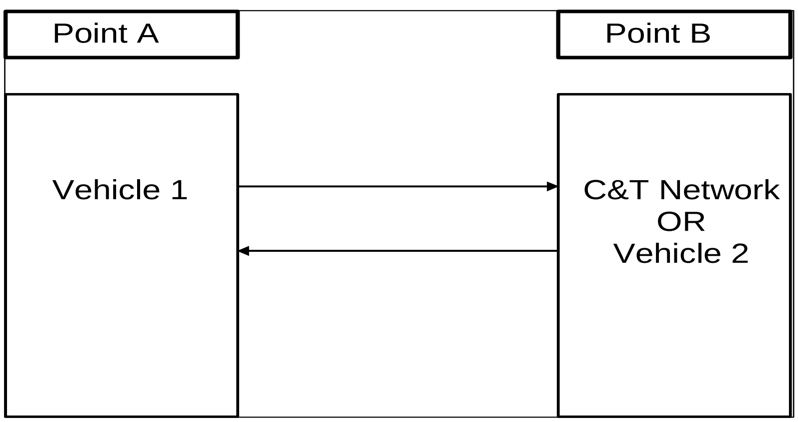

Figure 3.1-1 - Point A to Point B Relationship

3.1.1 Common RF Communication

Constellation SYSTEMS shall comply with spectrum selection/allocation, certification and usage restriction policies set forth in NASA Policy Directive (NPD) 2570.5D, NASA Electromagnetic (EM) Spectrum Management. [C3I-3]

> ***Rationale****: The NTIA regulates the licensure and use of radio frequency spectrum for U.S. Government SYSTEMS. Allocations of frequency spectrum for U.S. Government SYSTEMS, including NASA, is managed by the NTIA.*

Constellation SYSTEMS shall comply with radio frequency allocation and conditions of assignment for frequency spectrum usage approved by the National Telecommunications & Information Administration (NTIA). [C3I-584]

Constellation SYSTEMS shall use transmit/receive frequency assignments and spectrum characteristics as defined in CxP 70022 Constellation Command, Control, Communications and Information (C3I) Interoperability Standards Book, Volume 2: Constellation Spectrum and Channel Plan. [C3I-5]

> ***Rationale****: Constellation SYSTEMS need to support multiple frequency channel pairs (channels) in order to simultaneously interoperate with other SYSTEMS and Communications and Tracking Network. In order for channelization to be effective and have an acceptable level of inter-channel interference, a Constellation Channel Plan is being developed which will comply with the NTIA Manual of Regulation and Procedures for Federal Radio Frequency Management.*

3.1.2 Operational Point-to-Point RF Communication

This link provides a communication path to carry low to medium rate data (18 Kbps to 20 Mbps) between SYSTEMS and with communications infrastructure. It can be used to provide communication services such as voice, low-rate motion imagery, COMMAND, TELEMETRY, and basic file transfer. The specified link parameters provide greater resilience to atmospherics, poor antenna visibility, and decreased user power consumption. Operational Point-to-Point links may be used between in-space Constellation SYSTEMS (as in a crosslink configuration), as well as between SYSTEMS and communications and tracking infrastructure such as the Space Network, DSN, GN, future lunar relay systems and possible non-NASA network systems. The operational point-to-point link class also provides radiometric measurement capability between flight systems and communication and tracking infrastructure. Operational point-to-point links may be used in a rendezvous link mode in which two in-space SYSTEMS communicate with each other and perform relative radiometric measurement in support of rendezvous operations.

3.1.2.1 Common Operational Point-to-Point RF Communication

Constellation SYSTEMS shall transmit using LEFT-HAND CIRCULAR POLARIZATION for operational point-to-point links. [C3I-6]

> ***Rationale****: LHCP transmit is required to use SPACE NETWORK S-Band MA service. The Constellation Program may use SN MA or SA service. SYSTEMS are not limited to LHCP alone; polarization diversity can be used to enhance the ability to simultaneously communicate with each other and with the C&T Network, such as during lunar orbit rendezvous.*

Constellation SYSTEMS shall receive using LEFT-HAND CIRCULAR POLARIZATION for operational point-to-point links. [C3I-7]

> ***Rationale****: The Constellation Program plans to use the SPACE NETWORK S-Band MA service; LHCP receive is required to use this service. SYSTEMS are not limited to LHCP alone; polarization diversity can be used to enhance the ability to simultaneously*

communicate with each other and with the C&T Network, such as during lunar orbit rendezvous.

Constellation SYSTEMS shall communicate using at least two independent transmit/receive frequency pairs within the near Earth S-band spectrum allocation for multi-SYSTEM, simultaneous operational point-to-point communications. [C3I-11]

***Rationale**: Operation concepts include situations where two Constellation SYSTEMS must simultaneously communicate with C&T Network and with each other, such as during lunar orbit RENDEZVOUS. Simultaneous communication between C&T Network and the other in-space SYSTEMS require each SYSTEM to operate on more than one communication channel.*

Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3 to transmit data streams for operational point-to-point links. [C3I-22]

***Rationale**: Appropriate FORWARD ERROR CORRECTION coding is normally required to ease the implementation of transmit power and antenna gain requirements in space communications applications. LDPC shows greater spectral and power efficiency for a given increase of link margin through coding gain than the traditional CCSDS rate 1/2 convolutional and Reed-Solomon codes. Selection of the CCSDS code is based upon C3I SIG IDAC2 and IDAC3 studies (SIG-13-107).*

Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3 for decoding received data streams using FEC for operational point-to-point links. [C3I-590]

***Rationale**: Appropriate Forward Error Correction coding is normally required to ease the implementation of transmit power and antenna gain requirements in space communications applications. LDPC shows greater spectral and power efficiency for a given increase of link margin through coding gain than the traditional CCSDS rate 1/2 convolutional and Reed-Solomon codes. Selection of the CCSDS code is based on C3I SIG IDAC2 and IDAC3 studies (SIG-13-107).*

Constellation SYSTEMS shall enable and disable communication link forward error correction (FEC) upon receipt of COMMAND for operational point-to-point links. [C3I-653]

***Rationale**: Operations concepts, including diagnostic and low latency modes, require the ability to enable and disable communication link FEC.*

Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC-2427 for transmission of IP packets for operational point-to-point links. [C3I-668]

***Rationale**: MPoFR provides compatibility with existing and future commercial and CCSDS communication infrastructure. MPoFR has demonstrated a successful flight history on both US and international space missions. MPoFR provides organic support* *for both IPv4 and IPv6 packets. RFC-2427 specifies the addressing (Q.922), framing (Q.921) and data link layer (HDLC) definitions for use of MPoFR. Selection of MPoFR is based on studies conducted by CEV Project and C3I SIG during IDAC2 and IDAC3 analysis cycles.*

Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC-2427 for reception of IP packets for operational point-to-point links. [C3I-669]

***Rationale**: MPoFR provides compatibility with existing and future commercial and CCSDS communication infrastructure. MPoFR has demonstrated a successful flight history on both US and international space missions. MPoFR provides organic support for both IPv4 and IPv6 packets. RFC-2427 specifies the addressing (Q.922), framing (Q.921) and data link layer (HDLC) definitions for use of MPoFR. Selection of MPoFR is based on studies conducted by CEV Project and C3I SIG during IDAC2 and IDAC3 analysis cycles.*

Constellation SYSTEMS shall transmit Multiprotocol Interconnect over Frame Relay (MPoFR) as serial octet-aligned streams per CCSDS recommendation “IP over CCSDS Space Links”, CCSDS 702.1-R-1, using the Virtual Channel Access (VCA) service of CCSDS Advanced Orbiting Systems (AOS) Space Link Protocol as specified in CCSDS 732.0-B-2 for operational point-to-point links. [C3I-612]

***Rationale**: The AOS VCA service provides compatibility with existing space network and ground network hardware and software. . CCSDS recommendation CCSDS 702.1-R-1 (IP over CCSDS Space Links) specifies the use of VCA service (as defined for AOS in CCSDS 732.0-B-2) as the proper way to transport the serial octet-aligned streams produced by MPoFR. While AOS provides native support for the IPv4 packet, serial octet-aligned streams are required as CCSDS AOS does not provide native support for the IPv6 packet. Compliance with CCSDS recommendations provides the greatest compatibility and flexibility for interoperability with commercial and international partners. Selection of MPoFR is based on C3I SIG studies during IDAC2 and IDAC3, as well as decisions made as a result of the Constellation Program SRR. Note that the receive side of this REQUIREMENT is covered by the REQUIREMENT to implement the AOS service access points (C3I-596)*

Constellation SYSTEMS shall comply with the specifications for service access points as defined in section 3 of the AOS Space Data Link Protocol 732.0.B-2 for reception of Multiprotocol Interconnect over Frame Relay using the CCSDS AOS Virtual Channel Access (VCA) service frames over operational point-to-point links. [C3I-596]

***Rationale**: The service access points in section 3 of 732.0.B-2 define mechanisms to encapsulate higher-layer data for transmission and reception from to other systems. Using 732.0.B-2 will ensure compatibility among SYSTEMS, and with existing ground infrastructure. Compliance with CCSDS 732.0-B-2 service access point specifications provides the receive side (bitstream decapsulation) capability for VCA service. Use of*

AOS VCA is recommended by CCSDS 702.1-R-1, "IP over CCSDS Space Links", and allows support for both the IPv4 and IPv6 packets.

Constellation SYSTEMS shall apply the 64-bit Attached Sync Marker (ASM) defined in CCSDS 131.0-B-1 as specified in CCSDS 131.1-O-1, Section 3.5 to transmitted FEC code block frames for operational point-to-point links. [C3I-594]

Rationale*: Use of the CCSDS ASM (frame sync pattern) per CCSDS 131.0-B-1 provides receiver hardware the ability to perform synchronization of the start of a FEC code block frame, and will ensure interoperability between Constellation SYSTEMS and SYSTEMS/C&T network links. CCSDS 131.1-O-1 specifies the use of a 64-bit ASM pattern as defined in CCSDS 131.0-B-1 rather than the legacy 32-bit pattern.*

Constellation SYSTEMS shall use the 64-bit Attached Sync Marker (ASM) defined in CCSDS 131.0-B-1 for synchronization of received FEC code block frames as specified in CCSDS 131.1-O-1 for operational point-to-point links. [C3I-670]

Rationale*: Use of the CCSDS ASM (frame sync pattern) per CCSDS 131.0-B-1 provides receiver hardware the ability to perform synchronization of the start of a FEC code block frame, and will ensure interoperability between Constellation SYSTEMS and SYSTEMS/C&T network links. CCSDS 131.1-O-1 specifies the use of a 64-bit ASM pattern as defined in CCSDS 131.0-B-1 rather than the legacy 32-bit pattern.*

Constellation SYSTEMS shall use bit randomization techniques in accordance with CCSDS 131.0-B-1 for randomization of transmitted data streams for operational point-to-point links. [C3I-23]

Rationale*: Use of bit randomization technique as specified in CCSDS 131.0-B-1 ensures the proper bit synchronization process and interoperability between Constellation SYSTEMS, and compatibility between Constellation system/C&T Network links.*

Constellation SYSTEMS shall use bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-randomization of received data streams for operational point-to-point links. [C3I-592]

Rationale*: Use of bit randomization techniques as specified in CCSDS 131.0-B-1 will ensure the proper bit synchronization process and interoperability between Constellation SYSTEMS, and compatibility between Constellation SYSTEM/C&T Network links.*

Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for transmission of non-FEC coded data streams for operational point-to-point links. [C3I-671]

Rationale*: NRZ-M symbol coding provides the means for a receiving SYSTEM to resolve phase ambiguity of the modulated data stream. CCSDS 131.1-O-1 specifies that NRZ-M coding should not be used when the data stream is encoded with LDPC FEC codes.*

Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for resolution of symbol phase ambiguity of non-FEC coded data streams for operational point-to-point links. [C3I-672]

***Rationale**: NRZ-M symbol coding provides the means for a receiving SYSTEM to resolve phase ambiguity of the modulated data stream. CCSDS 131.1-O-1 specifies that NRZ-M coding should not be used when the data stream is encoded with LDPC FEC codes.*

3.1.2.2 Point A Operational Point-to-Point RF Communication

Table 3.1-2 - Point A Operational Point-to-Point Signal Characteristics

Coded Symbol Rate	Data Group	Mode	Doppler Measurement	PN Ranging	Modulation	PN Spreading
>= 18 Ksps <= 300 Ksps	DG1 Coherent	Mode 1	Two-Way	Yes	SQPN	Yes
>= 18 Ksps <= 300 Ksps	DG1 Non-Coherent	Mode 2	One-Way	No	SQPN	Yes
>= 300 Ksps <= 6 Msps	DG2 Coherent	-	Two-Way	No	Balanced SQPSK	No
>= 300 Ksps <= 6 Msps	DG2 Non-Coherent	-	One-Way	No	Balanced SQPSK	No
>= 6 Msps <= 20 Msps	DG2 Non-Coherent	-	One-Way	No	Balanced SQPSK	No
>= 18 Ksps <= 6 Mbps	DG1 Coherent	Mode 3	Two-Way	Yes	SQPN	Yes

Constellation point A SYSTEMS shall coherently re-transmit the received carrier with a turn-around ratio of 240/221(transmit/receive) for coherent point-to-point link operation. [C3I-308]

***Rationale**: The 240/221 turn-around ratio is required to be compatible with existing C&T Network and is described in the SNUG rev. 8. Coherent link operation is required for providing the radiometric measurements of range and range rate.*

Constellation point A SYSTEMS shall provide a non-coherent mode of operation for operational point-to-point links. [C3I-350]

***Rationale**: Non-coherent operation is required in order that Constellation point A SYSTEMS can deliver TELEMETRY and permit tracking to be performed when a forward link is not available. When two-way radiometric measurements are not required, a non-coherent mode of operation may be preferred since signal acquisition and tracking is easier, faster and requires a lower Eb/No.*

Constellation point A SYSTEMS shall coherently re-transmit the received range channel data to point B SYSTEM. [C3I-314]

***Rationale**: In order to provide range data at point B SYSTEM, the received range channel data at point A SYSTEM must be coherently re-transmitted to Point B SYSTEMS.*

Constellation point A SYSTEMS shall use transmit signals with modulation schemes in accordance with Table 3.1-2 for operational point-to-point links. [C3I-573]

> ***Rationale***: *Modulation schemes are chosen to be compatible with existing C&T Network infrastructure as described in the Space Network Users Guide (GSFC-450-SNUG), Rev. 8, sections 5.3 and 6.3. DG1/Mode 3 modulations are supported by both the Point A and Point B side of a link for rendezvous radiometrics simultaneous with high data rates.*

Constellation point A SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-3 for operational point-to-point links. [C3I-574]

> ***Rationale***: *Modulation schemes are chosen to be compatible with existing C&T Network infrastructure as described in the Space Network Users Guide (GSFC-450-SNUG), Rev. 8, sections 5.2 and 6.2. DG1/Mode 3 modulations are supported by both the Point A and Point B side of a link for rendezvous radiometrics simultaneous with high data rates.*

Constellation point A SYSTEMS shall transmit independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 (DG1). [C3I-633]

> ***Rationale***: *Transmitting two independent data streams allows for the use of different coding, permits discrimination between low and high latency tolerant data on the same downlink signal, and is compatible with the Space Network S-band Multiple Access (SMA) Demand Access Service (DAS).*

3.1.2.3 Point B Operational Point-to-Point RF Communication

Table 3.1-3 - Point B Operational Point-to-Point Signal Characteristics

Coded Symbol Rate	Doppler Measurement	PN Ranging	Modulation	PN Spreading
>= 18 Ksps <= 300 Ksps	Two-Way	Yes	Unbalanced SQPN (10:1)	Yes
>= 18 Ksps <= 300 Ksps	One-Way	Yes	Unbalanced SQPN (10:1)	Yes
>= 300 Ksps <= 6 Msps	Two-Way	No	BPSK	No
>= 300 Ksps <= 6 Msps	One-Way	No	BPSK	No
>= 18 Ksps <= 6 Msps	Two-Way	Yes	SQPN	Yes

Constellation Point B SYSTEMS shall generate and modulate the range channel (Q channel) with the Forward Link Range Channel PN code as defined in the Space Network Interoperable PN Code Libraries, Rev. 1 (451-PN CODE-SNIP). [C3I-591]

> ***Rationale***: *In order to make radiometric range measurements between SYSTEMS, Point B SYSTEMS must generate and modulate the range channel data for processing by Point A SYSTEMS.*

Constellation point B SYSTEMS shall process coherent turn-around ranging channel data to provide radiometric measurements of range data for operational point-to-point links. [C3I-572]

> ***Rationale****: In order to provide the range data, point B SYSTEM must be able to receive the coherent turn-around ranging channel data and process it.*

Constellation point B SYSTEMS shall transmit signals with modulation schemes in accordance with Table 3.1-3 for operational point-to-point links. [C3I-575]

> ***Rationale****: Modulation schemes are chosen to be compatible with existing C&T Network infrastructure as described in the Space Network Users Guide (GSFC-450-SNUG), Rev. 8, sections 5.2 and 6.2. . DG1/Mode 3 modulations are supported by both the Point A and Point B side of a link for rendezvous radiometrics simultaneous with high data rates.*

Constellation point B SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-2 for operational point-to-point links. [C3I-576]

> ***Rationale****: Modulation schemes are chosen to be compatible with existing C&T Network infrastructure as described in the Space Network Users Guide (GSFC-450-SNUG), Rev. 8, sections 5.3 and 6.3. DG1/Mode 3 modulations are supported by both the Point A and Point B side of a link for rendezvous radiometrics simultaneous with high data rates.*

Constellation point B SYSTEMS shall process the coherent turn-around carrier to make radiometric measurements of range rate data (two-way Doppler data) for operational point-to-point links. [C3I-315]

> ***Rationale****: Radiometric range-rate measurements observed from operational point-to-point links are used by flight dynamics to determine SYSTEM location, trajectory and plan maneuvers.*

Constellation point B SYSTEMS shall receive independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 (DG1). [C3I-634]

> ***Rationale****: Receiving two independent data streams allows for the use of different coding, permits discrimination between low and high latency tolerant data on the same downlink signal, and is compatible with the Space Network S-band Multiple Access (SMA) Demand Access Service (DAS).*

3.1.3 High-Rate Point-to-Point RF Communication

These links provide high bandwidth (up to 150 Mbps) to communicate high volume data between in-space SYSTEMS and with communications infrastructure. They can be used to provide communication services such as high rate MOTION IMAGERY, i.e., HDTV, recorder and stored telemetry dumps, and advanced file transfer. High Rate Point-to-Point links may be used between in-space Constellation SYSTEMS (as in a crosslink configuration) as well as between systems and communications and tracking infrastructure such as the Space Network, DSN, GN, future lunar relay systems and possible non-NASA network systems.

3.1.3.1 Common High Rate RF Communication

Constellation SYSTEMS shall transmit using Right-hand Circular polarization for high rate point-to-point links. [C3I-581]

> ***Rationale**: RHCP transmit is required to use Space Network Ka-Band service. SYSTEMS are not limited to RCHP alone; polarization diversity can be used to enhance the ability to simultaneously communicate with each other and with future non-Space Network Ka-band assets.*

Constellation SYSTEMS shall receive using Right-hand Circular polarization for high-rate point-to-point links. [C3I-589]

> ***Rationale**: The Constellation Program plans to use the Space Network Ka-Band SA service; RHCP receive is required to use this service. SYSTEMS are not limited to RCHP alone; polarization diversity can be used to enhance the ability to simultaneously communicate with each other and with future non-Space Network Ka-band assets.*

Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3, to transmit data streams for high rate point-to-point links. [C3I-30]

> ***Rationale**: Appropriate FORWARD ERROR CORRECTION coding is normally required to ease the implementation of transmit power and antenna gain requirements in space communications applications. LDPC shows greater spectral and power efficiency for a given increase of link margin through coding gain than the traditional CCSDS rate 1/2 convolutional and Reed-Solomon codes. Selection of the CCSDS Rate ½ LDPC code is based on C3I SIG IDAC2 and IDAC3 studies (SIG-13-107).*

Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3, for decoding of received data streams using FEC for high rate point-to-point links. [C3I-583]

> ***Rationale**: Appropriate Forward Error Correction coding is normally required to ease the implementation of transmit power and antenna gain requirements in space communications application. LDPC shows greater spectral and power efficiency for a given increase of link margin through coding gain than the traditional CCSDS rate 1/2 convolutional and Reed-Solomon codes. Selection of the CCSDS Rate ½ LDPC code is based on C3I SIG IDAC2 and IDAC3 studies (SIG-13-107).*

Constellation SYSTEMS shall enable and disable communication link forward error correction (FEC) upon receipt of COMMAND for high rate point-to-point links. [C3I-632]

> ***Rationale**: Operations concepts, including diagnostic and low latency modes, require the ability to enable and disable communication link FEC.*

Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for transmission of IP packets for high rate point-to-point links. [C3I-673]

***Rationale**: MPoFR provides compatibility with existing and future commercial and CCSDS communication infrastructure. MPoFR has demonstrated a successful flight history on both US and international space missions. MPoFR provides organic support for both IPv4 and IPv6 packets. RFC 2427 specifies the addressing (Q.922), framing (Q.921) and data link layer (HDLC) definitions for use of MPoFR. Selection of MPoFR is based on studies conducted by CEV Project and C3I SIG during IDAC2 and IDAC3 analysis cycles.*

Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC-2427 for reception of IP packets for high rate point-to-point links. [C3I-674]

***Rationale**: MPoFR provides compatibility with existing and future commercial and CCSDS communication infrastructure. MPoFR has demonstrated a successful flight history on both US and international space missions. MPoFR provides organic support for both IPv4 and IPv6 packets. RFC-2427 specifies the addressing (Q.922), framing (Q.921) and data link layer (HDLC) definitions for use of MPoFR. Selection of MPoFR is based on studies conducted by CEV Project and C3I SIG during IDAC2 and IDAC3 analysis cycles.*

Constellation SYSTEMS shall transmit Multiprotocol Interconnect over Frame Relay (MPoFR) as serial octet-aligned streams per CCSDS recommendation "IP over CCSDS Space Links", CCSDS 702.1-R-1, using the Virtual Channel Access (VCA) service of CCSDS Advanced Orbiting Systems (AOS) Space Link Protocol as specified in CCSDS 732.0-B-2 for High Rate point-to-point links. [C3I-603]

***Rationale**: The AOS VCA service provides compatibility with existing space network and ground network hardware and software. CCSDS recommendation CCSDS 702.1-R-1 (IP over CCSDS Space Links) specifies the use of VCA service (as defined for AOS in CCSDS 732.0-B-2) as the proper way to transport the serial octet-aligned streams produced by MPoFR. While AOS provides native support for the IPv4 packet, serial octet-aligned streams are required as CCSDS AOS does not provide native support for the IPv6 packet. Compliance with CCSDS recommendations provides the greatest compatibility and flexibility for interoperability with commercial and international partners. Selection of MPoFR is based on C3I SIG studies during IDAC2 and IDAC3, as well as decisions made as a result of the Constellation Program SRR. Note that the receive side of this REQUIREMENT is covered by the REQUIREMENT to implement the AOS service access points (C3I-601).*

Constellation SYSTEMS shall comply with the specifications for service access points as defined in section 3 of AOS Space Data Link Protocol 732.0.B-2 for reception of Multiprotocol Interconnect over Frame Relay using the CCSDS AOS Virtual Channel Access service over high rate point-to-point links. [C3I-601]

***Rationale**: The service access points in section 3 of 732.0.B-2 define mechanisms to encapsulate higher-layer data for transmission to other SYSTEMS. Using 732.0.B-2 will ensure compatibility among SYSTEMS, and with existing ground infrastructure.*

Compliance with CCSDS 732.0.B-2 service access point specifications provides the receive side (bitstream decapsulation) capability for the VCA service. Use of AOS VCA is recommended by CCSDS 702.1-R-1, "IP over CCSDS Space Links", and allows for both the IPv4 and IPv6 packets.

Constellation SYSTEMS shall apply the Attached Sync Marker (ASM) defined in CCSDS 131.0-B-1 as specified in CCSDS 131.1-O-1, Section 3.5, to transmit FEC code blocks high rate point-to-point links. [C3I-600]

***Rationale**: Use of the CCSDS ASM (frame sync pattern) per CCSDS 131.0-B-1 provides receiver hardware the ability to perform synchronization of the start of a FEC code block frame, and will ensure interoperability between Constellation SYSTEMS and SYSTEMS/C&T network links. CCSDS 131.1-O-1 specifies the use of a 64-bit ASM pattern as defined in CCSDS 131.0-B-1 rather than the legacy 32-bit pattern.*

Constellation SYSTEMS shall use the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 for synchronization of received FEC code block frames as specified in CCSDS 131.1-O-1 for high rate point-to-point links. [C3I-675]

***Rationale**: Use of the CCSDS ASM (frame sync pattern) per CCSDS 131.0-B-1 provides receiver hardware the ability to perform synchronization of the start of a FEC code block frame, and will ensure interoperability between Constellation SYSTEMS and SYSTEMS/C&T network links. CCSDS 131.1-O-1 specifies the use of a 64-bit ASM pattern as defined in CCSDS 131.0-B-1 rather than the legacy 32-bit pattern.*

Constellation SYSTEMS shall use bit randomization techniques in accordance with CCSDS 131.0-B-1 for randomization of transmitted data streams for high rate point-to-point links. [C3I-31]

***Rationale**: Use of bit randomization techniques as specified in CCSDS 131.0-B-1 ensure the proper bit synchronization process and interoperability between Constellation systems, and compatibility between Constellation system/C&T Network links.*

Constellation SYSTEMS shall use bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-randomization of received data streams for high rate point-to-point links. [C3I-598]

***Rationale**: Use of bit randomization techniques as specified in CCSDS 131.0-B-1 will ensure the proper bit synchronization process and interoperability between Constellation SYSTEMS, and compatibility between Constellation system/C&T Network links.*

Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for transmission of non-FEC coded data streams for high rate point-to-point links. [C3I-676]

***Rationale**: NRZ-M symbol coding provides the means for a receiving SYSTEM to resolve phase ambiguity of the modulated data stream. CCSDS 131.1-O-1 specifies that NRZ-M coding should not be used when the data stream is encoded with LDPC FEC codes.*

Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for resolution of symbol phase ambiguity of non-FEC coded data streams for high rate point-to-point links. [C3I-677]

> ***Rationale***: *NRZ-M symbol coding provides the means for a receiving SYSTEM to resolve phase ambiguity of the modulated data stream. CCSDS 131.1-O-1 specifies that NRZ-M coding should not be used when the data stream is encoded with LDPC FEC codes.*

3.1.3.2 Point A High-Rate Point-to-Point RF Communication

Table 3.1-4 - Point A High Rate Point-to-Point Signal Characteristics

Data rate	Data Group	Modulation	Doppler Measurement	Ranging	PN Spreading
> = 1 Mbps and <= 150 Mbps	DG2, Non-coherent	Balanced SQPSK	One-way	No	No

Constellation point A SYSTEMS shall use transmit signals with modulation schemes in accordance with Table 3.1-4 for high rate point-to-point links. [C3I-577]

> ***Rationale***: *Modulation schemes are chosen to be compatible with existing C&T Network infrastructure as described in the Space Network Users Guide (GSFC-450-SNUG), Rev. 8, section 8.3.*

Constellation point A SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-5 for high rate point-to-point links. [C3I-578]

> ***Rationale***: *Modulation schemes are chosen to be compatible with existing C&T Network infrastructure as described in the Space Network Users Guide (GSFC-450-SNUG), Rev. 8, section 8.2*

3.1.3.3 Point B High-Rate Point-to-Point RF Communication

Table 3.1-5 - Point B High Rate Point-to-Point Signal Characteristics

Data rate	Data Group	Modulation	Doppler	Ranging	PN Spreading
>1 Mbps and <= 25 Mbps	N/A	BPSK, NRZ-M	One-way	No	No

Constellation point B SYSTEMS shall transmit signals with modulation schemes in accordance with Table 3.1-5 for high rate point-to-point links. [C3I-579]

> ***Rationale****: Modulation schemes are chosen to be compatible with existing C&T Network infrastructure as described in the Space Network Users Guide (GSFC-450-SNUG), Rev. 8, section 8.3.*

Constellation point B SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-4 for high rate point-to-point links. [C3I-580]

> ***Rationale****: Modulation schemes are chosen to be compatible with existing C&T Network infrastructure as described in Space Network Users Guide (SNUG), Rev. 8.*

3.1.4 Multipoint Proximity RF Communication

Proximity links enable in-space systems to communicate in close proximity. This link provides services including voice, motion imagery (low or high-rate), command, telemetry and file transfer in a multi-user environment. This link supports wireless Extra-Vehicular Activity (EVA) or “mesh” communications. In addition to in-space close proximity operations, the Proximity Link class will be used by systems in close proximity on the Lunar surface. Protocols for Multipoint Proximity RF Communication are being studied by the NASA Lunar Architecture Team, Constellation C3I SIG, and NASA Space Communications Architecture Working Group. This section is reserved pending results of those studies for the lunar phase architecture <TBD 3-2>.

3.1.5 Recovery RF Communication

Recovery / Search and Rescue (SAR) Links provide a communications path between crew and vehicles and the recovery, search and rescue forces. These links provide high reliability voice and location information, and provide compatibility with US and international SAR systems.

3.1.5.1 Common Recovery RF Communication

Constellation SYSTEMS shall use amplitude modulation (AM) for analog voice communication with US and international search and rescue forces. [C3I-362]

> ***Rationale****: Constellation SYSTEMS must provide an analog voice communication path between the crew and rescue / recovery forces. Use of both UHF AM (UHF specified in CxP-70022, Vol 2) ensures the greatest possible interoperability with recovery forces.*

Constellation SYSTEMS shall use narrowband frequency modulation (FM) for analog voice communication with US and international maritime search and rescue forces. [C3I-678]

> ***Rationale***: *Constellation SYSTEMS must provide an analog voice communication path between the crew and rescue / recovery forces. Use of VHF FM (VHF specified in CxP-70022, Vol 2) ensures compatibility with civilian maritime traffic as well as government maritime search and rescue.*

Constellation SYSTEMS shall transmit to the COSPAS/SARSAT system per COSPAS/SARSAT document C/S T.001 Sections 2 and 3. [C3I-363]

> ***Rationale***: *The global COSPAS/SARSAT search and rescue system provides 24/7 emergency location and distress alerting services. Beacons compatible with COSPAS/SARSAT must comply with C/S T.001 (Specification for Cospas-Sarsat 406 MHz Distress Beacons).*

Constellation SYSTEMS shall transmit to the COSPAS/SARSAT system using the spectrum guidelines provided by ITU-R Recommendation M.633. [C3I-347]

> ***Rationale***: *ITU-R M.633 details the spectral characteristics of a satellite emergency position indicating radiobeacon (EPIRB) device for use with low-earth orbiting SAR systems such as COSPAS/SARSAT.*

Constellation SYSTEMS shall communicate using the US UHF SATCOM system per MIL-STD-188-181. [C3I-679]

> ***Rationale***: *UHF SATCOM provides global voice and data connectivity. MIL-STD-188-181 provides the detailed specifications for communication between user terminals (Constellation SYSTEMS) and the UHF SATCOM system.*

3.1.6 RF Contingency Voice Communication

The contingency voice link provides an independent, dissimilar voice link when nominal communications systems are unavailable due to failure, misconfiguration, or some anomaly. This link provides a communication path in the event of off-nominal spacecraft conditions such as unusual attitude (loss of antenna pointing), reduced power operations, and other conditions in which the system is not able to support a full capacity link, including the possibility of unidirectional links.

3.1.6.1 Common RF Contingency Voice Communication

Constellation SYSTEMS shall modulate the transmitted carrier using amplitude modulation for analog, half-duplex Contingency Voice links. [C3I-385]

> ***Rationale***: *Analog AM provides a basic voice or data capability between SYSTEMS. Half-duplex allows a simple, common channel communication in which one SYSTEM transmits while many listen. This permits multiple SYSTEMS to communicate simultaneously using a shared channel. 401-402 MHz has been identified (specified in CxP-70022, Vol 2) as available spectrum for multipoint direct half duplex*

communication and is supported for space-to-space, space-to-Earth, and Earth-to-space services.

Constellation SYSTEMS shall receive an amplitude modulated carrier for Contingency Voice links. [C3I-680]

***Rationale**: Analog AM provides a basic voice or data capability between SYSTEMS. While only one SYSTEM can transmit at a time using a common frequency, many systems can simultaneously receive the transmission. This permits multiple SYSTEMS to communicate simultaneously using a shared channel. 401-402 MHz has been identified (specified in CxP-70022, Vol 2) as available spectrum for multipoint direct half duplex communication and is supported for space-to-space, space-to-Earth, and Earth-to-space services.*

3.1.7 Future High Rate Link Class

RESERVED

3.1.8 Vehicle Internal Wireless Link Class

Constellation SYSTEMS shall use IEEE 802.11g on non-critical internal local area wireless data networks. [C3I-681]

***Rationale**: Portable Crew equipment such as laptops and PDAs will need access to flight vehicle resources. One of the most prevalent wireless standards, currently, for crew equipment such as a laptop computer is IEEE 802.11g. This may not be the standard for Lunar Missions.*

3.2 Hard-Line Communication

Hard line links provide a communication path between systems that are physically joined. This includes GSE connections during system integration, test, and launch operations, as well as connections between systems that have docked. Ground institutional links include all links required between ground systems that leverage NASA institutional networks. This includes links between control centers and ground sites, as well as ground-to-system links during test and verification (T&V).

3.2.1 High-Rate, Hard-Line Communication

This section specifies interoperability requirements for non-time-critical hard-line communication between and within Constellation systems. Note that requirements in this section include hardline interfaces used for flight-flight systems interfaces and flight-ground system interfaces.

Constellation SYSTEMS shall use IEEE Std 1394b™-2002 and SAE-AS5643/1 with RFC-2734 for high data volume, hard-line connections between Constellation SYSTEMS. [C3I-58]

***Rationale**: High rate data will be needed for interchange of data between directly connected Constellation SYSTEMS. IEEE-1394 and SAE-AS5643/1 are selected based on the trade study conducted by the Lockheed-Martin/Honeywell Team (DRD CEV-T-008,* *Section 31, Avionics Technology). The SAE-5643/1, S400 Copper Media Interface Characteristics over Extended Distances, is the copper media standard using IEEE 1394b in SAFETY CRITICAL/MISSION CRITICAL applications for military and aerospace covering items such as bus isolation for lightning protection, and cable requirements. RFC-2734 is the standard for IPv4 over 1394. IP based network communications will be used over the high rate hard-line interface.*

3.2.2 High-Rate, Ground Hard-line Communication

This section specifies interoperability requirements for non-time-critical hard-line communication between and within Constellation ground systems.

Constellation SYSTEMS shall use ground institutional IP routed networks. [C3I-336]

***Rationale**: Constellation data flows are based on the IP packet as the basic data block. All networks supporting Constellation flows between ground systems, including control centers, ground stations, and I&T systems must support IP flows. Connections between complexes and infrastructure are expected to be provided by NISN.*

3.2.3 Deterministic Hard-line Communication

Reserved

Constellation SYSTEMS shall use SAE-AS5643 and AS5643/1 standards for deterministic rate based hard-line connections between Constellation SYSTEMS. [C3I-682]

***Rationale**: Deterministic rate-based connection will be needed for interchange of data between directly connected Constellation SYSTEMS. IEEE-1394 and SAE-AS5643 are is selected based on the trade study conducted by the Lockheed-Martin/Honeywell Team (DRD CEV-T-008, Section 31, Avionics Technology). The SAE-AS5643, IEEE-1394b Interface Requirement for Military and Aerospace Vehicle Applications, is a deterministic rate-based communication protocol overlaid on IEEE Std 1394 for use in SAFETY CRITICAL/MISSION CRITICAL application interfaces for military and aerospace application. SAE-5643/1, S400 Copper Media Interface Characteristics over Extended Distances, is the copper media standard using IEEE-1394b in SAFETY CRITICAL/MISSION CRITICAL applications for military and aerospace covering items such as bus isolation for lightning protection, and cable requirements. This requirement is intended to be applicable for connectivity to flight SYSTEMS.*

3.3 Network

This section provides the requirements on Constellation SYSTEMS to implement the Internet Protocol (IP) as a networking layer. The IP provides a common format for encapsulating user data that includes end-to-end addressing, Quality of Service marking, and protocol multiplexing capabilities.

Figure 3.3-1 represents one possible method for NASA to assign IP addresses to systems. In this simplistic strategy, each 'enclave' is assigned a class B (/16) address space, with the Earth receiving 10.0.0.0/16 (all addresses beginning with 10.0), CEV1 receiving the 10.2.0.0/16 space, a Lunar Base allocated 10.3.0.0/16, and CEV2 using 10.4.0.0/16. All interfaces that radiate across space links (gray box) are drawn from the 10.1.0.0/16 address space, and the local area network (LAN) and wide area network (WAN) interfaces of each space system are explicitly called out. Three different types of ground-to-space communication mechanisms are shown. On the left is a networking relay capable of performing network-layer routing. A portion of the relay's routing table shows that all destinations matching 10.2.0.0/16 (CEV1) are forwarded out Interface_0 to the CEV, and those matching 10.0.0.0/16 (Earth) are forwarded out Interface_1. A direct connection is shown between GS2 and the lunar base. Finally, a layer1/layer2 relay is shown on the right. The portion of the routing table shown for the ground station shows that it is directly connected to CEV2 (10.1.0.47) via Interface_0. The fact that the ground station's signal is transponded through an orbiting relay is transparent to the network layer. If the ground station itself were a legacy ground station, it might not contain a routing table at all, in which case some other mechanism such as the CCSDS Space Link Extensions (SLE) could be used to carry pre-formatted (at the data link layer) traffic from a mission operations center to the ground station.

Custom interfaces will be required in order to communicate with legacy SYSTEMS such as STS and ISS. These interfaces will need to conform to the existing physical and data link layer specifications, and will presumably need to interoperate with existing applications. As existing applications typically encapsulate their data inside CCSDS packets inside CCSDS Telecommand, TELEMETRY, or Advanced Orbiting Systems frames, Constellation legacy interfaces will need to do the same. Note that because legacy systems do not implement the networking functions of Constellation, COMMAND, control, and TELEMETRY with legacy systems will most likely be limited to a single physical layer communications hop as shown in Figure 3.3-2; multi-hop communications such as those used by one Constellation SYSTEM to communicate with another several hops away will likely not be possible. Tunneling mechanisms such as Space Link Extensions (SLE) may be used to extend the communications endpoint over a routed network. A number of IP-enabled network appliances such as IP telephones and webcams may exist within Constellation SYSTEMS. These devices usually, but not always, implement the configuration functions described in this specification and required of Constellation network-addressable endpoints (ability to set IP address, next hop router, and DNS information via a management interface).

Due to the relative maturities of the protocols, early phases of Constellation will use primarily IPv4, with a transition to IPv6 sometime during the program. Unless otherwise stated, the requirements in this section apply to both IPv4 and IPv6. Those requirements marked as applying to IPv4 and IPv6 only also apply to all dual-stack (IPv4/IPv6) instances.

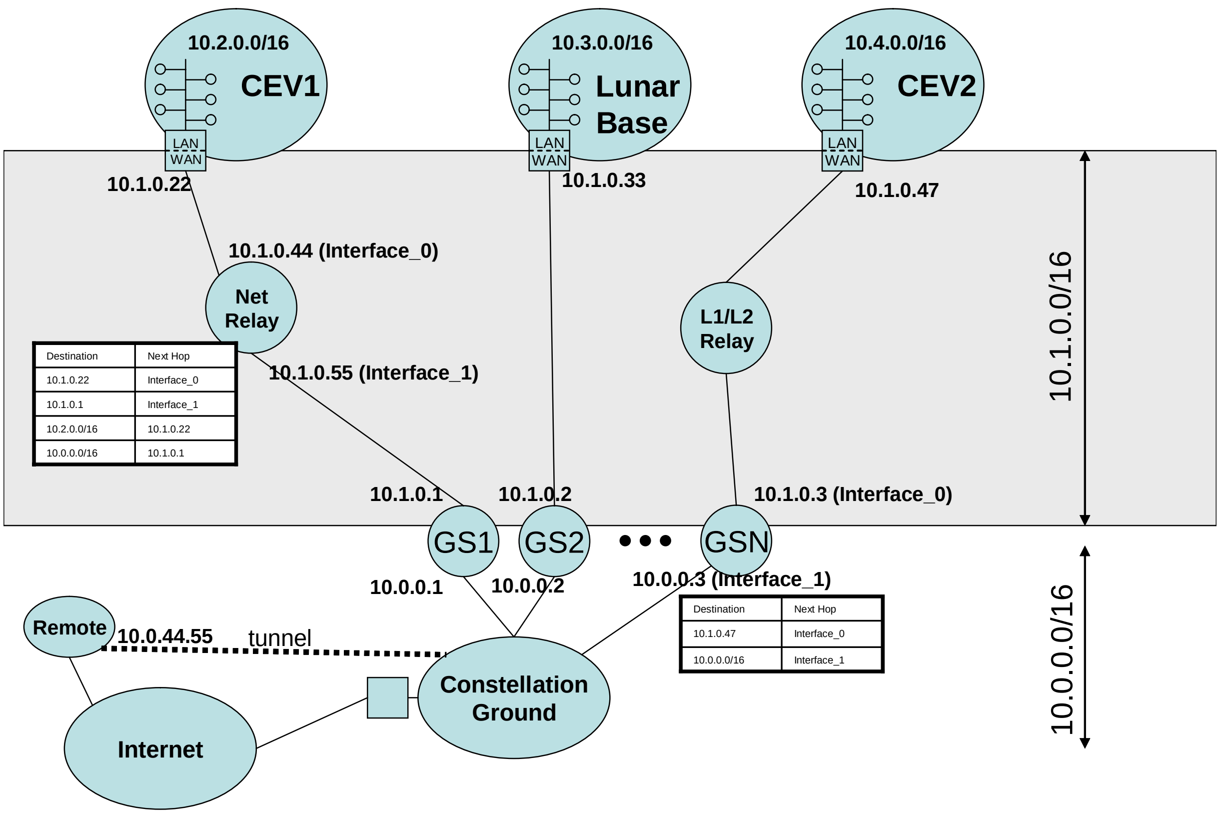

Figure 3.3-1 - Notional Addressing Scheme Using Private Addresses

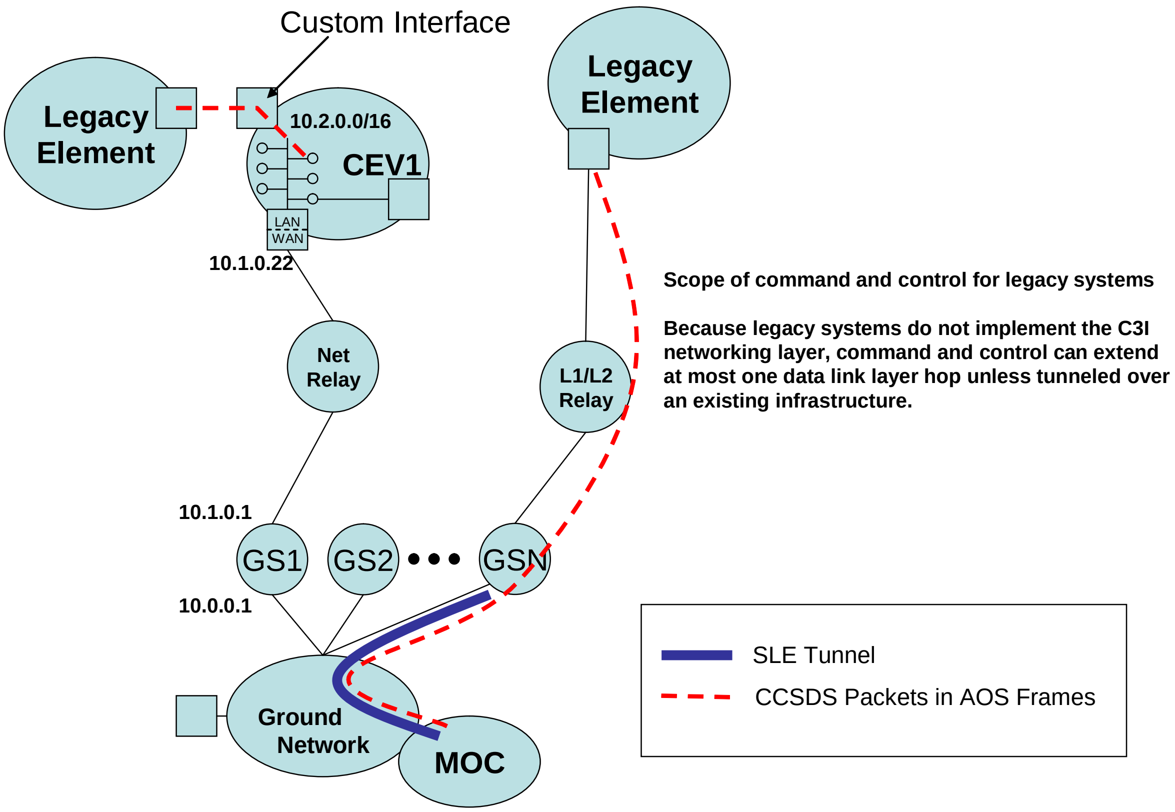

Figure 3.3-2 - Communication with Legacy Systems

3.3.1 Connectivity

This section defines how data packets will be instructed to traverse the Constellation network. The approach is based on a dynamic/mobile network environment with automatic "multi-hop" routing from one end-point to another endpoint. Note that data paths are not forced to go through earth-based systems (hub and spoke) if a more direct path exists between end systems.

NOTE: Static routing can be used to facilitate routing convergence, to provide routing information when only simplex links are available, and to minimize packet loss when routing changes occur. Route path changes are especially prevalent within networks that consist of constantly moving systems like the Constellation network. Requiring support for managed (often referred to as 'static') ARP and routing table entries ensures that it will be possible to support critical operations with little or no interference from conditions such as simplex links or route convergence issues caused by link interruptions.

While the utilization of static routes often requires more administrative resources and manual processes than dynamic routing, it is possible to automate and minimize the administrative impact of static routing given a deterministic routing environment of reasonable scale.

Constellation SYSTEMS shall implement version 4 of the Internet Protocol (IPv4) as specified in STD-0005. [C3I-61]

> ***Rationale****: IP provides end-to-end addressing capability and traffic prioritization markings for data. STD-005 includes the following RFCs: 791, 792, 919, 922, 950 and 1122. RFC-791 is updated by RFC-1349, which is obsoleted by RFC-2474 (definition of the differentiated services field). RFC-2474 is included as a separate requirement. RFC-792 (ICMP) is updated by RFC-950 (Internet Standard Subnetting Procedure), which is specified separately. STD-0005, and hence this requirement, applies only to IPv4.*

Constellation SYSTEMS shall implement the Multiprotocol Border Gateway Protocol (MBGP) as specified in RFC-2858. [C3I-654]

> ***Rationale****: The multiprotocol BGP (MBGP) feature adds capabilities to BGP to enable multicast routing policy throughout the Internet and to connect multicast topologies within and between BGP autonomous systems.*

Constellation SYSTEMS shall implement the Multicast Listener Discovery protocol, version 2, as specified in RFC-3810 <TBR 3-24>. [C3I-655]

> ***Rationale****: The Multicast Listener Discovery (MLD) protocol is an essential protocol for multicasting traffic in IPv6 systems. MLD enables IPv6 routers to discover the presence of multicast subscribers and to determine which multicast groups are of interest to attached subscribers.*

Constellation SYSTEMS shall implement Multicast Extension to OSPF as specified in RFC-1584. [C3I-656]

> ***Rationale****: OSPF is one of the most common interior gateway protocols used in the Internet today. MOSPF is the multicast extension to OSPF.*

Constellation SYSTEMS shall implement the Internet Group Management Protocol (IGMP) as specified in RFC-3376. [C3I-657]

> ***Rationale****: The Internet Group Management Protocol (IGMP) is an essential protocol for multicasting traffic in IPv4 systems. Hosts use IGMP to dynamically register their multicast group memberships and network devices use IGMP to discover group members and route or switch multicast traffic accordingly.*

Constellation SYSTEMS shall implement Internet Protocol version 6 (IPv6) per RFC 2460 Internet Protocol, Version 6 (IPv6) Specification. [C3I-620]

> ***Rationale****: IP provides end-to-end addressing capability and traffic prioritization markings for data. This REQUIREMENT and the REQUIREMENT to implement IPv4 require Constellation SYSTEMS to implement "dual stack" IPv4/IPv6 routing capabilities. RFC2460 defines IPv6, and hence is not applicable for IPv4.*

Constellation SYSTEMS shall implement the Internet Control Messaging Protocol (ICMP) per RFC 792, Internet Control Message Protocol. [C3I-621]

Rationale*: ICMP is needed to inform hosts/routers when destinations are not reachable, when packets have timed out, and to carry other diagnostic information.*

Constellation SYSTEMS shall implement the Internet Control Messaging Protocol version 6 (ICMPv6) per RFC 4443 Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification. [C3I-622]

Rationale*: ICMP is needed to inform hosts/routers when destinations are not reachable, when packets have timed out, and to carry other diagnostic information.*

Constellation SYSTEMS shall use unicast addresses as defined in RFC-1918, Address Allocation for Private Internets. [C3I-62]

Rationale*: Using private unicast address space would allow easier administration/allocation of addresses and ensure the AVAILABILITY of enough contiguous address space for the Constellation network. Using publicly routable addresses would allow direct communication between non-Constellation Networks and space assets. This REQUIREMENT simply ensures that the private address spaces, which by convention are not routed across the Internet, are supported for Constellation. RFC1918 applies to IPv4 addressing only.*

Constellation SYSTEMS shall use multicast addresses as defined in RFC-3171, IANA Guidelines for IPv4 Multicast Address Assignments. [C3I-63]

Rationale*: Existing ground infrastructure may already use public multicast addresses (224.0.0.0/8 through 233.0.0.0/8). The 239.0.0.0/8 address block is used for multicast in private networks. RFC3171 applies to IPv4 addressing only.*

Constellation SYSTEMS shall provide a mechanism to manually configure the addresses of all IP-addressable interfaces. [C3I-64]

Rationale*: While most IP addresses in Constellation will remain fixed, it may be desirable to reconfigure some or all addresses on a particular system. The exception for devices that support only DHCP and self-assigned addresses is an attempt to allow COTS network appliances that may not support full manual configuration. Typically this mechanism is implemented in a management interface.*

Constellation SYSTEMS shall perform multi-hop routing as specified in RFC-1812, Requirements for IP Version 4 Routers as updated by RFC-2644. [C3I-75]

Rationale*: These Constellation SYSTEMS are generally referred to as "routing elements". This and STD-0003 leverage the maturation and experience gained via 10+ years of commercial internet deployments. These are the BASELINE specification documents utilized by commercial network EQUIPMENT providers in providing standards compliant devices using the internet protocols. RFC-2644 allows routers to decline to forward directed broadcasts.*

Constellation SYSTEMS shall comply with RFC-1122 (STD-0003), Requirements for Internet Hosts – Communications Layers. [C3I-76]

***Rationale**: The aforementioned document reflects a neatly packaged REQUIREMENTS and specifications list outlining fundamental internet host and routing functions. The document leverages the maturation and experienced gained via 10+ years of commercial internet deployments. This is the baseline specification document utilized by commercial network equipment providers in providing standards compliant devices using the internet protocols. RFC1122 is updated by RFCs 1349 and 4379. RFC-1349 is obsoleted by RFC-2474 which is required separately. RFC-4379 has to do with detecting MPLS data plane failures. Since this document does not require the use of MPLS, RFC-4379 is not required. RFC-1122 applies to IPv4 hosts only.*

Constellation SYSTEMS shall use manually configured routes instead of dynamically learned ones when there is an exact match in the prefix length for a given destination external to the SYSTEM. [C3I-78]

***Rationale**: When static routes are preferred over exactly matching dynamic routes, it provides for more flexibility and control in managing the routing and data flow within a network. This feature allows the ground controllers to manually set a route for a destination on the network when the dynamic route is not desired. In this scenario, it is assumed that dynamic routing is predominantly used within the Constellation network and static routes are the exception instead of the norm.*

Constellation SYSTEMS shall provide IP network address to data link layer address mappings for IP addresses external to the SYSTEM. [C3I-72]

***Rationale**: The link layer addresses of the next hop(s) is(are) required to transmit the packet. The population of the mapping information may be via a management interface (local or remote), or via an automated protocol such as the Address Resolution Protocol (ARP) on Ethernet. In general, protocols for address resolution are link-layer dependent.*

Constellation SYSTEMS shall use managed associations to map IP addresses to data link layer addresses for IP addresses external to the SYSTEM. [C3I-73]

***Rationale**: If there is no address resolution protocol, the only way for one IP node to determine the data link address of a neighboring node (needed in order to communicate with the neighbor) is to use managed entries. This requirement merely says that SYSTEMS will be able to have and use managed entries; the actual set of entries in use at any particular time by a particular SYSTEM may consist of a mix of dynamically populated and managed entries.*

Constellation SYSTEMS shall accept modifications to the IP address to data-link layer address mapping information via the network for IP addresses external to the SYSTEM. [C3I-74]

***Rationale**: Ground controllers may need to manage entries in the IP-to-data link layer mapping tables of the various IP-addressable SYSTEMS. This requirement ensures that the IP-to-data link mapping information can be managed remotely (via IP).*

Constellation SYSTEMS shall use static routing table entries. [C3I-79]

> ***Rationale***: *Ground controllers need to be able to manually configure the path that packets take through the network. This is especially important early in the program as the communications network will be managed more manually.*

Constellation SYSTEMS shall accept changes to the routing tables via the network. [C3I-80]

> ***Rationale***: *There needs to be some way for ground controllers to manipulate the routing tables.*

Constellation SYSTEMS shall have a default route specified in the routing tables. [C3I-89]

> ***Rationale***: *There will always be a usable route in the routing table even if the routing process is not functioning (i.e. in an emergency). This default route will be the route of last resort. Note that the 'next hop' in the default route may include redundancy, such as with the virtual router redundancy protocol (vrrp).*

Constellation SYSTEMS shall fail over to default routes when there is a loss of all routing information or a loss of communication to all SYSTEM network neighbors participating in the dynamic routing protocol for more than 20 seconds. [C3I-90]

> ***Rationale***: *In case of a loss of all dynamic routing information, Constellation SYSTEMS need to fail over to a well-known, operational, default route. Such routes may be sub-optimal in terms of performance, but should be extremely robust. The exact value of the default route will be configured; failover to the default will take no more than 20 seconds from the time data link layer connectivity is lost.*

Constellation SYSTEMS shall advertise only non-default routes via the routing protocols. [C3I-87]

> ***Rationale***: *Not advertising default routes will cause Constellation SYSTEMS to avoid routes that may not be appropriate for operations. This will also give greater control on bandwidth utilization.*

Constellation SYSTEMS shall resolve symbolic names to IP addresses using static host table. [C3I-93]

> ***Rationale***: *While DOMAIN NAME SERVICES (DNS) may be available in addition to static host tables, static host tables will provide high-reliability mechanisms for mapping 'important' DNS names to addresses. Using tables at each host relieves the need for connectivity to a DNS server. Some laboratory work will be needed to determine the best way to manage DNS zone transfers among intermittently-connected SYSTEMS, and how, or if, an appropriate DNS hierarchy can be set up.*

Constellation SYSTEMS shall accept changes to the static host table via the network. [C3I-95]

> ***Rationale***: *In general, symbolic names are used to reference Constellation SYSTEMS when humans are interacting with Constellation SYSTEMS or there is a visual representation of the Constellation network. This visual representation is usually portrayed via a NETWORK MANAGEMENT station or something similar. Symbolic*

names are also used to mask potential IP address changes that may take place on Constellation SYSTEMS which are not assigned their own block of static IP addresses. This allows the SYSTEM to refer to one identifying label for each SYSTEM and would alleviate the need to keep track of IP address changes if they should occur. Given the fact that initially there will be a small finite number of Constellation SYSTEMS, it is recommended that there be a technology evolution and growth path from using static host tables to Domain Name Service for symbolic name to address mappings.

Constellation SYSTEMS shall implement <TBR 3-25> RFC-2205, Resource ReSerVation Protocol (RSVP) Version 1 Functional Specification. [C3I-98]

***Rationale**: RSVP is the Internet standard signaling protocol supporting integrated services. RSVP provides the mechanism for the reservation of end-to-end resources within the Constellation network. RSVP would require support in the ground network as well from either an RSVP proxy at the 'edges' of the controlled bandwidth segments (e.g. edge routers on C3I systems and in ground station) or RSVP in the end SYSTEMS.*

RFC-2205 is updated by RFC-2750, RFC-3936, and RFC-4495. RFC-2750 has to do with carrying policy information inside RSVP messages. This is not required by Constellation, so RFC-2750 is not needed. RFC-3936 is a Best Common Practice (BCP) that discusses methods for updating the RSVP specification, which is not required by Constellation. RFC-4495 discusses ways to modify existing reservations to reduce their resource allocations; this capability is not required by Constellation and RFC-4495 is not required.

Constellation SYSTEMS shall implement the Simple Network Management Protocol version 3 as defined in STD0062. [C3I-99]

***Rationale**: SNMP is the industry standard for managing network elements. There is an abundance of software that uses SNMP to harvest information and display network status to operators. STD0062 includes RFCS 3410-3418, with RFC3410 being an Informational RFC. Note: SNMP runs over a wide range of transport protocols, including UDP.*

Constellation SYSTEMS shall implement STD-0006 - UDP, USER DATAGRAM PROTOCOL, for communication with all IP-addressable endpoints. [C3I-105]

***Rationale**: UDP is the standard Internet transport for unreliable datagram transfer, and functions over simplex paths. STD-0006 is also known as RFC-0768.*

Constellation SYSTEMS shall implement Internet STD-0007: TRANSMISSION CONTROL PROTOCOL (TCP). [C3I-103]

***Rationale**: TCP is the standard Internet protocol for reliable data delivery over bi-directional paths, and is used by many common applications including email (SMTP) and web browsing (HTTP). TCP provides a common transport service that frees applications from having to implement congestion control and reliable data delivery, thus freeing them to focus on application-specific issues. Note that TCP should only be used when* *there are not lengthy communications delays. STD-0007 is also known as RFC-0793. RFC-3168 updates RFC-793 with the addition of Explicit Congestion Notification (ECN). Constellation is currently not requiring the use of ECN, so RFC-3168 is not required.*

Constellation SYSTEMS shall implement RFC-1323 - TCP Extensions for High Performance. [C3I-104]

***Rationale**: RFC-1323 defines extensions that allow tuning of TCP parameters for better performance over paths with high bandwidth*delay products. Without these extensions, TCP performance degrades as the product of the network bandwidth and the end-to-end delay increases.*

Constellation SYSTEMS shall implement a split-connection TCP Performance Enhancing Proxy (PEP) that implements the SCPS-TP transport layer per CCSDS 714.0.B-1, Space Communications Protocol Specification (SCPS) - Transport Protocol (SCPS-TP), Blue Book, Issue 1, May 1999, on links where the maximum bandwidth*delay product of the link exceeds 1e6 bits and/or whose design bit error rate is equal to or greater than 1e-6. [C3I-619]

***Rationale**: Performance Enhancing Proxies are needed to increase TCP performance over paths that have large products of path bandwidth and RTT (large bandwidth*delay product, BDP, paths).*

Constellation SYSTEMS shall implement RFC-2474, Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers. [C3I-96]

***Rationale**: This is necessary to specify how to mark packets to comply with the IP Differentiated Services (DiffServ) architecture. DiffServ provides a scalable mechanism for providing differentiated treatment for different data. As such certain data can be marked as 'higher priority' than other data, with lower priority data discarded first in the case of network congestion. Support for any specific version of IP is not implied by this REQUIREMENT.*

RFC-2474 is updated by RFC-3168 and RFC-3260. RFC-3168 specifies how the 2 bits marked as 'unused' in RFC-2474 should be used to implement explicit congestion notification (ECN). Constellation does not specify the use of ECN, so RFC-3168 is not required. RFC-3260 is an Informational RFC that clarifies terminology for differentiated services.

Constellation SYSTEMS shall implement RFC-3550 (STD-0064), RTP: A Transport Protocol for Real-Time Applications. [C3I-106]

***Rationale**: RTP is the industry standard transport protocol for handling real-time data such as voice. Supporting RTP will facilitate the use of COTS applications such as VOICE-OVER-IP (VOIP) phones.*

Constellation SYSTEMS shall implement RFC-2211, Specification of the Controlled-Load Network System Service. [C3I-97]

> ***Rationale**: The Controlled-Load service provides service to flows that is roughly equivalent to what they would receive in an unloaded network, regardless of current network traffic volumes. This service could be used, for example, to ensure low-latency delivery of voice packets competing with large file transfers for bandwidth.*

Constellation SYSTEMS shall implement RFC-3140, Per Hop Behavior Identification Codes. [C3I-281]

> ***Rationale**: This is necessary to identify behaviors in order to comply with the IP Differentiated Services (DiffServ) architecture.*

Constellation SYSTEMS shall implement RFC-3246, An Expedited Forwarding PHB (PER HOP BEHAVIOR). [C3I-282]

> ***Rationale**: This is necessary to identify an additional behavior in order to comply with the IP Differentiated Services (DiffServ) architecture.*

3.3.2 Dynamic Routing Between Systems

Constellation may want to use dynamic routing to manage the systems' routing tables. The routing protocols specified here are mature internet standards with 10-15 years of production field experience. Commercially available internet routers have extensive field experience in supporting multiple routing protocols running simultaneously in a routing environment. The evolution and growth path of the routing strategy is described fully in a later section. The routing protocols listed include both internal and external gateway routing protocols.

NOTE: Experience with the Onboard Communications Adaptor (OCA) has shown that changes and/or disruptions in connectivity can impact IP communications, especially when dynamic routing protocols are used. An IDAC-3 study will investigate performance implications and possible mitigations using different dynamic routing protocols. Note that static routes may be used in conjunction with automated protocols to help mitigate these types of disruptions.

Constellation SYSTEMS shall implement RFC-2453, STD-0056 - RIP Version 2. [C3I-82]

> ***Rationale**: RIP is included because it runs over UDP and could thus function over simplex links. Note: It is not particularly clear that RIP will be useful, as if there is no bi-directional connectivity between SYSTEM A and SYSTEM B, having SYSTEM A inform SYSTEM B of the endpoints that SYSTEM A can reach does not particularly help SYSTEM B. Where this may be useful is in pre-advertising routing information to SYSTEM B (and SYSTEMS beyond B) in advance of establishing bi-directional connectivity between A and B. RFC2453 (RIPv2) applies to IPv4 operations only.*

Constellation SYSTEMS shall implement RFC-2080, RIPng for IPv6 . [C3I-662]

> ***Rationale**: RIP is included because it runs over UDP and could thus function over simplex links. Note: It is not particularly clear that RIP will be useful, as if there is no bi-directional connectivity between SYSTEM A and SYSTEM B, having SYSTEM A inform SYSTEM B of the endpoints that SYSTEM A can reach does not particularly help SYSTEM B. Where this may be useful is in pre-advertising routing information to*

SYSTEM B (and SYSTEMS beyond B) in advance of establishing bi-directional connectivity between A and B. This requirement applies only to IPv6 and dual IPv4/IPv6 operations.

Constellation SYSTEMS shall implement RFC-2328 (STD-0054), OPEN SHORTEST PATH FIRST (OSPF) Version 2. [C3I-83]

***Rationale**: OSPF is one of the most common INTERIOR GATEWAY PROTOCOLS (IGPs) used in the Internet today.*

Constellation SYSTEMS shall implement RFC-2740 , OSPF for IPv6. [C3I-663]

***Rationale**: OSPF is one of the most common INTERIOR GATEWAY PROTOCOLS (IGPs) used in the Internet today. RFC-2740 describes modifications to support IP version 6 (IPv6). This requirement applies only to IPv6 and dual IPv4/IPv6 operations.*

Constellation SYSTEMS shall implement RFC-3626 Optimized Link State Routing Protocol (OLSR). [C3I-295]

***Rationale**: OLSR supports the type of MANET routing that may be required for the space segment of Constellation.*

3.3.3 External Connectivity

Constellation SYSTEMS shall implement RFC-4271-A BORDER GATEWAY PROTOCOL (BGP) Version 4, as specified in RFC4271 "A BORDER GATEWAY PROTOCOL 4 (BGP-4) [C3I-81]

***Rationale**: BGP is the most commonly used EXTERIOR GATEWAY PROTOCOL (EGP) used in the Internet today. It allows for complex policy to be applied to routing exchanges.*

Constellation SYSTEMS shall use external routes learned by Border Gateway Protocol Version 4, as specified in RFC4271 “A Border Gateway Protocol 4 (BGP-4), before those learned via other dynamic routing protocols. [C3I-280]

***Rationale**: BGP is used for inter-AS routing and allows for extensive policy to be applied to route advertisements and injection. As such, external routes learned by BGP should be ‘better’ than similar routes learned via other routing protocols. This is typically implemented by specifying the priority in a field in the forwarding table.*

3.3.4 Name Service

This section describes the use of symbolic names and the process of mapping the names to network addresses. Humans often prefer to refer to IP addresses via these symbolic names, such as instrument1.CEV3.nasa.gov or instrument5.LSAM4.nasa.gov rather than having to memorize numeric addresses. In the Internet, the Domain Name System (DNS) is responsible for mapping these symbolic names to (sets of) IP addresses. For example, www.nasa.gov maps to the IP addresses 65.214.50.141 and 4.78.20.12. As with other ancillary protocols supporting IP, the mapping of symbolic names to IP addresses can take many forms.

Constellation SYSTEMS shall implement IETF STD-0013, Domain Name SYSTEM. [C3I-296]

> ***Rationale****: DNS provides a mechanism for hosting name-to-address binding information at a set of servers that are accessed via the network. This will greatly simplify the task of managing these bindings, as well as support applications that use DNS to store routability information, such as email (SMTP).*

3.3.5 Disruption Tolerance

This section defines how data packets will traverse regions of the Constellation network that are characterized by periodic link availability, such as some near-term orbiting assets that cannot maintain continuous end-to-end communication pathways to remote sources or destination of data.

Constellation SYSTEMS shall implement <TBR 3-12> DTN, DELAY/DISRUPTION TOLERANT NETWORKING Specifications, http://www.ietf.org/internet-drafts/draft-irtf-dtnrg-bundle-spec-05.txt. [C3I-107]

> ***Rationale****: All IP-based protocols (including TCP and UDP) require at least a contemporaneous end-to-end path in order to function. If the network is partitioned, IP data will be lost and there will be no connectivity. DTN provides a network service that is analogous to TCP and UDP but which functions without the need for contemporaneous end-to-end connectivity. Note that the details of how DTN will be used in conjunction with other protocols are currently considered future work (i.e. storage capacities, planned usage, etc.).*

3.3.6 Dynamic Address Assignment

This section defines how IP addresses will be automatically and dynamically assigned, as necessary, to communicating entities within Constellation SYSTEMS.

Constellation SYSTEMS shall implement the DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP) Server functions as specified in RFC-2131 and updated by RFC-4361. [C3I-67]

> ***Rationale****: This REQUIREMENT is designed to support DHCP to space suits and other small mobile SYSTEMS. This will allow large SYSTEMS to provide DHCP services to small IP addressable endpoints (EVA suits or even devices within SYSTEMS such as laptops). RFC3396 updates RFC-2131 by allowing longer option exchange in DHCP, and is not required. RFC-4361 addresses some problems with respect to DHCP client identifiers in RFC-2131.*

3.3.7 Dynamic Address Retrieval

This section defines how IP addresses will be automatically and dynamically obtained, as necessary, by communicating entities within Constellation SYSTEMS.

Constellation SYSTEMS shall 'self-assign' an IP address from the 169.254.0.0/16 private address block as specified in RFC-3927, Dynamic Configuration of IPv4 Link-Local Addresses of IPv4 interfaces when unable to obtain an IP address from pre-configuration information and/or DHCP. [C3I-70]

> ***Rationale****: This REQUIREMENT is designed to support DHCP to space suits and other small mobile SYSTEMS. RFC-3927 allows SYSTEMS (particularly systems configured for DHCP) to self-assign addresses to interfaces in the event of DHCP failure. This way, a SYSTEM may still be able to communicate at the network level even if no other network configuration information is available. RFC3927 applies to IPv4 address self-assignment only.*

Constellation SYSTEMS shall obtain network addresses via the DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP) as specified in RFC-2131 and updated by RFC-4361. [C3I-69]

> ***Rationale****: This REQUIREMENT is designed to support DHCP to space suits and other small mobile SYSTEMS. This will allow large SYSTEMS to provide DHCP services to small IP addressable endpoints (EVA suits or even devices within SYSTEMS such as laptops). RFC-3396 updates RFC2131 by allowing longer option exchange in DHCP, and is not required. RFC-4361 addresses some problems with respect to DHCP client identifiers in RFC-2131.*

3.3.8 Tunneling (GRE)

This section defines how IP packets will be encapsulated when it is necessary to transmit Constellation's IP traffic over non-IP communication infrastructure.

Constellation SYSTEMS shall implement RFC-2784, GENERIC ROUTING ENCAPSULATION (GRE). [C3I-92]

> ***Rationale****: Tunneling is necessary to support Mobile IP, and GRE is a tunneling protocol successfully tested by NASA in space operations. Tunneling through GRE will also allow controllers to perform traffic engineering and to force traffic to follow particular paths in the network that are different from the routes that might be 'default' or learned via dynamic routing protocols.*

Constellation SYSTEMS shall implement RFC-2473, Generic Packet Tunneling in IPv6 Specification. [C3I-664]

> ***Rationale****: Tunneling is necessary to support some forms of mobility. Tunneling will also allow controllers to perform traffic engineering and to force traffic to follow particular paths in the network that are different from the routes that might be 'default' or learned via dynamic routing protocols. This requirement applies only to IPv6 and dual IPv4/IPv6 operations.*

3.3.9 Header Compression

This section defines how Constellation's IP network communication traffic will be compressed in lossless fashion for transmission over resource constrained links, to maximize the volume of meaningful data conveyed by means of these limited resources.

Constellation SYSTEMS shall implement RFC-2507 IP Header Compression. [C3I-307]

> ***Rationale**: On low-bandwidth links IP headers can consume a significant percentage of total traffic, particularly if carrying pure TCP acknowledgements. RFC-2507 header compression can reduce the IP/TCP header from around 40 bytes to around 4-6 byte, and also compresses the IP headers of non-TCP traffic.*

Constellation SYSTEMS shall implement RFC 2508 Compressing IP/UDP/RTP Headers for Low-Speed Serial Links. [C3I-588]

> ***Rationale**: On low-bandwidth links RTP headers can consume a significant percentage of total traffic. RFC-2508 header compression will reduce the IP/UDP/RTP header from a typical length of 40 bytes to from 2 to 4 bytes.*

3.3.10 Network Management

This section defines how Constellation's IP network is configured, managed, tuned for improved performance, and repaired when operational anomalies occur.

Constellation SYSTEMS shall implement RFC-4293 Management Information Base for the Internet Protocol (IP). [C3I-100]

> ***Rationale**: The data for various networking systems in SNMP is specified in a set of Management Information Bases (MIBS). Since TCP/IP for Constellation is expected, RFC-4293 needs to be supported.*

Constellation SYSTEMS shall implement RFC-4292, IP Forwarding Table MIB. [C3I-294]

> ***Rationale**: RFC-4292 allows management of parameters for IP routers via the Simple Network Management Protocol (SNMP).*

Constellation SYSTEMS shall implement RFC-4113, Management Information Base for USER DATAGRAM PROTOCOL (UDP). [C3I-302]

> ***Rationale**: RFC-4113, the UDP MIB, defines the information carried by SNMP to configure the UDP portion of a communications stack.*

Constellation SYSTEMS shall implement RFC-4022, Management Information Base for TRANSMISSION CONTROL PROTOCOL (TCP). [C3I-301]

> ***Rationale**: The data for various networking systems in SNMP is specified in a set of Management Information Bases (MIBS). Since TCP/IP for Constellation is expected, RFC-4022 needs to be supported. This requirement applies regardless of the version of IP (IPv4/IPv6) in use.*

Constellation SYSTEMS shall implement RFC-2959, Real Time Protocol MIB. [C3I-303]

> ***Rationale**: RFC-2959, the RTP MIB, defines the information carried by SNMP to configure the RTP portion of a communications stack.*

Constellation SYSTEMS shall implement RFC-3289, MIB for the Differentiated Services Architecture. [C3I-299]

***Rationale**: RFC-3298, the Diffserv Architecture MIB, defines the management information carried by SNMP to configure parameters associated with Differentiated Services.*

Constellation SYSTEMS shall implement RFC-3747, Differentiated Services Configuration MIB. [C3I-298]

***Rationale**: RFC-3747, the DiffServ Configuration MIB, defines the management information carried by SNMP to configure aspects of Differentiated Services.*

Constellation SYSTEMS shall implement RFC-2213, Integrated Services Management Information Base using SMIv2. [C3I-300]

***Rationale**: RFC-2213 defines the management information carried by SNMP to configure parameters associated with Integrated Services.*

3.4 Security

The importance and sensitivity of some inter-system C3I interactions drive the need for integrity and confidentiality protections. This section specifies the minimum set of capabilities that Constellation SYSTEMS must provide to enable an interoperable and manageable approach to securing C3I interactions between SYSTEMS. The REQUIREMENTS in this section are based on standards for security protocols and algorithms in order to meet Federal policies and to promote interoperability through the use of commercial technology. Selections are based on Federal policies, best practices, and suitability for all Constellation missions' types (e.g., ISS, Moon, Mars).

3.4.1 Network Layer Security

Network layer security can be used to secure a wide range of information exchanges. An IP Security (IPsec) based approach is adopted to provide end-to-end security for SYSTEMS that will communicate primarily over IP.

Constellation SYSTEMS shall implement RFC 4301, Security architecture for the Internet Protocol, at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces. [C3I-199]

***Rationale**: The C3I security architecture uses a combination of network layer security and application layer security to provide a robust and flexible set of security services (i.e., AUTHENTICATION, integrity, confidentiality) that can be used to provide ample security for a variety of MISSION types. IPSec was chosen for the network layer security portion of the security architecture because IPSec is a widely recognized and implemented industry standard RFC 4301 defines the overall approach to IPSec, which provides a configurable ability to encrypt and/or authenticate (and verify the integrity of) IP packets in such a way that does not interfere with routing or access to the IP Header.*

Constellation SYSTEMS shall implement RFC-4302, IP AUTHENTICATION HEADER (AH), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces. [C3I-200]

***Rationale**: The AH provides AUTHENTICATION of the source address of each IP packet and the ability to detect unauthorized modification of the header and payload of each IP packet. The ability to authenticate the source of IP packets and detect changes in the header and payload of packets serves to ensure the integrity of IP based communications in cases where encryption is not needed and integrity of the IP header is important. The IP Encapsulating Security Payload (ESP) only protects the integrity of the payload of IP packets.*

Constellation SYSTEMS shall implement RFC-4303, IP ENCAPSULATING SECURITY PAYLOAD (ESP), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces. [C3I-201]

***Rationale**: The ESP provides AUTHENTICATION of the source of IP packets (note that the "source" is the node that secures a packet via the ESP, and this may be a security gateway rather than the original source of a packet), detection of changes to the payload (but not the header) of IP packets, and encryption of IP packet payloads and (optionally) the original header. If the original header is encrypted (i.e., "tunnel mode"), the ESP adds a clear header to the packet in order to facilitate routing and other layer 3 services. Using the ESP in tunnel mode provides partial traffic flow confidentiality because the IP addresses of internal networks can be hidden behind the IP addresses of security gateways. The ESP also provides a "transport mode" that protects traffic from original source to ultimate destination (rather than between two gateways). The ESP is part of the IPsec architecture, which provides the ability to configure (for each source-destination pair) if the ESP is used, which security services of the ESP are used, and which cryptographic keys are used. The ESP protocol does not interfere with routing or the processing of IP datagrams.*

Constellation SYSTEMS shall implement RFC 4305, Cryptographic Algorithm Implementation Requirements for Encapsulating Security Payload (ESP) and Authentication Header (AH), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces. [C3I-204]

***Rationale**: There is a need to support multiple cryptographic modes to cover the range of likely uses of the AES algorithm. The required modes of operation are typically included in commercial products and are consistent with Internet standards associated with the use of AES.*

Constellation SYSTEMS shall implement RFC 4309, Using Advanced Encryption Standard (AES) CCM Mode with IPsec Encapsulating Security Payload (ESP), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces. [C3I-565]

***Rationale**: RFC 4309 describes the use of Advanced Encryption Standard (AES) in Counter with CBC-MAC (CCM) Mode, with an explicit initialization vector (IV), as an IPsec Encapsulating Security Payload (ESP) mechanism to provide confidentiality, data origin authentication, and connectionless integrity.*

3.4.2 Internet Key Exchange (IKE)

The Internet Key Exchange (IKE) provides a mechanism for SYSTEMS to securely negotiate traffic encryption/authentication keys as needed.

Constellation SYSTEMS shall implement RFC-4306, The INTERNET KEY EXCHANGE (IKEv2), for all inter-SYSTEM management of security associations and keys used by IPSec. [C3I-209]

> ***Rationale**: The ability for network nodes to negotiate IPsec security associations (SAs) and keys as described in RFC-4306 increases security by reducing the amount of information authenticated/encrypted with the same key. Reducing the use of cryptographic keys reduces the likelihood of the keys being compromised.*

Constellation SYSTEMS shall implement RFC-4307, Cryptographic Algorithms for use in the Internet Key Exchange Version 2 (IKEv2). [C3I-568]

> ***Rationale**: SYSTEMS will not be able to perform IKEv2 negotiations unless the SYSTEMS use the same authentication and encryption algorithms. RFC-4307 is the Internet standard that specifies which algorithms are used in the IKEv2 protocol. Adopting RFC-4307 facilitates wide-scale interoperability and the use of commercial products for IKEv2 negotiations.*

3.4.3 Application Layer Security

Application layer security mechanisms are important for applications that require fine grained access controls and other cases in which network layer security is insufficient. The REQUIREMENT in this section pertain to the management of the security information (e.g., policies, keys, and identity data) used by application layer security mechanisms, particularly the Data Exchange (DE) Protocol.

Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for all inter-SYSTEM exchanges of the authentication keys and encryption keys used by application layer security functions. [C3I-569]

> ***Rationale**: Some SYSTEMS will need to exchange keys used by application layer security functions. An interoperable approach to key exchange is needed to ensure that elements developed by different suppliers can properly communicate with each other.*

Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for all inter-system exchanges of the security policy information used by application layer security functions. [C3I-566]

> ***Rationale**: Some SYSTEMS will need to exchange security policy information used by application layer security functions. An interoperable approach to security policy*

exchange is needed to ensure that SYSTEM developed by different suppliers can properly communicate with each other.

Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification and described in the for all inter-SYSTEM exchanges of the identity data used by application layer security functions. [C3I-567]

> ***Rationale**: Some SYSTEMS will need to exchange identity data (e.g., user attributes, groups/roles, public key certificates) used by application layer security functions. An interoperable approach to identity data exchange is needed to ensure that elements developed by different suppliers can properly communicate with each other.*

Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for inter-SYSTEM updates of security processing logic. [C3I-210]

> ***Rationale**: The protocols and algorithms used in the security processing of IPSec and application layer security functions may need to be updated on long-lived Constellation (and supporting) SYSTEMS. SYSTEMS that are required to produce or consume security protocol and/or algorithm updates should use interoperable approaches so that systems developed by different suppliers can communicate properly.*

3.4.4 FIPS Compliant Algorithms

The REQUIREMENTS in this subsection ensure that implementations of the algorithms needed by Constellation SYSTEMS conform to the relevant National Institute of Standards and Technology (NIST) Federal Information Processing Standard (FIPS) publications that document Federally approved cryptographic algorithms.

Constellation SYSTEMS shall implement FIPS PUB 197, ADVANCED ENCRYPTION STANDARD (AES), for all ENCRYPTION of inter-SYSTEM data exchanges. [C3I-203]

> ***Rationale**: AES has replaced the DIGITAL ENCRYPTION STANDARD (DES) as the algorithm of choice for Federal Information Systems per FIPS PUB 197.*

Constellation SYSTEMS shall implement SHA-1 per FIPS PUB 180-2, Secure Hash Standard, for hash generation performed for inter-SYSTEM data exchanges. [C3I-206]

> ***Rationale**: Creating hashes is a typical security function that requires the use of the same algorithm by the different parties sending and receiving digital hashes. The SHA is a Federal government standard that has been widely adopted by industry. SHA-1 is widely used today and is assumed to provide sufficient security for the rest of the decade.*

Constellation SYSTEMS shall implement truncation of SHA-1 based 160-bit Hash Based Messaged Authentication Codes (HMACs) to 96 bits. [C3I-666]

***Rationale**: The HMAC truncation described in this requirement maintains sufficient security while reducing the bandwidth used for authentication. This requirement is not a duplicate of C3I-204 (which requires the HMAC-SHA-1-96 algorithm for use with IPSec) because this requirement also applies to the application layer.*

Constellation SYSTEMS shall implement SHA-256 per FIPS PUB 180-2, Secure Hash Standard, for hash generation performed for inter-SYSTEM data exchanges. [C3I-665]

***Rationale**: Creating hashes is a typical security function that requires the use of the same algorithm by the different parties sending and receiving digital hashes. The SHA is a Federal government standard that has been widely adopted by industry. SHA-256 is needed to provide sufficient security in future years.*

Constellation SYSTEMS shall implement truncation of SHA-256 based 256-bit Hash Based Messaged Authentication Codes (HMACs) to 128 bits. [C3I-667]

***Rationale**: The HMAC truncation described in this requirement maintains sufficient security while reducing the bandwidth used for authentication. This requirement is not a duplicate of other requirements (e.g., C3I-204) that specify HMAC based algorithms because the other requirements do not cover truncation of 256-bit HMACs.*

Constellation SYSTEMS shall implement FIPS PUB 186-2, DIGITAL SIGNATURE STANDARD (DSS) using the DIGITAL SIGNATURE ALGORITHM (DSA) for all digital signatures exchanged between SYSTEMS. [C3I-207]

***Rationale**: Digital signatures are security mechanisms that may be used in AUTHENTICATION/integrity protocols, and nodes have to use the same algorithm in order to make use of digital signatures. The DSA is unencumbered in the United States and is the algorithm selected by the CCSDS for digital signatures.*

Constellation SYSTEMS shall implement FIPS PUB 198, Keyed-HASH MESSAGE AUTHENTICATION CODE (HMAC), for all MESSAGE AUTHENTICATION CODES (MACs) exchanged between SYSTEMS. [C3I-208]

***Rationale**: MACs are security mechanisms that may be used for authentication. MACs are less computationally intensive and shorter (bitwise) than digital signatures with a comparable strength of mechanism. The HMAC described in FIPS PUB 198 has been adopted by the Federal government for its SYSTEMS. The IETF and CCSDS have chosen to use HMAC per FIPS PUB 198 as the interoperability standard for message AUTHENTICATION codes.*

3.5 Data Exchange

This section covers near-term requirements for the protocols necessary to exchange data between SYSTEMS. Specifically, this section discusses IP-based protocols for routine voice exchange, motion imagery transfer, data exchange messages for command and telemetry, file transfer and time exchange. Additional data exchange mechanisms and data types include static host table updates, SNMP traffic, key management messages, and traffic management control files.

Bandwidth management and security concepts must be applied across the aggregate of all data exchange message traffic.

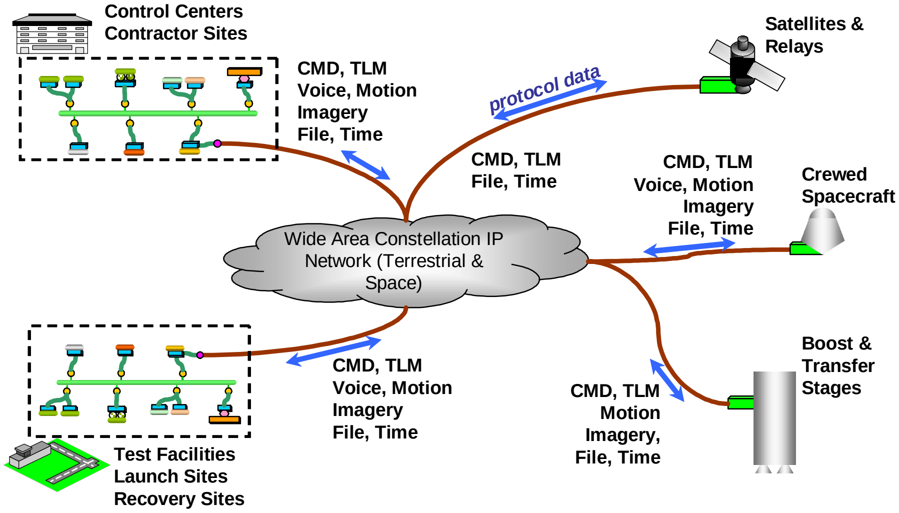

Figure 3.5-1 - Notional Data Exchange System Topology

3.5.1 Voice Exchange

This section specifies interoperability REQUIREMENTS for digitally encoded audio stream distribution between Constellation SYSTEMS.

Constellation SYSTEMS shall assign a delivery priority to voice data sent to another SYSTEM. [C3I-173]

> ***Rationale***: *Voice conversations may require a greater delivery priority than other data exchanges.*

Constellation SYSTEMS shall transfer voice data over a one way link. [C3I-175]

> ***Rationale***: *This is necessary to support some planned operations with one way links. This capability can also be useful during contingency operations.*

Constellation SYSTEMS shall transfer voice in accordance with IETF RFC 3550, Real-Time Transport Protocol (RTP). [C3I-555]

> ***Rationale***: *Real-time Transport Protocol (RTP) is the most commonly used transport for Voice over IP (VoIP) applications. It uses UDP with either unicast or multicast addressing and its packets contain information typically needed for internet streaming applications.*

Constellation SYSTEMS shall use ITU G.729, "Coding of speech at 8 kbit/s using conjugate-structure algebraic-code-excited linear prediction (CS-ACELP)". [C3I-176]

***Rationale**: G.729 is an audio codec that is commonly used in Voice over IP (VoIP) applications. It provides voice conversation quality audio with relatively low network bandwidth.*

Constellation SYSTEMS shall provide a mechanism to add voice codecs. [C3I-557]

***Rationale**: Voice codec technology will improve throughout the Constellation program. SYSTEMS should be designed to accommodate these as upgrades without incurring excessive cost. This REQUIREMENT is intended to support the graceful evolution of Constellation.*

Constellation SYSTEMS shall provide a mechanism to remove voice codecs. [C3I-558]

***Rationale**: Some voice codec technology will become obsolete during the Constellation program. SYSTEMS should be designed to accommodate elimination of codecs as they become obsolete without incurring excessive cost. This REQUIREMENT is intended to support the graceful evolution of Constellation.*

3.5.2 Motion Imagery Transfer

This section specifies interoperability requirements for digitally encoded MOTION IMAGERY (combined audio and video) distribution between Constellation SYSTEMS.

Constellation SYSTEMS shall assign a delivery priority for motion imagery data sent to another SYSTEM. [C3I-184]

***Rationale**: Some motion imagery streams may require a greater delivery priority than other data exchanges.*

Constellation SYSTEMS shall transfer motion imagery over a one way link. [C3I-185]

***Rationale**: This is necessary to support some planned operations with one way links. This capability can also be useful during contingency operations.*

Constellation SYSTEMS shall transfer motion imagery in accordance with RFC 3550, Real-Time Transport Protocol (RTP). [C3I-283]

***Rationale**: Real-time Transport Protocol (RTP) is the most commonly used transport for motion imagery over IP applications. It uses UDP and its packets contain information typically needed for internet streaming applications.*

Constellation SYSTEMS shall use ITU H.264, "Advanced Video Coding for Generic Audiovisual Services". [C3I-186]

***Rationale**: H.264 provides scalable quality audio and MOTION IMAGERY streaming over IP and is a common standard in industrial broadcast MOTION IMAGERY applications. Normative REQUIREMENTS are defined and specified in the referenced document. Note that this is a common MOTION IMAGERY codec required for interoperability. However, given that codec technology advances quickly, it is expected that new, more efficient codecs may be added as the ARCHITECTURE evolves. While* *this may be used between new SYSTEMS, H.264 may provide commonality with older SYSTEMS. The phrase "Generic Audiovisual Services" is part of the ITU H.264 specification document title. For Constellation purposes, the phrase is defined as general purpose motion imagery, with optional synchronized audio content, suitable for broadcast distribution. It is not intended for engineering, scientific or any critical applications which could require subsequent frame by frame image analysis.*

Constellation SYSTEMS shall use <TBR 3-13> ISO/IEC 15444-3, "Motion JPEG 2000 (Part 3)". [C3I-559]

***Rationale**: JPEG 2000 uses advanced wavelet transformation technology to provide improved compression while maintaining image quality. It is scalable, can be lossy or lossless, and it implements non-intraframe compression suitable for use in image capture and analysis applications. Part 3 of the JPEG 2000 specification is currently in development and has not yet been released. It is expected that when released, JPEG 2000 Part 3 will be a viable upgrade to H.264 with increased image quality and reduced bandwidth needs.*

Constellation SYSTEMS shall provide a mechanism to add MOTION IMAGERY codecs. [C3I-560]

***Rationale**: MOTION IMAGERY codec technology will improve throughout the Constellation program. SYSTEMS should be designed to accommodate these as upgrades without incurring excessive cost. This REQUIREMENT is intended to support the graceful evolution of Constellation.*

Constellation SYSTEMS shall provide a mechanism to remove MOTION IMAGERY codecs. [C3I-561]

***Rationale**: Some MOTION IMAGERY codec technology will become obsolete during the Constellation program. SYSTEMS should be designed to accommodate elimination of codecs as they become obsolete without incurring excessive cost. This REQUIREMENT is intended to support the graceful evolution of Constellation.*

3.5.3 Data Exchange Message Formatting and Transmission

This section specifies interoperability REQUIREMENTS for distribution of asynchronous data exchange messages between Constellation SYSTEMS.

Constellation SYSTEMS shall assign to each data exchange message that is sent to another SYSTEM the priority that was assigned to the Data of that data exchange message. [C3I-659]

***Rationale**: Some data exchange messages may require a greater delivery priority than other data exchanges messages.*

Constellation SYSTEMS shall transfer data exchange messages over a one way link. [C3I-130]

***Rationale**: This is necessary to support some planned operations with one way links. This capability can also be useful during contingency operations.*

Constellation SYSTEMS shall use a common data exchange message format as defined in Appendix C of CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification. [C3I-135]

> ***Rationale***: *Common data exchange message formatting supports interoperability between SYSTEMS.*

3.5.4 File Transfer

This section specifies interoperability REQUIREMENTS for reliable transfers of files between Constellation SYSTEMS. File transfer may also be used to support file based commanding, software upgrades, and still image transfer.

Constellation SYSTEMS shall assign a delivery priority to each file sent to another SYSTEM. [C3I-161]

> ***Rationale***: *Some file transfers may require a greater delivery priority than other data exchanges.*

Constellation SYSTEMS shall transfer files in accordance with CCSDS 727.0-B-3, "CCSDS File Delivery Protocol (CFDP) – Recommended Standard". [C3I-165]

> ***Rationale***: *CFDP provides file transfer and remote file SYSTEM access over connectionless and unreliable network transports including UDP.*

3.5.5 Time Exchange

This section specifies interoperability REQUIREMENTS for synchronization of time among a Constellation of SYSTEMS. Synchronization of time among SYSTEMS is important for correlation of events/data and multi-SYSTEM COMMAND activities.

Constellation SYSTEMS shall exchange time in accordance with IETF RFC 1305, NETWORK TIME PROTOCOL (NTP) Version 3. [C3I-111]

> ***Rationale***: *NTP allows one SYSTEM to exchange time with another SYSTEM in order to establish a common time base. SYSTEMS may also choose to synchronize clocks using that common time base. Millisecond level accuracies are attainable in low network latency environments. This does not preclude some Constellation SYSTEMS from using other clock synchronization mechanisms to enable clock synchronization in space flight applications over longer distances and/or to synchronize clocks more precisely (e.g., within 10 nsec) to meet Navigation requirements. NTP is the open international standard for clock synchronization in the Internet. It has been proven through flight testing to function in low-Earth orbit spaceflight applications as documented in Internet Access to Spacecraft (http://ipinspace.gsfc.nasa.gov/documents/Small-Sat2000Paper.doc). NTP implementations are currently available in most commercial real-time operating systems. The specification of NTP and an appropriate version number is the subject of TDS number SIG-13-204, "Time Services Study".*

3.5.6 Traffic Prioritization

This section specifies interoperability REQUIREMENTS for assuring that service quality levels requested by Constellation SYSTEMS are satisfied by the Constellation network.

Constellation SYSTEMS shall effect observance of the delivery priorities assigned to voice data, MOTION IMAGERY data, data exchange messages, and files by invoking traffic prioritization mechanisms provided by the underlying network. [C3I-660]

> ***Rationale****: Failure to honor priority designations could result in failure to deliver high priority information. This could represent significant risk when the volume of information awaiting transmission exceeds the communication system's available bandwidth due to degraded service modes, emergencies, etc.*

3.6 Information

Information interoperability is the ability of information systems and their users to accurately interpret and make use of the information that is exchanged among them. For this to happen, alignment is needed of terminology, messages structures, field formats and types, and the interfaces between Constellation SYSTEMS. The basic mechanism to enable this alignment is to use a set of information abstractions, required to get a common understanding about the exchanged information. These REQUIREMENTS apply to all information exchanged between SYSTEMS.

Achieving interoperability will require standardizing vocabulary, definitions, and identification methods, to be governed by NASA-owned registries. Exchanged information will be formalized and structured in conformity with standards that ensure a common and unambiguous definition and usage to enable communications between Constellation SYSTEMS. The format and method of exchange might range from an XML or ASN.1 file to the support of real-time semantic services, depending on the role of the SYSTEM and specific needs within the SYSTEM lifecycle.

3.6.1 Basic Information Definition

Constellation Systems shall define METADATA that complies with the CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification. [C3I-661]

> ***Rationale****: METADATA describes the data itself. METADATA is necessary for interoperability in order that the data can be understood, interpreted and used appropriately. For all Constellation SYSTEMS data that will be shared or exchanged with other SYSTEMS, the accompanying METADATA must be provided. Guidelines for defining METADATA are provided in CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification. Examples of METADATA include parameter descriptors (such as units, sizes, formats, data types, limits), command descriptors (such as command types, alternative identifiers, arguments, return codes), voice and video*

descriptors (such as priority, recipients, ownership rights), and file descriptors (format, content description, purpose, source).

Constellation SYSTEMS shall exchange METADATA that complies with the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification. [C3I-229]

***Rationale**: Interoperability requires consistent naming, typing and structuring. This consistency applies to notification-type messages to human operators as well as machine-generated messages at specific levels of the C3I Information Hierarchy, from the device level to the Constellation SYSTEM level. METADATA includes definitions for Services and Message types and their legitimate content value, for example, enumerations, and their mnemonic short-hand representations. Constellation Systems must have their METADATA defined (see REQUIREMENT C3I-661) and be prepared to provide their METADATA upon request. It is not required that METADATA be transmitted with the data it describes, but it must be possible to retrieve the data's associated METADATA when needed. The C3I data exchange protocol (Volume 5) contains METADATA pointers that can be used to locate and retrieve METADATA. METADATA repositories should be located appropriately. For example, it may not be possible to store METADATA on-board a vehicle. In this case, there should be an accessible repository on the ground from which the METADATA can be retrieved.*

Constellation SYSTEMS shall use common voice METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification. [C3I-169]

***Rationale**: Common voice METADATA supports interoperability and discovery between SYSTEMS. This data may include a unique information or call IDENTIFIER, a description, related information references, codec types, and timing information.*

Constellation SYSTEMS shall use common motion imagery METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification. [C3I-180]

***Rationale**: Common motion imagery METADATA supports interoperability and discovery between SYSTEMS. This data may include unique information or stream IDENTIFIER, a description, related information references, codec types, and timing information.*

Constellation SYSTEMS shall use common telemetry METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification. [C3I-140]

***Rationale**: Using common METADATA for command-, TELEMETRY-, and reconfiguration-related data directly supports system interoperability, simplified integration testing, and efficient Constellation operations. Telemetry METADATA includes data types, units, parameters and addressing schemes.*

Constellation SYSTEMS shall use common COMMAND METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification. [C3I-119]

> ***Rationale****: Common COMMAND METADATA supports interoperability and discovery between SYSTEMS. This METADATA may include a description, status return codes, related system state or measures and references, argument METADATA (names, units, types, limits, enumerations, description, etc.).*

Constellation SYSTEMS shall use Universal Resource Indicators (URIs) and namespace constructs using conventions described in RFC3986. [C3I-231]

> ***Rationale****: Universal Resource Indicators provide an unambiguous way to reference entities within hierarchical structures to any level of specificity. This is the technique applied to construct names and addresses.*

Constellation SYSTEMS shall use a hierarchical addressing structure as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification. [C3I-355]

> ***Rationale****: A hierarchical addressing structure necessitates agreement over the ordering of address SYSTEMS. Some ordering is taken care of through DNS names; other ordering requires specification of pathname conventions in URNs. Studies have shown that efficient packet specification IDs with short DNS-type IDENTIFIERS eliminate the overhead of hierarchical addressing. Each party needs only to look up the packet definition once to create a mapping of hierarchical names to data SYSTEM in each packet of the same type.*

Constellation SYSTEMS shall use data types as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3. [C3I-228]

> ***Rationale****: The SYSTEM will be interoperable with other Constellation SYSTEMS only if the vendor provides sufficient and C3I compliant data about the Constellation SYSTEM and its constituent SYSTEMS, in the form of common information types and service registry entries. It is expected that a given SYSTEM will comply with the usage of specific INFORMATION MODEL types if they are used by a given SYSTEM. It would not be expected that a given SYSTEM would support use of all the data types if it does not use them all.*

Constellation SYSTEMS shall use a common convention for file formats as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3. [C3I-157]

> ***Rationale****: Common file formatting conventions can enhance interoperability between systems by providing a known set of formats.*

Constellation SYSTEMS shall use a common file naming convention as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Sec 3.3. [C3I-357]

> ***Rationale**: Common file name conventions can enhance interoperability between SYSTEMS. These conventions can include file name extensions as well as namespace prefixes or fields. A unique information IDENTIFIER may also be included in a file name.*

Constellation SYSTEMS shall issue inter-SYSTEM COMMANDS in the format defined by the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Sec 3.8. [C3I-366]

> ***Rationale**: The SYSTEM will be interoperable with other Constellation SYSTEMS if and only if COMMANDS are specified in a common way. COMMAND specification includes common naming, categories, definitions, event management, scripting, and network operations.*

Constellation SYSTEMS shall exchange application layer security policies between SYSTEMS in a representation that complies with CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume 4: C3I Information Representation Specification, Section 3.12 Security Representation <TBR 3-26>. [C3I-544]

> ***Rationale**: Common representation of digital security policies that control the operation of application layer security controls makes it possible to generate policies in one SYSTEM (e.g., Mission Systems) for use by another SYSTEM (e.g., the Crew Exploration Vehicle).*

Constellation SYSTEMS shall exchange application layer cryptographic keys between SYSTEMS in a representation that complies with the CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume 4: C3I Information Representation Specification, Section 3.12 Security Representation <TBR3-26>. [C3I-545]

> ***Rationale**: Common representation of cryptographic keys used by application layer security controls makes it possible to generate keys in one SYSTEM (e.g., Mission Systems) for use by another SYSTEM (e.g., the Crew Exploration Vehicle).*

Constellation SYSTEMS shall exchange application layer identity information between SYSTEMS in a representation that complies with CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume 4: C3I Information Representation Specification, Section 3.12 Security Representation <TBR 3-26>. [C3I-546]

***Rationale**: Common representation of digital identity information used by application layer security controls makes it possible to generate identity information in one SYSTEM (e.g., Mission Systems) for use by another SYSTEM (e.g., the Crew Exploration Vehicle).*

Constellation SYSTEMS shall exchange application layer security audit data between SYSTEMS in a representation that complies with the CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume 4: C3I Information Representation Specification, Section 3.12 Security Representation <TBR 3-26>. [C3I-652]

***Rationale**: Common representation of digital security policies that control the operation of application layer security controls makes it possible to generate security audit data in one SYSTEM (e.g., Mission Systems) for use by another SYSTEM (e.g., the Crew Exploration Vehicle).*

3.6.2 Adaptive Information Definition

Constellation SYSTEMS shall use a hierarchical naming scheme in accordance with the CXP-70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification. [C3I-222]

***Rationale**: With a common naming scheme there is no ambiguity over information, and verification that data is from particular sources is guaranteed. With a common naming scheme, consistency can be achieved across all Constellation SYSTEMS for interoperability. The common naming scheme uniquely identifies and disambiguates identification of a SYSTEM, subsystem, component, device, dataset, algorithmset, variable, parameter, and event. Spacecraft, Ground SYSTEMS, Habitats and Launch Vehicles are inherently hierarchical in their composition. Reflecting that structure in the TELEMETRY provides a uniform consistency and a guiding convention across all Constellation SYSTEMS. Managing IDs is more readily achieved by introducing the idea of type (class) and ID. This allows the space of IDENTIFIERS to be delimited by each type (class), and mitigates the risk of running out of IDs. Otherwise ranges of identifiers will have to be managed in order to anticipate new types in the future.*

With this structuring there is also no risk of naming clashes and ambiguity over which parameters or variables are being referenced. At any level of the hierarchy a packet type ID and instance ID can refer to an indexed or mapped telemetry structure. This provides a technique for minimizing the amount of transmitted information and requires that the participating SYSTEMS have a map-translation capability.

Constellation SYSTEMS shall define TELEMETRY processing algorithms in accordance with CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification. [C3I-215]

***Rationale**: In certain Constellation SYSTEMS, such as ground stations and specific data consumer points, algorithms are needed for a number of signal processing tasks, such as signal enhancements, compressions and decompressions, and data conversions. In these* *cases endpoints need to ensure that they use the same processing algorithms with the same coefficients. A standard identification scheme will be used for both pre-defined and formally-described algorithms and their coefficients. This supports the verification of the correct use of algorithms and facilitates reuse of algorithms across Constellation SYSTEMS.*

Constellation SYSTEMS shall request data using data identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification. [C3I-547]

***Rationale**: A standard syntax for naming data, expressing data types, their constraints, and naming conventions is needed to ensure (a) human comprehensibility for retrieval, (b) machine processing of data names, (c) interoperability between systems, and (d) improved assurance for reuse.*

Constellation SYSTEMS shall request files using file identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27>of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification. [C3I-548]

***Rationale**: A standard syntax for naming data, expressing data types, their constraints, and naming conventions is needed to ensure (a) human comprehensibility for retrieval, (b) machine processing of data names, (c) interoperability between systems, and (d) improved assurance for reuse.*

Constellation SYSTEMS shall construct requests for data using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR) Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification. [C3I-549]

***Rationale**: Data retrieval will require Application Program Interfaces (APIs), or services to access registries, repositories and databases. Each will have its own protocol. By having a neutral protocol a common interface can be presented to data consumers and producers, at the same time allowing local systems and databases to retain their own interface specifications.*

Constellation SYSTEMS shall construct requests for file submissions and retrievals using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR) Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification. [C3I-550]

***Rationale**: File access will require Application Program Interfaces (APIs), or services to access registries, directories and other file storage systems. Each will have its own protocol. By having a neutral protocol a common interface can be presented to file consumers and producers, at the same time allowing local systems to retain their own interface specifications.*

3.7 Command and Control

REQUIREMENTS in this section will be created to provide a linkage to the REQUIREMENTS in the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 8: Command and Control <TBD 3-15>.

3.8 Interoperability Requirements Applicability

The CEV shall comply with CxP 70022, Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume1: Interoperability Specification as specified in Appendix E, Table E-1. [C3I-701]

> ***Rationale****: To ensure command and control, communications, and information interoperability between the systems, a common standard must be used. Specific sections of the specification are applied based on the functions and interfaces of the CEV. Rationale for application of each of these sections is provided in Table E-1.*

The CLV shall comply with CxP 70022, Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume1: Interoperability Specification as specified in Appendix E, Table E-2. [C3I-702]

> ***Rationale****: To ensure command and control, communications, and information interoperability between the systems, a common standard must be used. Specific sections of the specification are applied based on the functions and interfaces of the CLV. Rationale for application of each of these sections is provided in Table E-2.*

The LSAM shall comply with CxP 70022, Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume1: Interoperability Specification as specified in Appendix E, Table E-3. [C3I-703]

> ***Rationale****: To ensure command and control, communications, and information interoperability between the systems, a common standard must be used. Specific sections of the specification are applied based on the functions and interfaces of the LSAM. Rationale for application of each of these sections is provided in Table E-3.*

The CaLV shall comply with CxP 70022, Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume1: Interoperability Specification as specified in Appendix E, Table E-4. [C3I-704]

> ***Rationale****: To ensure command and control, communications, and information interoperability between the systems, a common standard must be used. Specific sections of the specification are applied based on the functions and interfaces of the CaLV. Rationale for application of each of these sections is provided in Table E-4.*

The Ground Systems shall comply with CxP 70022, Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume1: Interoperability Specification as specified in Appendix E, Table E-5. [C3I-705]

***Rationale**: To ensure command and control, communications, and information interoperability between the systems, a common standard must be used. Specific sections of the specification are applied based on the functions and interfaces of the Ground Systems. Rationale for application of each of these sections is provided in Table E-5.*

The Mission Systems shall comply with CxP 70022, Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume1: Interoperability Specification as specified in Appendix E, Table E-6. [C3I-706]

***Rationale**: To ensure command and control, communications, and information interoperability between the systems, a common standard must be used. Specific sections of the specification are applied based on the functions and interfaces of the Mission Systems. Rationale for application of each of these sections is provided in Table E-6.*

The EVA System shall <TBD E-25> comply with CxP 70022, Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume1: Interoperability Specification as specified in Appendix E, Table E-7. [C3I-707]

***Rationale**: To ensure command and control, communications, and information interoperability between the systems, a common standard must be used. Specific sections of the specification are applied based on the functions and interfaces of the EVA System. Rationale for applicability (or non- applicability) of each of these sections is provided in Table E-7. Applicability of the C3I specification will be assessed for EVA surface operations as part of the Lunar Surface Operations Concept development.*

4 Verification

The verification process is performed by the end item developer to ensure the product complies with the requirement as specified and as determined by the verification requirement. There is a verification requirement in section 4 for each requirement in section 3. Each requirement is called, either singly or in sets, from a parent document such as the CARD or a specific IRD. Compliance to the verification requirements in this document must be met in addition to any verification requirement specified in the parent document. (C3I_4 Ver:01)

4.1 Verification Approach

Where feasible, common test set(s) will be developed and made available to support verification activities. Common test set(s) provide a cost-effective means of ensuring interoperability, the main goal of this standard. Additionally, universally accepted test standards will be cited when possible. Finally, test equipment that is developed and used to verify common requirements may be made available to other developers, subject to availability and sharing agreements. (C3I_4.1 Ver:01)

4 Requirements

4.1 RF Communication

4.1.1 Common RF Communication

[C3I-3V] Compliance with spectrum selection/allocation, certification and usage restriction policies set forth in NPD 2570.5D, NASA EM Spectrum Management document by Constellation SYSTEMS shall be verified by Test and Analysis.

Operational parameters stated in the NTIA Stage Review will be met either by test or analysis or both. Test and analysis of key operational design parameters such as spectral measurements of RF emissions using representative flight operational modulation and power levels shall be performed. The highest flight power mode and a medium flight power mode (if applicable) shall be exercised to estimate flight performance. Also measurements of spectrum roll-off and bandwidth will be made to determine the worst-case power flux density (PFD) for the Constellation flight system.

Verification shall be considered successful when the modulated signal and spurious power and power flux density (PFD) is shown to meet the key operational parameters specified in the NTIA Stage Review. The NTIA Stage Review is referenced in NPD 2570.5D.

> ***Rationale**: Verification, by test and analysis, will be successfully accomplished once Constellation Systems receives the NTIA documentation set that identifies the key operational parameters that must be met to ensure the Constellation System is in compliance with NPD 2570.5D and the applicable NTIA regulations.*

[C3I-5V] The user transmit/receive frequency assignments and spectrum characteristics as defined in CxP 70022 Constellation Command, Control, Communications and Information (C3I) Interoperability Standards Book, Volume 2: Constellation Spectrum and Channel Plan by Constellation SYSTEMS shall be verified by test and analysis.

Transmit/receive frequency assignments shall be tested for each specified frequency pair using the full communications string from multiplexer to antenna. Spectrum characteristics, operational bandwidths, and power flux density shall be analyzed.

Verification shall be considered successful when a) tests and analysis are conducted for each specified frequency channel pair, b) tests show the frequency assignments are correct, c) analysis shows the spectrum characteristics and bandwidths are correct, and d) the power flux density specified limit is met.

> ***Rationale****: Verification, by inspection, will be successfully accomplished once Constellation SYSTEMS receive the NTIA Spectrum Certifications that identify the key operational parameters that must be met to ensure the Constellation SYSTEMS are in compliance with NPD 2570.5D.*

[C3I-584V] Compliance with radio frequency (RF) allocation and conditions of assignment for frequency spectrum usage approved by the National Telecommunications & Information Administration (NTIA) shall be verified by inspection.

An inspection of the NTIA Spectrum Certifications (1 certification per RF system) shall be performed. The NTIA spectrum certificate is granted to a transmit/receiving system upon examination of individual system RF characteristics including power, frequency, modulation, emission bandwidth and profile, power flux density, out-of-band emissions, and condition/limitation of assignment/certification.

Verification shall be considered successful when the inspection shows an approved NTIA Spectrum Certification for each RF system.

> ***Rationale****: Verification, by inspection, will be successfully accomplished once the Constellation SYSTEM receives the NTIA Spectrum Certifications that identify the key operational parameters that must be met to ensure the Constellation SYSTEM is in compliance with NTIA regulations.*

4.1.2 Operational Point-to-Point RF Communication

4.1.2.1 Common Operational Point-to-Point RF Communication

[C3I-6V] Constellation systems' antennas intended for use in operational point-to-point links shall be tested in an anechoic chamber with a standard (per IEEE’s definition <TBR 4-1>), left-hand circularly polarized antenna acting as a receiving antenna. Co-polarization radiation patterns shall be measured at the low end, high end, and Constellation systems’s channel center frequencies of the 2025 – 2290 MHz band to verify the antennas’ gain, beamwidth, and bandwidth. Tests shall also be performed to verify Constellation systems’ antennas’ axial ratio.

The verification shall be considered successful when the measured co-polarization radiation patterns demonstrate that Constellation systems’ antennas meet the specified gain, beamwidth and bandwidth and the axial ratio test result demonstrates that Constellation systems’ antennas meet the specified axial ratio requirement.

***Rationale**: Verification of the antennas' polarization at the component level in an anechoic chamber is appropriate because for singly polarized antennas, there is no polarization ambiguity (as opposed to antennas with dual, selectable polarizations) after they are installed on Constellation systems.*

[C3I-7V] Constellation SYSTEMS' capability to receive using Left-hand Circular polarization (LHCP) for operational point-to-point links shall be verified by test.

Constellation SYSTEMS' antennas intended for use in operational point-to-point links shall be tested in an anechoic chamber with a standard (per IEEE's definition <TBR 4-1>), left-hand circularly polarized antenna acting as a transmitting antenna. Co-polarization radiation patterns shall be measured at the low end, high end, and Constellation SYSTEMS' channel center frequencies of the 2025 – 2290 MHz band to verify the antennas' gain, beamwidth, and bandwidth. Tests shall also be performed to verify Constellation SYSTEMS' antennas' axial ratio.

The verification shall be considered successful when the measured co-polarization radiation patterns demonstrate that Constellation SYSTEMS' antennas meet the specified gain, beamwidth and bandwidth and the axial ratio test result demonstrates that Constellation SYSTEMS' antennas meet the specified axial ratio requirement.

***Rationale**: Verification of the antennas' polarization at the component level in an anechoic chamber is appropriate because for singly polarized antennas, there is no polarization ambiguity (as opposed to antennas with dual, selectable polarizations) after they are installed on Constellation SYSTEMS.*

[C3I-11V] Constellation SYSTEMS' ability to operate on at least two independent transmit/receive frequency pairs within the near Earth S-band allocation for multi-system, simultaneous operational point-to-point communications shall be verified by analysis and test.

(i) Analyses shall be performed to verify that each of the two independent transmit/receive frequency pairs or channels, when operated singly or both simultaneously, will not cause unacceptable performance degradation or component damage in the other channel.

(ii) Tests shall be performed during Constellation SYSTEMS' integration and test, using Communication & Tracking Network emulation systems, to verify their ability to operate on at least two independent transmit/receive frequency pairs. RF link tests shall be performed to verify that Constellation SYSTEMS are able to operate on these (at least) two frequency pairs at one frequency pair at a time and both frequency pairs simultaneously.

The verification shall be considered successful when test results verify that Constellation SYSTEMS are able to operate on at least two independent transmit/receive pairs within the near Earth S-band allocation, per the CxP 70022, Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 2: Constellation Spectrum and Channel Plan, at one frequency pair at a time and both frequency pairs simultaneously without unacceptable self-interference. Communications link performance degradation due to self-interference shall not exceed <TBD 4-1> dB.

***Rationale**: Constellation SYSTEMS' ability to operate on at least two independent transmit/receive frequency pairs can be verified by hardline RF tests during systems' integration and test. Verification of Constellation SYSTEMS' ability to operate on both transmit/receive frequency pairs simultaneously requires RF link tests because self-interference, if exists, is due to RF couplings between antennas.*

[C3I-22V] Constellation SYSTEMS usage of CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) per CCSDS 131.1-O-1 Section 3 to transmit data streams for operational point-to-point links shall be verified by Inspection and Test.

(1) An inspection shall be performed on the SYSTEM coding implementation for adherence to CCSDS 131.1-O-1 Section 3. (2) A test shall be performed using flight or flight like components in a controlled environment (e.g. ESTL test bed) to assess the performance of the transmitter coding. Detailed verification objectives shall be developed to assess performance in the relevant RF environments expected in the Constellation mission for both nominal and maximum data rates. Measurements of codeword error rate (CWER), undetected codeword error rate (UER), bit error rate (BER), TRP or TRP/NSD as applicable and PDL (if applicable) shall be recorded. (3) End-to-End data flow tests shall be performed on Constellation SYSTEMS with each of the networks or other in-space Constellation SYSTEMS. The interfaces, hardware and test conditions are specified below. The data used for these tests shall be representative of the mission data, including engineering data as well as compressed or uncompressed video data as applicable. Tests shall be conducted at the data rates specified in the applicable Interface Requirements Document (IRD). The CCSDS Rate-1/2 LDPC decoder used for these tests (e.g at WSC) shall be identically implemented (including decoding algorithm and iteration) as the actual decoder that will be used to support Constellation Missions.

a) Operational Point-to-Point Links through the Space Network or Near-Earth Relay Satellite: Tests shall be conducted with the transmitted signal relayed through the actual Tracking and Data Relay Satellite (TDRS) and received at the White Sands Complex (WSC).

b) Operational Point-to-Point Links with Direct-to-Earth networks (DSN, GN, etc.): Tests shall be conducted using a CTN compatibility test set or equivalent equipped with hardware that are identically implemented as those used in the networks' ground stations.

c) Operational Point-to-Point Links with other In-space Constellation Systems: Tests shall be conducted using emulators or test sets of the other in-space Constellation SYSTEMs containing hardware that is identically implemented as in the flight SYSTEMS.

d) Operational Point-to-Point Links with Lunar Relay Satellite (TBR): Tests shall be conducted with the transmitted signal relayed through the actual Lunar Relay Satellite (TBR) and received at the applicable ground station.

Bit error rates shall be measured during these tests. Tests shall be conducted first without the CCSDS Rate-1/2 coding in order to establish the performance baseline and then with the CCSDS Rate-1/2 coding. The coding gain shall be verified against the value specified in the

Constellation Master Link Book (CXP-70022 Volume 3). Data latency requirements as specified in (TBD) shall also be verified during these tests.

Verification shall be considered successful when (1) the inspection shows compliance to CCSDS 131.1-O-1 Section 3, (2) detail verification objectives are met for all tested conditions and data rates with a performance that achieves theoretical or idealized simulation results within the tolerance of the specified implementation loss, and (3) the end-to-end test demonstrates good data flow and the determination that the coding gain and data latency requirements are met.

> ***Rationale****: Testing is required for the following reasons: a) different decoding algorithms will produce different error performance even though the code specification is the same, b) error performance is channel dependent - a channel with correlated errors/statistics will produce different results, c) incompatibilities can occur from incomplete or poorly written code specifications, d) complexities of the coding and decoding algorithms are large enough that data rate can affect error performance, e) symbol and frame synchronization algorithms can impact error performance of CCSDS Rate 1/2 LDPC codes.*

[C3I-23V] Constellation SYSTEMS' use of bit randomization and frame synchronization techniques as specified in CCSDS 131.0-B-1 for operational point-to-point links shall be verified by test.

The test shall consist of data exchanges from the SYSTEM under test to an external system. Traffic shall be observed using a channel monitoring tool. Frame synchronization techniques and pseudo-bit randomization shall be observed.

The verification shall be considered successful when the bit synchronization for the received communications signal is maintained in compliance with CCSDS 131.0-B-1

> ***Rationale****: Using a channel monitoring tool to measure the SYSTEMS' data exchanges will verify compliance to the CCSDS 131.0-B-1 standard.*

[C3I-590V] Constellation SYSTEMS usage of CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) per CCSDS 131.1-O-1 Section 3 for decoding received data streams using forward error correction for operational point-to-point links shall be verified by Inspection and Test.

(1) An inspection shall be performed on the SYSTEM decoding implementation for adherence to CCSDS 131.1-O-1 Section 3. (2) A test shall be performed using flight or flight like components in a controlled environment (e.g. ESTL test bed) to assess the performance of the receiver decoding. Detailed verification objectives shall be developed to assess performance in the relevant RF environments expected in the Constellation mission for both nominal and maximum data rates. Measurements of codeword error rate (CWER), undetected codeword error rate (UER), bit error rate (BER), TRP or TRP/NSD as applicable and PDL (if applicable) shall be recorded. (3) End-to-End data flow tests shall be performed on Constellation SYSTEMS with each of the networks or other in-space Constellation SYSTEMS. The interfaces, hardware and test conditions are specified below. The data used for these tests shall be representative of the

mission data, including engineering data as well as compressed or uncompressed video data as applicable. Tests shall be conducted at the data rates specified in the applicable Interface Requirements Document (IRD). The Rate-1/2 LDPC encoder used for these tests (e.g. at WSC) shall be identically implemented as the actual encoder that will be used to support Constellation Missions.

a) Operational Point-to-Point Links through the Space Network or Near-Earth Relay Satellite: Tests shall be conducted with the WSC-transmitted signal relayed through the actual Tracking and Data Relay Satellite (TDRS) and received by the Constellation SYSTEMS under test.

b) Operational Point-to-Point Links with Direct-to-Earth networks (DSN, GN, etc.): Tests shall be conducted using a CTN compatibility test set or equivalent equipped with hardware that are identically implemented as those used in the networks' ground stations.

c) Operational Point-to-Point Links with other In-space Constellation Systems: Tests shall be conducted using emulators or test sets of the other in-space Constellation SYSTEMs containing hardware that is identically implemented as in the flight SYSTEMS.

d) Operational Point-to-Point Links with Lunar Relay Satellite (TBR): Tests shall be conducted with the ground station- transmitted signal relayed through the actual Lunar Relay Satellite (TBR) and received by the Constellation SYSTEMS under test.

Bit error rates shall be measured during these tests. Tests shall be conducted first without the CCSDS Rate-1/2 coding in order to establish the performance baseline and then with the CCSDS Rate-1/2 coding. The coding gain shall be verified against the value specified in the Constellation Master Link Book (CXP-70022 Volume 3). Data latency requirements as specified in (TBD) shall also be verified during these tests.

Verification shall be considered successful when (1) the inspection shows compliance to CCSDS 131.1-O-1 Section 3, (2) detail verification objectives are met for all tested conditions and data rates with a performance that achieves theoretical or idealized simulation results within the tolerance of the specified implementation loss, and (3) the end-to-end test demonstrates good data flow and the determination that the coding gain and data latency requirements are met.

> ***Rationale****: Testing is required for the following reasons: a) different decoding algorithms will produce different error performance even though the code specification is the same, b) error performance is channel dependent - a channel with correlated errors/statistics will produce different results, c) incompatibilities can occur from incomplete or poorly written code specifications, d) complexities of the coding and decoding algorithms are large enough that data rate can affect error performance, e) symbol and frame synchronization algorithms can impact error performance of CCSDS Rate 1/2 LDPC codes.*

[C3I-592V] Constellation SYSTEMS use of bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-randomization of received data streams for operational point-to-point links shall be verified by Demonstration.

Data flow demonstrations using C&T Networks or integrating multiple Cx SYSTEMS shall be performed.

Verification shall be considered successful following good data flow during compatibility testing with TDRSS, DSN (if dissimilar from TDRSS), and applicable C3I relay implementations.

> ***Rationale****: Demonstration can be at "strong signal." AOS is a specialized, loose specification and C3I will implement a version of it. Test suites are not common as for widely used standards like IP or 1553. Data flow through real ground stations or at least real ground station hardware is necessary for each type of dissimilar ground station implementation (DSN, TDRSS, SCN, and STDN). Validation of the prototype is required to avoid expensive rework or workarounds. Flight validation can be less rigorous, verifying that problems were corrected.*

[C3I-594V] Constellation SYSTEMS use of attached Sync Marker (ASM) in accordance with CCSDS 131.0-B-1 for frame sync of received CCSDS frames for operational point-to-point links shall be verified by Demonstration.

Data flow demonstrations using C&T Networks or integrating multiple Cx SYSTEMS shall be performed.

Verification shall be considered successful following good data flow during compatibility testing with TDRSS, DSN (if dissimilar from TDRSS), or applicable C3I relay implementations.

> ***Rationale****: Demonstration can be at "strong signal." AOS is a specialized, loose specification and C3I will implement a version of it. Test suites are not common as for widely used standards like IP or 1553. Data flow through real ground stations or at least real ground station hardware is necessary. Validation of the prototype is required to avoid expensive rework or workarounds. Flight validation can be less rigorous, verifying that problems were corrected. This particular requirement is a very simple implementation of a fixed pattern appearing at regular intervals; verification with the ground station would find improper MSB/LSB order or byte swapping or other fundamental error.*

[C3I-596V] Constellation SYSTEMS compliance with the specifications for service access point as defined in section 3 of the AOS Space Data Link Protocol 732.0.B-2 for reception of AOS frames over operational point-to-point links shall be verified by Demonstration.

Data flow demonstrations using C&T Networks or integrating multiple Cx SYSTEMS shall be performed.

Verification shall be considered successful following good data flow during compatibility testing with TDRSS, DSN (if dissimilar from TDRSS), and applicable C3I relay implementations.

> ***Rationale****: Demonstration can be at "strong signal." AOS is a specialized, loose specification and C3I will implement a version of it. Test suites are not common as for widely used standards like IP or 1553. Data flow through real ground stations or at least real ground station hardware is necessary for each type of dissimilar ground station*

implementation (DSN, TDRSS, SCN, and STDN). Validation of the prototype is required to avoid expensive rework or workarounds. Flight validation can be less rigorous, verifying that problems were corrected.

[C3I-612V] Constellation SYSTEMS encapsulation of HDLC bitstreams per ISO/IEC

13239.2002 for transmission using the Bitstream Service of AOS Space Link Protocol (AOS) 732.0.B-2 for operational point-to-point links shall be verified by Demonstration.

Data flow demonstrations using C&T Networks or integrating multiple Cx SYSTEMS shall be performed.

Verification shall be considered successful following good data flow during compatibility testing with TDRSS, DSN (if dissimilar from TDRSS), and applicable C3I relay implementations.

***Rationale**: Demonstration can be at "strong signal." AOS is a specialized, loose specification and C3I will implement a version of it. Test suites are not common as for widely used standards like IP or 1553. Data flow through real ground stations or at least real ground station hardware is necessary for each type of dissimilar ground station implementation (DSN, TDRSS, SCN, and STDN). Validation of the prototype is required to avoid expensive rework or workarounds. Flight validation can be less rigorous, verifying that problems were corrected.*

[C3I-653V] The ability of Constellation SYSTEMS to enable and disable communication link forward error correction for operational point-to-point links upon receipt of command shall be verified by test.

Each system to be used shall be tested by commanding each system to all Error Correction (EC) state transitions and observing the resulting forward data link output. Tests shall be performed on flight or equivalent systems. Tests may be conducted in a testbed or using actual systems. The commanding system may be simulated.

Transitions to be tested are:

(1) Initial power-on state to No Error Correction, (2) Error-Correction to No Error Correction, (3) No Error-Correction to Error-Correction, (4) No Error-Correction to No Error-Correction. and (5) Error-Correction to Error-Correction.

The verification shall be considered successful when, for every system after commanding, all initial error correction states result in the commanded state being observed in the forward link data received. Should there be more than one error correction protocol implemented, the verification shall be considered successful for this requirement if every protocol available, considered alone, is capable of the five (5) transitions tested.

***Rationale**: Observing the resulting output of the forward link is the only way to assure that the commanded state has occurred. There may also be a telemetry discrete that may be checked, and if present should properly indicate the state of forward link error correction encoding (but it is not necessary for validation of this requirement.) Since neither the error correction protocol nor the number of such protocol is specified, the* *conditional success criteria is needed. Transition from one error correction protocol to another may be possible and even desirable, but is not necessary for correct operation. If the final design allows for such, operational testing should perform those tests to assure that the specific equipment works. A very difficult case to test could arise if the error correction method is totally configurable. In that case we would limit to those methods available and intended for use and proof that the reconfiguration can be successfully performed from one protocol to a not-yet configured protocol both of which are intended for use. It is also assumed that the initial power-on sequence will consistently place the system into one of the forward link error correction states and not have persistence from the previous use.*

4.1.2.2 Point A Operational Point-to-Point RF Communication

[C3I-308V] Constellation point A systems' ability to coherently re-transmit the received carrier with a turn-around ratio of 240/221(transmit/receive) for coherent point-to-point link operation shall be verified by test.

Constellation point A systems' transmit frequency shall be measured while the systems' receiver is locked to a forward link signal at the assigned frequency that is in the 2025 – 2110 MHz band and while the transponder is in the coherent mode of operation. Furthermore, after the determination that the transmit frequency is 240/221 times the frequency of the received signal, the forward link signal shall be swept in frequency over a +/- <TBD 4-2> Hz band at a <TBD4-2> rate and the transmit frequency shall be monitored to ensure that it follows the received signal's frequency as it is swept.

The verification shall be considered successful when the measured Constellation point A systems' transmit frequency is demonstrated to be 240/221 times the frequency of the received forward link signal while the systems' transponder is in the coherent mode of operation and that the transmit frequency follows the received frequency (by the 240/221 ratio) as the forward link is swept in frequency.

***Rationale**: Measuring the systems' transmit frequency while the systems' transponder is locked to the forward link signal, while the transponder is in the coherent mode of operation, and monitoring the systems' transmit frequency while forward link signal is swept in frequency ensures the verification of the 240/221 ratio and the coherency between the transmit frequency and the received carrier.*

[C3I-314V] Constellation point A SYSTEMS' ability to coherently re-transmit the received range channel data to point B SYSTEM shall be verified by analysis and test.

An analysis shall be performed to verify that Constellation point A SYSTEMS' transmitted (return link) carrier frequency and PN code clock frequency are derived from the received (forward link) carrier frequency. Test shall be performed to verify that point A SYSTEMS' transmitted (return link) I channel PN code epoch is synchronized with the epoch of the received (forward link) range channel PN code.

The verification shall be considered successful when the analysis result indicates that Constellation point A SYSTEMS' transmitted (return link) carrier frequency and PN code clock frequency are derived from the received (forward link) carrier frequency and test result indicates that point A SYSTEMS' transmitted (return link) I channel PN code epoch is synchronized with the epoch of the received forward link range channel PN code.

> ***Rationale****: In order to coherently re-transmit the received range channel "data" (i.e., PN code), it is necessary for Constellation point A SYSTEMS to derive their transmitted carrier frequency and PN code clock frequency from the received carrier frequency. Furthermore, point A SYSTEMS' transmitted (return) I channel PN code epoch needs to be synchronized to the epoch of the received forward link range channel PN code.*

[C3I-350V] Constellation point A systems' ability to provide a non-coherent mode of operation for operational point-to-point links shall be verified by test.

(i) Tests shall be performed on Constellation point A systems during the systems' integration and test, using calibrated commercial test equipment and the C&T Network test set or equivalent, to verify that the systems will transmit a carrier which is independent of the received carrier frequency or in the absence of the received carrier frequency, which shall be within +/- 700 Hz of 240/221 times the assigned center frequency of the receive channel <TBR 4-6>, and which shall meet the frequency stability, phase noise and other requirements listed in Table 6-12 of GSFC-450-SNUG, and that the C&T Network test set or equivalent can receive Constellation point A systems' transmitted signal at the specified data rate(s).

(ii) End-to-End RF link tests shall be performed on fully integrated Constellation point A systems, using the C&T Network test set or equivalent and point B systems emulators <TBR 4-7> to demonstrate compatibility between Constellation point A systems and infrastructure and between Constellation point A systems and Constellation point B systems when point A systems operate in the non-coherent mode.

The verification shall be considered successful when:

(i) Test results measured on Constellation point A systems during the systems' integration and test, using calibrated commercial test equipment and the C&T Network test set or equivalent, demonstrate that the systems transmit a carrier which is independent of the received carrier frequency or in the absence of the received carrier frequency, which is within +/- 700 Hz of 240/221 times the assigned center frequency of the receive channel <TBR 4-6>, and which meets the frequency stability, phase noise and other requirements listed in Table 6-12 of GSFC-450-SNUG,

(ii) Results of the End-to-End RF link tests performed on fully integrated Constellation point A systems, using the C&T Network test set or equivalent and point B systems emulators <TBR 4-7>, demonstrates compatibility between Constellation point A systems and infrastructure and between Constellation point A systems and Constellation point B systems, with C&T Network and mission operations <TBR 4-7> and Constellation point B systems being able to acquire and receive Constellation point A systems' transmitted signal at the specified data rate(s) when Constellation point A systems operate in the non-coherent mode.

> ***Rationale**: Tests performed during Constellation point A systems' integration and test will verify point A systems' ability to provide the non-coherent mode of operation with the transmitted signal meeting the signal constraints specified in Table 6-12 of GSFC-450-SNUG. End-to-end RF link tests will verify compatibility between Constellation point A systems and infrastructure and Constellation point A systems and Constellation point B systems when operating in the non-coherent mode.*

[C3I-573V] Constellation point A SYSTEM'S use of transmit signal with modulation scheme in accordance with Table 3.1-2 for operational point-to-point links shall be verified by test.

(i) Tests shall be performed at the component level and during Constellation point A SYSTEMS integration and test using calibrated commercial test equipment and the C&T Network test set or equivalent, respectively, to verify that the modulation scheme of point A SYSTEMS' transmit signal for operational point-to-point links is in accordance with Table 3.1-2 and in compliant with the signal constraints listed in section 5.3 and 6.3 of the SNUG Rev. 8.

(ii) End-to-end RF link tests shall be performed on Constellation point A SYSTEMS to verify that the C&T Network test set or equivalent and Constellation point B SYSTEMS' emulators can receive Constellation point A SYSTEMS' transmit signal for operational point-to-point links.

The verification shall be considered successful when:

(i) Results of the tests performed on Constellation point A SYSTEMS' components or fully integrated point A SYSTEMS demonstrate that the modulation scheme of point A SYSTEMS' transmit signal for operational point-to-point links is in accordance with Table 3.1-2 and in compliant with the signal constraints listed in sections 5.3 and 6.3 of the SNUG Rev. 8;

(ii) Results of the end-to-end tests demonstrate that the C&T Network test set or equivalent and Constellation point B SYSTEMS' emulators can receive the signal for operational point-to-point links sent by Constellation point A SYSTEMS.

> ***Rationale**: Testing at the component level and during the point A SYSTEMS integration and test verify the transmit signal's modulation scheme and its characteristics. Compliant with the signal constraints listed in sections 5.3 and 6.3 of the SNUG ensure that the performance of the point-to-point communications link will not be degraded when the transmit signal is received by the C&T network or the point B SYSTEMS. The end-to-end RF link tests ensure compatibility between Constellation point A SYSTEMS and the C&T Network and the point B SYSTEMS.*

[C3I-574V] Constellation point A SYSTEMS ability to receive signal with modulation scheme in accordance with Table 3.1-3 for operational point-to-point links shall be verified by test.

(i) Tests shall be performed on Constellation point A SYSTEMS during their integration and test using the C&T Network test set or equivalent to verify that Constellation point A SYSTEMS can receive signal with modulation scheme in accordance with Table 3.1-3 and with salient characteristics shown in sections 5.2 and 6.2 of the SNUG Rev. 8.

(ii)End-to-end RF link tests shall be performed on fully integrated Constellation point A SYSTEMS to verify that they are able to receive signal sent by C&T Network test set or equivalent and Constellation point B SYSTEMS' emulators with modulation scheme in accordance with Table 5 and with salient characteristics listed in sections 5.2 and 6.2 of the SNUG Rev. 8 for operational point-to-point links.

The verification shall be considered successful when:

(i) Results of the tests performed on Constellation point A SYSTEMS during their integration and test that they are able to receive signal with the modulation scheme in accordance with Table 3.1-3 and with salient characteristics listed in Section 5.2 and 6.2 of the SNUG Rev. 8;

(ii) Results of the end-to-end tests demonstrate that the Constellation point A SYSTEMS are able to receive signal from the C&T Network test set or equivalent and Constellation point B SYSTEMS' emulators with modulation scheme in accordance with Table 3.1-3 and with salient characteristics listed in sections 5.2 and 6.2 of the SNUG for operational point-to-point links.

> ***Rationale***: *Testing during the point A SYSTEMS integration and test reduces programmatic risk. The end-to-end RF link tests ensure compatibility between Constellation point B SYSTEMS and the C&T Network.*

[C3I-633V] The ability of Constellation point A SYSTEMS to transmit independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 shall be verified by test and analysis.

The Point A SYSTEM under test shall be placed in the Data Group 1 data transmission mode and the resulting output transmission signal observed and the resulting decoded transmission observed. The following conditions shall be tested:

(1) Separate data streams being presented simultaneously, one for inphase modulation and a second for quadrature modulation at separate supported bit rates.

(2) A data stream for inphase modulation at a supported bit-rate presented with no data presented at the quadrature modulation port

(3) A data stream for quadrature modulation presented at a supported bit-rate with no data presented at the inphase modulation port

(4) No data presented at either the quadrature or inphase modulation port. The resulting signal shall be decoded with ground equipment to be used in support of the Constellation project or similar equipment and the resulting data received compared to the data sent and sample signals from each case shall be analyzed using waveform analysis equipment.

The verification shall be considered successful when waveform analysis shows that data is transmitted simultaneously (not interleaved) when both inphase and quadrature modulation channels and in every case for all bit rates specified as being supported, the data presented for modulation can be successfully received by the ground equipment.

> ***Rationale**: To be sure that the data is not being interleaved, the actual signal must be observed. It is insufficient to only observe macro-results as interleaving can be virtually indistinguishable from the simultaneous independent transmission required. In the event that ground equipment is unable to interpret the signal, analysis of the received signal will also be required to determine if the fault is with the transmission or with the receiving equipment.*

4.1.2.3 Point B Operational Point-to-Point RF Communication

[C3I-315V] The processing of coherent turn-around carrier to make radiometric measurements of range rate data (two-way Doppler data) for operational point-to-point links shall be verified by analysis and test.

Operational scenarios shall be analyzed and representative conditions shall be tested exercising limits, nominal cases, noisy cases, rate changes, and the integration/sample intervals defined in the Space Network Users Guide (SNUG). Dynamic link emulation using these profiles shall be executed and presented to the hardware and software.

Software algorithms shall be analyzed to observe error paths, limits, and capability to consider sampling intervals.

Verification of radiometric calculations shall be considered successful when (1) resulting solutions agree with the emulated scenarios in every nominal test case and (2) noisy source data is detected and properly reported by the software.

> ***Rationale**: Measurement of the Doppler and ranging propagation of the communication channel provides data required for navigation. Emulating the flight profile operational environment dynamic delays and data capture will be reasonable data with which to test the radiometric calculations developed. Correctness of the calculations from test results alone though would be inconclusive to assurance that all software paths are covered. While there is no expressed requirement for the handling of invalid data, a lack of detection by the processing chain should be unacceptable.*

[C3I-572V] The processing of coherent turn-around ranging channel data to provide radiometric measurements of range data for operational point-to-point links shall be verified by analysis and test.

Operational scenarios shall be analyzed and representative conditions shall be tested exercising limits, nominal cases, noisy cases, rate changes, and the integration/sample intervals defined in the Space Network Users Guide (SNUG). Dynamic link emulation using these profiles shall be executed and presented to the hardware and software.

Software algorithms shall be analyzed to observe error paths, limits, and capability to consider sampling intervals.

Verification of radiometric calculations shall be considered successful when (1) resulting solutions agree with the emulated scenarios in every nominal test case and (2) noisy source data is detected and properly reported by the software.

> ***Rationale****: Measurement of the Doppler and ranging propagation of the communication channel provides data required for navigation. Emulating the flight profile operational environment dynamic delays and data capture will be reasonable data with which to test the radiometric calculations developed. Correctness of the calculations from test results alone though would be inconclusive to assurance that all software paths are covered. While there is no expressed requirement for the handling of invalid data, a lack of detection by the processing chain should be unacceptable.*

[C3I-575V] Constellation point B SYSTEMS use of transmit signal with modulation scheme in accordance with Table 3.1-3 for operational point-to-point links shall be verified by test.

(i) Tests shall be performed at the component level and during Constellation point B SYSTEMS' integration and test using calibrated commercial test equipment and the C&T Network test set or equivalent, respectively, to verify that the modulation scheme of point B SYSTEMS' transmit signal for operational point-to-point links is in accordance with Table 3.1-3 and in compliant with the signal constraints listed in sections 5.2 and 6.2 of the SNUG Rev. 8.

(ii) End-to-end RF link tests shall be performed on Constellation point B SYSTEMS to verify that the C&T Network test set or equivalent and Constellation point A SYSTEMS' emulators can receive Constellation point B SYSTEMS' transmit signal for operational point-to-point links.

The verification shall be considered successful when:

(i) Results of the tests performed on Constellation point B SYSTEMS' components or fully integrated point B SYSTEMS demonstrate that the modulation scheme of point B SYSTEMS' transmit signal for operational point-to-point links is in accordance with Table 3.1-3 and in compliance with the signal constraints listed in sections 5.2 and 6.2 of the SNUG Rev. 8;

(ii) Results of the end-to-end tests demonstrate that the C&T Network test set or equivalent and Constellation point B SYSTEMS' emulators can receive the signal for operational point-to-point links sent by Constellation point A SYSTEMS.

> ***Rationale****: Testing at the component level and during the point B SYSTEMS integration and test verify the transmit signal's modulation scheme and its characteristics. Compliant with the signal constraints listed in sections 5.2 and 6.2 of the SNUG ensure that the performance of the point-to-point communications link will not be degraded when the transmit signal is received by the C&T network or the point A SYSTEMS. The end-to-end RF link tests ensure compatibility between Constellation point B SYSTEMS and the C&T Network and the point A SYSTEMS.*

[C3I-576V] Constellation point B SYSTEMS' ability to receive signal with modulation scheme in accordance with Table 3.1-2 for operational point-to-point links shall be verified by test.

(i) Tests shall be performed on Constellation point B SYSTEMS during their integration and test using a GFE test set or equivalent to verify that Constellation point B SYSTEMS can receive signal with modulation scheme in accordance with Table 3.1-2.

(ii) End-to-end RF link tests shall be performed on fully integrated Constellation point B SYSTEMS to verify that they are able to receive signal sent by C&T Network test set or equivalent, and Constellation point B SYSTEMS' emulators with modulation scheme inaccordance with Table 3.1-2.

The verification shall be considered successful when:

(i) Results of the tests performed on Constellation point B SYSTEMS during their integration and test that they are able to receive signal with the modulation scheme in accordance with Table 3.1-2, and

(ii) Results of the end-to-end tests demonstrate that the Constellation point B SYSTEMS are able to receive signal from the C&T Network test set or equivalent and Constellation point A SYSTEMS' emulators with modulation scheme in accordance with Table 3.1-2.

> ***Rationale****: Testing during the point B SYSTEMS integration and test reduces programmatic risk. The end-to-end RF link tests ensure compatibility between Constellation point A SYSTEMS and the C&T Network.*

[C3I-591V] The transmission of Constellation point B SYSTEMS range channel data to point A SYSTEMS shall be verified by test and analysis.

Mission use cases for point B SYSTEMS ranging data shall be developed for extreme, median, and nominal ranges and trajectories. Each case shall be analyzed to determine expected ranging errors and compared to mission ranging requirement budgets. For each use case, all symbol rates and Doppler measurements (8 cases) shall be tested by simulating the RF linkage using a standard test set. Simulated mission attenuation, Doppler profiles, and signal delays shall be used during the tests for commanding of B SYSTEMS to simulate mission use case distances and trajectories.

The verification shall be considered successful when the analysis shows that all planned conditions have ranging errors within the mission required budgets, and testing show that all simulated test ranging results using B SYSTEM hardware remain within the mission error budget.

> ***Rationale****: Range channel data for Pseudo-Noise (PN) ranging must be stable and generated based upon a commonly understood time base, the exact contents of the measurement signal encoding, the carrier frequency and modulation are specified elsewhere. Test sets already exist to perform the simulations for this sort of testing as instantiated in TDRSS User Radio Frequency Test Set (TURFTS) and TDRSS Simulator (TSIM) from RT LOGIC Corporation.*

[C3I-634V] The ability of Constellation point B SYSTEMS to receive independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 shall be verified by test and analysis.

The Point B SYSTEM under test shall be placed in the Data Group 1 data receive mode and presented with data signals generated by Cx flight or similar equipment appropriate to that mode with nominal center frequency. The transmission signal shall be observed and the resulting demodulated signal and decoded transmission observed. The following conditions shall be tested:

(1) Separate data streams being presented simultaneously at the input of transmission ports, one an inphase modulation and a second for quadrature modulation at separate supported bit rates. (2) A data stream for inphase modulation at a supported bit-rate presented with no data presented at the quadrature modulation port. (3) A data stream for quadrature modulation presented at a supported bit-rate with no data presented at the inphase modulation port. (4) No data presented at either the quadrature or inphase modulation port.

Each of the cases shall be performed both with and without planned data encoding so that the I and Q channels can be separately observed and analyzed at the signal level. For each case, the resulting signal shall be decoded by the equipment under test and the resulting data received compared to the data sent.

The verification shall be considered successful when waveform analysis shows that data transmitted simultaneously (not interleaved) on both inphase and quadrature modulation channels for all bit rates specified as supported was successfully received and decoded by the system equipment.

> ***Rationale**: The testing should be able to be performed independently as well as part of an integrated system testing. The source modulator must be able to encode I and Q channels separately. Observing the output of modulation with no signal will produce a single spike at the carrier. With modulation present on both channels, the signal will spread as 1/sin X from the center frequency. With the signal only on one channel, there will be a spike present from the unmodulated channel. Phase analysis equipment will produce a characteristic pattern for the phase encoding that is used. This will verify that the signal presented is reasonable for the A system to be able to interpret. To be sure that the data are not interleaved, the cases of single presentation may be observed and analyzed. It is possible to distinguish an interleaved signal from a single quadrature signal on a frequency analyzer and the simultaneous transmission. It is insufficient to only observe macro-results as interleaving can be virtually indistinguishable from the simultaneous independent transmission required. In the event that ground equipment is unable to interpret the signal, analysis of the received signal will also be required to determine if the fault is with the transmission or with the receiving equipment.*

4.1.3 High-Rate Point-to-Point RF Communication

4.1.3.1 Common High Rate RF Communication

[C3I-30V] Constellation SYSTEMS usage of CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) per CCSDS 131.1-O-1 Section 3 to transmit data streams for high rate point-to-point links shall be verified by Inspection and Test.

(1) An inspection shall be performed on the SYSTEM coding implementation for adherence to CCSDS 131.1-O-1 Section 3. (2) A test shall be performed using flight or flight like components in a controlled environment (e.g. ESTL test bed) to assess the performance of the transmitter coding. Detailed verification objectives shall be developed to assess performance in the relevant RF environments expected in the Constellation mission for both nominal and maximum data rates. Measurements of codeword error rate (CWER), undetected codeword error rate (UER), bit error rate (BER), TRP or TRP/NSD as applicable and PDL (if applicable) shall be recorded. (3) End-to-End data flow tests shall be performed on Constellation SYSTEMS with each of the networks or other in-space Constellation SYSTEMS. The interfaces, hardware and test conditions are specified below. The data used for these tests shall be representative of the mission data, including engineering data as well as compressed or uncompressed video data as applicable. Tests shall be conducted at the data rates specified in the applicable Interface Requirements Document (IRD). The CCSDS Rate-1/2 LDPC decoder used for these tests (e.g at WSC) shall be identically implemented (including decoding algorithm and iteration) as the actual decoder that will be used to support Constellation Missions.

a) High Rate Point-to-Point Links through the Space Network or Near-Earth Relay Satellite: Tests shall be conducted with the transmitted signal relayed through the actual Tracking and Data Relay Satellite (TDRS) and received at the White Sands Complex (WSC).

b) High Rate Point-to-Point Links with Direct-to-Earth networks (DSN, GN, etc.): Tests shall be conducted using a CTN compatibility test set or equivalent equipped with hardware that are identically implemented as those used in the networks' ground stations.

c) High Rate Point-to-Point Links with other In-space Constellation Systems: Tests shall be conducted using emulators or test sets of the other in-space Constellation SYSTEMs containing hardware that is identically implemented as in the flight SYSTEMS.

d) High Rate Point-to-Point Links with Lunar Relay Satellite (TBR): Tests shall be conducted with the transmitted signal relayed through the actual Lunar Relay Satellite (TBR) and received at the applicable ground station.

Bit error rates shall be measured during these tests. Tests shall be conducted first without the CCSDS Rate-1/2 coding in order to establish the performance baseline and then with the CCSDS Rate-1/2 coding. The coding gain shall be verified against the value specified in the Constellation Master Link Book (CXP-70022 Volume 3). Data latency requirements as specified in (TBD) shall also be verified during these tests.

Verification shall be considered successful when (1) the inspection shows compliance to CCSDS 131.1-O-1 Section 3, (2) detail verification objectives are met for all tested conditions and data rates with a performance that achieves theoretical or idealized simulation results within the tolerance of the specified implementation loss, and (3) the end-to-end test demonstrates good data flow and the determination that the coding gain and data latency requirements are met.

> ***Rationale****: Testing is required for the following reasons: a) different decoding algorithms will produce different error performance even though the code specification is the same, b) error performance is channel dependent - a channel with correlated errors/statistics will produce different results, c) incompatibilities can occur from incomplete or poorly written code specifications, d) complexities of the coding and decoding algorithms are large enough that data rate can affect error performance, e) symbol and frame synchronization algorithms can impact error performance of CCSDS Rate 1/2 LDPC codes.*

[C3I-31V] Constellation SYSTEMS' use of bit randomization and frame synchronization techniques as specified in CCSDS 131.0-B-1 for High Rate point-to-point links shall be verified by test.

The test shall consist of data exchanges from the SYSTEM under test to an external system. Traffic shall be observed using a channel monitoring tool. Frame synchronization techniques and pseudo-bit randomization shall be observed.

The verification shall be considered successful when the bit synchronization for the received communications signal is maintained in compliance with CCSDS 131.0-B-1.

> ***Rationale****: Using a channel monitoring tool to measure the SYSTEMS' data exchanges will verify compliance to the CCSDS 131.0-B-1 standard.*

[C3I-581V] Constellation SYSTEMS' capability to transmit using Right-hand Circular polarization (RHCP) for high rate links shall be verified by test.

Constellation SYSTEMS' antennas intended for use in high rate links shall be tested in an anechoic chamber with a standard (per IEEE’s definition <TBR 4-1>), right-hand circularly polarized antenna acting as a receiving antenna. Co-polarization radiation patterns shall be measured at the low end, high end, and Constellation SYSTEMS' channel center frequencies of the 25.5 – 27 GHz band to verify the antennas’ gain, beamwidth, and bandwidth. Tests shall also be performed to verify Constellation SYSTEMS’ antennas’ axial ratio.

The verification shall be considered successful when the measured co-polarization radiation patterns demonstrate that Constellation SYSTEMS’ antennas meet the specified gain, beamwidth and bandwidth and the axial ratio test result demonstrates that Constellation SYSTEMS’ antennas meet the specified axial ratio requirement.

> ***Rationale****: Verification of the antennas' polarization at the component level in an anechoic chamber is appropriate because for singly polarized antennas, there is no polarization ambiguity (as opposed to antennas with dual, selectable polarizations) after they are installed on Constellation SYSTEMS.*

[C3I-583V] Constellation SYSTEMS usage of CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) per CCSDS 131.1-O-1 Section 3 for decoding received data streams using FEC for high rate point-to-point links shall be verified by Inspection and Test.

(1) An inspection shall be performed on the SYSTEM decoding implementation for adherence to CCSDS 131.1-O-1 Section 3. (2) A test shall be performed using flight or flight like components in a controlled environment (e.g. ESTL test bed) to assess the performance of the receiver decoding. Detailed verification objectives shall be developed to assess performance in the relevant RF environments expected in the Constellation mission for both nominal and maximum data rates. Measurements of codeword error rate (CWER), undetected codeword error rate (UER), bit error rate (BER), TRP or TRP/NSD as applicable and PDL (if applicable) shall be recorded. (3) End-to-End data flow tests shall be performed on Constellation SYSTEMS with each of the networks or other in-space Constellation SYSTEMS. The interfaces, hardware and test conditions are specified below. The data used for these tests shall be representative of the mission data, including engineering data as well as compressed or uncompressed video data as applicable. Tests shall be conducted at the data rates specified in the applicable Interface Requirements Document (IRD). The Rate-1/2 LDPC encoder used for these tests (e.g. at WSC) shall be identically implemented as the actual encoder that will be used to support Constellation Missions.

a) High Rate Point-to-Point Links through the Space Network or Near-Earth Relay Satellite: Tests shall be conducted with the WSC-transmitted signal relayed through the actual Tracking and Data Relay Satellite (TDRS) and received by the Constellation SYSTEMS under test.

b) High Rate Point-to-Point Links with Direct-to-Earth networks (DSN, GN, etc.): Tests shall be conducted using a CTN compatibility test set or equivalent equipped with hardware that are identically implemented as those used in the networks' ground stations.

c) High Rate Point-to-Point Links with other In-space Constellation Systems: Tests shall be conducted using emulators or test sets of the other in-space Constellation SYSTEMs containing hardware that is identically implemented as in the flight SYSTEMS.

d) High Rate Point-to-Point Links with Lunar Relay Satellite (TBR): Tests shall be conducted with the ground station- transmitted signal relayed through the actual Lunar Relay Satellite (TBR) and received by the Constellation SYSTEMS under test.

Bit error rates shall be measured during these tests. Tests shall be conducted first without the CCSDS Rate-1/2 coding in order to establish the performance baseline and then with the CCSDS Rate-1/2 coding. The coding gain shall be verified against the value specified in the Constellation Master Link Book (CXP-70022 Volume 3). Data latency requirements as specified in (TBD) shall also be verified during these tests.

Verification shall be considered successful when (1) the inspection shows compliance to CCSDS 131.1-O-1 Section 3, (2) detail verification objectives are met for all tested conditions and data rates with a performance that achieves theoretical or idealized simulation results within the tolerance of the specified implementation loss, and (3) the end-to-end test demonstrates good data flow and the determination that the coding gain and data latency requirements are met.

> ***Rationale**: Testing is required for the following reasons: a) different decoding algorithms will produce different error performance even though the code specification is the same, b) error performance is channel dependent - a channel with correlated errors/statistics will produce different results, c) incompatibilities can occur from incomplete or poorly written code specifications, d) complexities of the coding and decoding algorithms are large enough that data rate can affect error performance, e) symbol and frame synchronization algorithms can impact error performance of CCSDS Rate 1/2 LDPC codes.*

[C3I-589V] Constellation SYSTEMS' capability to receive using Right-hand Circular polarization (RHCP) for high rate links shall be verified by test.

Constellation SYSTEMS' antennas intended for use in high rate links shall be tested in an anechoic chamber with a standard (per IEEE's definition <TBR 4-1>), right-hand circularly polarized antenna acting as a transmitting antenna. Co-polarization radiation patterns shall be measured at the low end, high end, and Constellation SYSTEMS' channel center frequencies of the 25.5 – 27 GHz band to verify the antennas' gain, beamwidth, and bandwidth. Tests shall also be performed to verify Constellation SYSTEMS' antennas' axial ratio.

The verification shall be considered successful when the measured co-polarization radiation patterns demonstrate that Constellation SYSTEMS' antennas meet the specified gain, beamwidth and bandwidth and the axial ratio test result demonstrates that Constellation SYSTEMS' antennas meet the specified axial ratio requirement.

> ***Rationale**: Verification of the antennas' polarization at the component level in an anechoic chamber is appropriate because for singly polarized antennas, there is no polarization ambiguity (as opposed to antennas with dual, selectable polarizations) after they are installed on Constellation SYSTEMS.*

[C3I-598V] Correct implementation of data frame format shall be verified by Demonstration.

Data flow demonstrations using C&T Networks or integrating multiple Cx SYSTEMS shall be performed.

Verification shall be considered successful following good data flow during compatibility testing with TDRSS, DSN (if dissimilar from TDRSS), and applicable C3I relay implementations.

> ***Rationale**: AOS is a specialized, loose specification and C3I will implement a version of it. Test suites are not common as for widely used standards like IP or 1553. Data flow through real ground stations or at least real ground station hardware is necessary for each type of dissimilar ground station implementation (DSN, TDRSS, SCN, and STDN). Demonstration can be at "strong signal". Validation of the prototype is required to avoid expensive rework or workarounds. Flight validation can be less rigorous, verifying that problems were corrected.*

[C3I-600V] Compatible implementation of data frame format shall be verified by Demonstration.

Data flow demonstrations using C&T Networks or integrating multiple Cx SYSTEMS shall be performed.

Verification shall be considered successful following good data flow during compatibility testing with TDRSS, DSN (if dissimilar from TDRSS), or applicable C3I relay implementations.

> ***Rationale****: Demonstration can be at "strong signal." AOS is a specialized, loose specification and C3I will implement a version of it. Test suites are not common as for widely used standards like IP or 1553. Data flow through real ground stations or at least real ground station hardware is necessary for each type of dissimilar ground station implementation (DSN, TDRSS, SCN, and STDN). Validation of the prototype is required to avoid expensive rework or workarounds. Flight validation can be less rigorous, verifying that problems were corrected. This particular requirement is a very simple implementation of a fixed pattern appearing at regular intervals; verification with the ground station would find improper MSB/LSB order or byte swapping or other fundamental error.*

[C3I-601V] Correct implementation of data frame format shall be verified by Demonstration.

Data flow demonstrations using C&T Networks or integrating multiple Cx SYSTEMS shall be performed.

Verification shall be considered successful following good data flow during compatibility testing with TDRSS, DSN (if dissimilar from TDRSS), and applicable C3I relay implementations.

> ***Rationale****: Demonstration can be at "strong signal." AOS is a specialized, loose specification and C3I will implement a version of it. Test suites are not common as for widely used standards like IP or 1553. Data flow through real ground stations or at least real ground station hardware is necessary for each type of dissimilar ground station implementation (DSN, TDRSS, SCN, and STDN). Validation of the prototype is required to avoid expensive rework or workarounds. Flight validation can be less rigorous, verifying that problems were corrected.*

[C3I-603V] Compatible implementation of data frame format shall be verified by Demonstration.

Data flow demonstrations using C&T Networks or integrating multiple Cx SYSTEMS shall be performed.

Verification shall be considered successful following good data flow during compatibility testing with TDRSS, DSN (if dissimilar from TDRSS), and applicable C3I relay implementations.

> ***Rationale****: Demonstration can be at "strong signal." AOS is a specialized, loose specification and C3I will implement a version of it. Test suites are not common as for widely used standards like IP or 1553. Data flow through real ground stations or at least real ground station hardware is necessary for each type of dissimilar ground station*

implementation (DSN, TDRSS, SCN, and STDN). Validation of the prototype is required to avoid expensive rework or workarounds. Flight validation can be less rigorous, verifying that problems were corrected.

[C3I-632V] The ability of Constellation systems to enable and disable communication link forward error correction upon receipt of command shall be verified by test.

Each system to be used shall be tested by commanding each system to all Error Correction (EC) state transitions and observing the resulting forward data link output. Tests shall be performed on flight or equivalent systems. Tests may be conducted in a testbed or using actual systems. The commanding system may be simulated.

Transitions to be tested are:

(1) Initial power-on state to No Error Correction, (2) Error-Correction to No Error Correction, (3) No Error-Correction to Error-Correction, (4) No Error-Correction to No Error-Correction. and (5) Error-Correction to Error-Correction.

The verification shall be considered successful when, for every system after commanding, all initial error correction states result in the commanded state being observed in the forward link data received. Should there be more than one error correction protocol implemented, the verification shall be considered successful for this requirement if every protocol available, considered alone, is capable of the five (5) transitions tested.

***Rationale**: Observing the resulting output of the forward link is the only way to assure that the commanded state has occurred. There may also be a telemetry discrete that may be checked, and if present should properly indicate the state of forward link error correction encoding (but it is not necessary for validation of this requirement.) Since neither the error correction protocol nor the number of such protocol is specified, the conditional success criteria is needed. Transition from one error correction protocol to another may be possible and even desirable, but is not necessary for correct operation. If the final design allows for such, operational testing should perform those tests to assure that the specific equipment works. A very difficult case to test could arise if the error correction method is totally configurable. In that case we would limit to those methods available and intended for use and proof that the reconfiguration can be successfully performed from one protocol to a not-yet configured protocol both of which are intended for use. It is also assumed that the initial power-on sequence will consistently place the system into one of the forward link error correction states and not have persistence from the previous use.*

4.1.3.2 Point A High-Rate Point-to-Point RF Communication

[C3I-577V] Constellation point A SYSTEMS' use of transmit signal with modulation scheme in accordance with Table 3.1-4 for high rate point-to-point links shall be verified by test.

(i) Tests shall be performed at the component level and during Constellation point A SYSTEM integration and test using calibrated commercial test equipment and the GSE test set or equivalent to verify that the modulation scheme of point A SYSTEMS' transmit signal for operational point-to-point links is in accordance with Table 3.1-4.

(ii) End-to-end RF link tests shall be performed on Constellation point A SYSTEMS to verify that the C&T Network test set or equivalent, and Constellation point B SYSTEMS' emulators can receive Constellation point A SYSTEMS' transmit signal for high rate point-to-point links.

The verification shall be considered successful when:

(i) Results of the tests performed on Constellation point A SYSTEMS' components or fully integrated point A SYSTEMS demonstrate that the modulation scheme of point A SYSTEMS' transmit signal for high rate point-to-point links is in accordance with Table 3.1-4, and

(ii) Results of the end-to-end tests demonstrate that the C&T Network test set or equivalent, and Constellation point B SYSTEMS' emulators can receive the signal for high rate point-to-point links sent by Constellation point A SYSTEMS.

> ***Rationale****: Testing at the component level and during the point A SYSTEMS integration and test verify the transmit signal's modulation scheme and its characteristics. The end-to-end RF link tests ensure compatibility between Constellation point A SYSTEMS and the C&T Network and the point B SYSTEMS.*

[C3I-578V] Constellation point A SYSTEMS' ability to receive signal with modulation scheme in accordance with Table 3.1-5 for high rate point-to-point links shall be verified by test.

(i) Tests shall be performed on Constellation point A SYSTEMS during their integration and test using a GFE test set or equivalent to verify that Constellation point A SYSTEMS can receive signal with modulation scheme in accordance with Table 3.1-5.

(ii) End-to-end RF link tests shall be performed on fully integrated Constellation point A SYSTEMS to verify that they are able to receive signal sent by C&T Network test set or equivalent, and Constellation point B SYSTEMS' emulators with modulation scheme in accordance with Table 3.1-5.

The verification shall be considered successful when:

(i) Results of the tests performed on Constellation point A SYSTEMS during their integration and test are shown to receive signals with the modulation scheme in accordance with Table 3.1-5, and

(ii) Results of the end-to-end tests demonstrate that the Constellation point A SYSTEMS are able to receive signal from the C&T Network test set or equivalent, and Constellation point B SYSTEMS' emulators with modulation scheme in accordance with Table 3.1-5.

> ***Rationale****: Testing during the point A SYSTEMS integration and test reduces programmatic risk. The end-to-end RF link tests ensure compatibility between Constellation point B SYSTEMS and the C&T Network.*

4.1.3.3 Point B High-Rate Point-to-Point RF Communication

[C3I-579V] Constellation point B SYSTEMS use of transmit signal with modulation scheme in accordance with Table 3.1-5 for high rate point-to-point links shall be verified by test.

(i) Tests shall be performed at the component level and during Constellation point B SYSTEMS' integration and test using calibrated commercial test equipment and a GFE test set or equivalent to verify that the modulation scheme of point B SYSTEMS' transmit signal for high rate point-to-point links is in accordance with Table 3.1-5.

(ii) End-to-end RF link tests shall be performed on Constellation point B SYSTEMS to verify that the C&T Network test set or equivalent, and Constellation point A SYSTEMS' emulators can receive Constellation point B SYSTEMS' transmit signal for high rate point-to-point links.

The verification shall be considered successful when:

(i) Results of the tests performed on Constellation point B SYSTEMS' components or fully integrated point B SYSTEMS demonstrate that the modulation scheme of point B SYSTEMS' transmit signal for high rate point-to-point links is in accordance with Table 3.1-5, and

(ii) Results of the end-to-end tests demonstrate that the C&T Network test set or equivalent, and Constellation point B SYSTEMS' emulators can receive the signal for high rate point-to-point links sent by Constellation point A SYSTEMS.

> ***Rationale****: Testing at the component level and during the point B SYSTEMS integration and test verify the transmit signal's modulation scheme and its characteristics. The end-to-end RF link tests ensure compatibility between Constellation point B SYSTEMS and the C&T Network and the point A SYSTEMS.*

[C3I-580V] Constellation point B SYSTEMS' ability to receive signal with modulation scheme in accordance with Table 3.1-4 for high rate point-to-point links shall be verified by test.

(i) Tests shall be performed on Constellation point B SYSTEMS during their integration and test using the GFE test set or equivalent to verify that Constellation point B SYSTEMS can receive signal with modulation scheme in accordance with Table 3.1-4.

(ii) End-to-end RF link tests shall be performed on fully integrated Constellation point B SYSTEMS to verify that they are able to receive signal sent by C&T Network test set or equivalent, and Constellation point B SYSTEMS' emulators with modulation scheme in accordance with Table 3.1-4.

The verification shall be considered successful when:

(i) Results of the tests performed on Constellation point B SYSTEMS during their integration and test that they are able to receive signals with the modulation scheme in accordance with Table 3.1-4, and

(ii) Results of the end-to-end tests demonstrate that the Constellation point B SYSTEMS are able to receive signal from the C&T Network test set or equivalent and Constellation point A SYSTEMS' emulators with modulation scheme in accordance with Table 3.1-4.

***Rationale**: Testing during the point B SYSTEMS integration and test reduces programmatic risk. The end-to-end RF link tests ensure compatibility between Constellation point A SYSTEMS and the C&T Network.*

4.1.4 Multipoint Proximity RF Communication

4.1.5 Recovery RF Communication

4.1.5.1 Common Recovery RF Communication

[C3I-347V] The ability of the Constellation SYSTEMS to transmit to the COSPAS/SARSAT system using the spectrum guidelines provided by ITU-R Recommendation M.633 shall be verified by test and analysis.

Tests shall be performed on Constellation SYSTEM'S Radio-beacon in coordination with COSPAS/SARSAT. The radio-beacon shall be registered with COSPAS/SARSAT. Testing of the spectrum emitted shall occur in a Radio-Frequency (RF) shielded environment. The spectrum emitted shall be measured and analyzed. After analysis of the testing in the shielded environment is successful, all radio-beacons to be used shall be tested in coordination with COSPAS/SARSAT.

The test in an RF shielded environment shall be considered successful if the center frequency, spectrum, registered beacon code, and emitted power are in accord with the ITU-R Recommendation M.633 and the COSPAS/SARSAT system successfully receives the beacon signal, beacon identification, and GPS information encoded by the beacon.

***Rationale**: The radio-beacon is essential safety equipment and requires testing for adherence to spectra to guarantee inter-operability. Testing in an RF shielded environment will assure that the center frequency is in the appropriate band for M.633. Testing with SARSAT will assure that the encoded transmission is being properly broadcast. ITU-R M.633 covers the transmission characteristics of a Satellite Emergency Position-indicating Radio-beacon (Satellite EPIRB) System Operating Through a Low Polar-orbiting Satellite System in the 406 MHz Band. Every beacon has a unique code assigned to it and a testing capability that transmits a single encoded burst to SARSAT. SARSAT will be able to confirm that the beacon successfully transmitted based on that code. It is also desirable that similar equipment be tested at the nominal landing site and at contingency landing sites as part of retrieval exercises as a part of mission assurance activities.*

[C3I-362V] The Constellation SYSTEM'S analog voice communications shall be analyzed and tested for AM and narrowband FM modulation with US and international search and rescue.

Analysis shall be performed to verify analog voice communications is capable of AM and narrowband FM modulation.

***Rationale**: Tests shall be performed, using signal and spectral monitoring equipments, on analog audio communications to verify AM and narrowband FM modulation.*

[C3I-363V] The compliance of Constellation SYSTEMS to transmit to the COSPAS/SARSAT system as per C/S T.001 (Specification for COSPAS/SARSAT 406 MHz Distress Beacons, Issue 3 - Revision 7 - Nov 2005), Sections 2 and 3 shall be verified by test and analysis.

Tests shall be performed on Constellation SYSTEMS' Radio-beacon in coordination with COSPAS/SARSAT. The radio-beacon shall be registered with COSPAS/SARSAT. Testing of the operation of the Emergency Position-Indicating Radio Beacons (EPIRB) shall occur in a Radio-Frequency (RF) shielded environment. Every requirement of the C/S T.001 applicable to EPIRB shall be tested. Items to be monitored during testing: Time between signal bursts, Center frequency, Unmodulated carrier lead in, Message data, Frequency (to be plotted), Transmitted power into a 50 ohm load, Data message, Spurious emissions, and Rise & Fall of modulated wave-form. Antenna characteristics are to be determined: (Measured in all expected configurations), Pattern, Polarization, Gain (Azimuth to Horizon), VSWR (Voltage Standing-Wave Ratio). Test shall include the following conditions: Stabilization period (15 minutes), Temperature variation period, Thermal shock response, Open circuit to transmitter, Short circuit to transmitter, VSWR at 1:1, 3:1, and nominal. The signal emitted shall be measured and analyzed. After analysis of the testing in the shielded environment is successful, all radio-beacons to be used shall be tested in coordination with COSPAS/SARSAT and re-tested in accordance with COSPAS/SARSAT schedules.

The initial test in an RF shielded environment shall be considered successful when all results from testing the beacon are in accord with C/S T.001. The field test of the beacon shall be considered successful if COSPAS/SARSAT system successfully receives the beacon signal, beacon identification, and GPS information encoded by the beacon.

> ***Rationale****: The emergency radio-beacon is essential safety equipment and requires testing for adherence to C/S T.001 and confirmation of inter-operability with the COPAS/SARSAT system. Testing with COPAS/ SARSAT will assure that the encoded transmission is being properly formatted and broadcast with sufficient signal strength. Since COPAS/SARSAT is an operational emergency system, coordinating every test is necessary to avoid activating emergency responses unnecessarily. Testing in an RF shielded environment will assure that signals are appropriate and full adherence to C/S T.001 is in place. C/S T.001 includes specifications for the manufacture of Emergency Position-Indicating Radio Beacons (EPIRBs). Every beacon has a unique code assigned to it and a testing capability that transmits a single encoded burst to SARSAT. SARSAT will be able to confirm that a beacon successfully transmitted based on that code. This is adequate for maintenance testing once the unit is certified. Certification testing would be much more extensive. It is also desirable that similar equipment be tested at the nominal landing site and at contingency landing sites as part of retrieval exercises as a part of mission assurance activities.*

4.1.6 RF Contingency Voice Communication

4.1.6.1 Common RF Contingency Voice Communication

[C3I-385V] Ability to use Analog AM Modulation for contingency voice shall be verified by test.

Tests shall be performed using representative power electronics, voice modulator, and receive electronics at appropriate SNR levels. These shall include hardline tests with measurements of voice intelligibility, system bandwidth and magnitude and phase characteristics.

Successful verification shall occur when the received voice signal is determined to be of good quality as indicated using the Mean Opinion Score (MOS) evaluation methodology with a required score of at least <TBD 4-3>.

> ***Rationale****: Verification of the intelligibility of received contingency voice communications is vital for crew safety and mission survival during critical non-nominal situations.*

4.1.7 Future High Rate Link Class

4.1.8 Vehicle Internal Wireless Link Class

4.2 Hard-Line Communication

4.2.1 High-Rate, Hard-Line Communication

[C3I-58V]

4.2.2 High-Rate, Ground Hard-line Communication

[C3I-336V] Constellation SYSTEMS' use of IP routed networks for ground institutional links shall be verified by test.

The test shall consist of interconnection of the SYSTEM under test to a ground network using appropriate physical and link-layer interfaces. An application-layer connectivity testing tool shall be used to determine IP connectivity between the SYSTEM under test and one or more systems in the ground network.

The verification shall be considered successful when the connectivity testing tool determines that there is bidirectional connectivity between the SYSTEM under test and the ground network system(s).

> ***Rationale****: Using a connectivity testing the SYSTEMS' IP data exchanges will verify that IP routed networks for ground institutional links.*

4.2.3 Deterministic Hard-line Communication

4.3 Network

4.3.1 Connectivity

[C3I-61V] Constellation systems' implementation of STD-0005, the Internet Protocol, shall be verified by test.

The test shall consist of endpoint transmission of IPv4 packets over a testbed network link. The packets shall be observed with a network traffic monitoring tool. The test shall include evaluation of fields in the IPv4 headers of packets observed by the monitoring tool.

The verification shall be considered successful when evaluation of the IPv4header fields shows no protocol violations and correct calculation of length and checksum values for 100% of observed IPv4 packets.

> ***Rationale****: Using a traffic monitoring tool to measure the SYSTEMS' IP data exchanges will verify compliance to the Internet Protocol standards.*

[C3I-62V] The use of public and private unicast IP addresses as defined in RFC-1918 shall be verified by test.

The test shall consist of configuration of a network of Constellation systems with RFC-1918 private unicast IP addresses and, subsequently, public unicast IP addresses. In each case, traffic shall be transmitted in both directions between this network and an external network with public unicast IP addresses using an application-layer connectivity testing tool.

The verification shall be considered successful when the testing tool determines that the external network can be reached when the test network uses public unicast IP addresses, but not when the test network uses private unicast IP addresses.

> ***Rationale****: Using a connectivity testing tool to measure element data exchanges will verify public and private IPv4 unicast address compliance to RFC-1918.*

[C3I-63V] The use of public and private multicast IP addresses as defined in RFC-3171 shall be verified by test.

The test shall consist of configuration of a network of Constellation systems with RFC-3171 private multicast IP addresses and, subsequently, public multicast IP addresses. In each case, multicast traffic shall be transmitted in both directions between this network and an external network with public addresses using an application-layer multicast connectivity testing tool.

The verification shall be considered successful when the testing tool determines that multicast traffic can be passed between the test network and the external network when the test network uses public multicast IP addresses, but not when the test network uses private multicast IP addresses.

> ***Rationale****: Using a connectivity testing tool to measure element data exchanges will verify public and private multicast address compliance to RFC-3171.*

[C3I-64V] Manual configuration of IP addresses on addressable Constellation system interfaces shall be verified by test.

The test shall consist of manually configuring an IP address on each addressable interface. IP packets shall be transmitted from each interface and observed with a network traffic monitoring tool. The source address field in the IP headers shall be examined.

The verification shall be considered successful when the value of the source address field of the observed IP packet headers from each tested interface is equal to the manually configured address for that interface.

> ***Rationale****: Using a traffic monitoring tool to measure element data exchanges will verify manual configuration IPv4-addressable interfaces.*

[C3I-72V] IP network address to Link-layer address mappings for external IP addresses by Constellation SYSTEMS shall be verified by test.

The test shall consist of invocation of a network-specific address resolution function to determine the IP addresses to the corresponding link-layer addresses of external systems with link-layer connectivity to the SYSTEM under test. The test shall be conducted for a range of IP addresses and repeated at least twice with different values.

The verification shall be considered successful when the IP address resolution function returns the correct link-layer address for each tested IP address.

> ***Rationale****: Using a test set to measure SYSTEM data exchanges will verify link-layer address to IP network address mappings for IP addresses external to the SYSTEM.*

[C3I-73V] The utilization of managed associations to map IP addresses to data link layer addresses for IP addresses external to the SYSTEM shall be verified by test.

The test shall consist of manually entering a set of managed associations in order to map IP address to link-layer address mappings, then invoking the address resolution function to determine the link-layer addresses corresponding to IP addresses in the set of mappings. The test shall be conducted for a range of values and repeated at least twice with different values.

The verification shall be considered successful when the address resolution function returns the corresponding link layer address for each IP address specified in the manually-entered mapping.

> ***Rationale****: Comparison of link layer addresses returned by the address resolution function with the manually entered mapping will verify the correct resolution of entries using the static managed associations.*

[C3I-74V] Modification of the IP address to data-link layer address mapping information via the network on Constellation SYSTEMS shall be verified by test.

The test shall consist of sending IP address to data-link layer address mapping information via the network to the SYSTEM under test, then invoking the address resolution function to determine the link-layer addresses corresponding to IP addresses in the set of mappings. The test shall be conducted for a range of values and repeated at least twice with different values.

The verification shall be considered successful when the address resolution function returns the corresponding link-layer address for each IP address specified in the mapping sent via the network.

> ***Rationale****: Comparison of link layer addresses returned by the address resolution function with the mapping received via the network will verify the correct resolution of entries using network-modified IP address to data-link layer address mapping.*

[C3I-75V] The ability of Constellation SYSTEMS to perform multi-hop routing as specified in RFC-1812 and updated by RFC-2644 shall be verified by test.

The test shall consist of invoking each of the functions and options specified by RFC-1812 and update RFC-2644, with the SYSTEM under test connected via a network to other systems known to be compliant with RFC-1812 and update RFC-2644 acting as sources and sinks of traffic. Traffic transmitted by the SYSTEM under test shall be observed with a network monitoring system.

The verification shall be considered successful when each function or option is observed to conform to the requirements of RFC-1812 and updated RFC-2644.

> ***Rationale****: Testing each of the specified functions during communication with an external system known to be compliant with RFC-1812 and update RFC-2644 will verify RFC-1812 and updated RFC-2644 compliance for the SYSTEM under test.*

[C3I-76V] The compliance of Constellation systems with RFC-1122 shall be verified by test.

The test shall consist of invoking each of the functions and options specified by RFC-1122, with the system under test connected via a network to other systems known to be compliant with RFC-1122 and acting as sources and sinks of traffic. Traffic transmitted by the system under test shall be observed with a network monitoring system.

The verification shall be considered successful when each function or option is observed to conform to the requirements of RFC-1122.

> ***Rationale****: Testing each of the specified functions during communication with an external system known to be compliant with RFC-1122 will verify RFC-1122 compliance for the system under test.*

[C3I-78V] Constellation systems' preference for manually configured routes over exactly matching dynamically learned routes shall be examined by test.

The test shall consist of injecting routes for a set of destination IP address blocks into the dynamic routing protocol, then manually configuring routes for an identical set of address blocks on the system under test. The route query function shall then be invoked for addresses within each destination address block in the set to determine the preferred route.

The verification shall be considered successful when the route query function returns the manually configured routes instead of the dynamically learned routes for all queries.

> ***Rationale****: Injecting identical routes both statically and dynamically, and then invoking the route selection function will verify the requirement. Testing is required to perform this verification.*

[C3I-79V] Determination of routes using static routing tables by Constellation systems shall be verified by test.

The test shall consist of manually configuring routes for a set of destination IP address blocks on the system under test. The route query function shall then be invoked for addresses within each destination address block in the set to determine the preferred route.

The verification shall be considered successful when the route selection function returns the corresponding route for each network block in the manually-entered mapping.

> ***Rationale****: Entering routes into the static routing table, then observing if the route query function returns the correct route from the static routing table will verify that the system does use the static routing table in the route selection process.*

[C3I-80V] Modification of the routing tables via the network on Constellation systems shall be verified by test.

The test shall consist of sending a set of routing table modifications via the network to the system under test, then invoking the route query function for destination addresses within each address block contained in the update to determine the preferred route.

The verification shall be considered successful when the route query function returns the corresponding network-supplied route for each IP address specified.

> ***Rationale****: Sending network modifications to the system under test, then observing if the route query function returns the correct route from the network-modified routing table will verify that the system does accept and use routing table modifications sent via the network in the route selection process.*

[C3I-87V] Suppression of default route advertisements via routing protocols by Constellation elements shall be verified by test.

The test shall consist of configuring a default route on the system under test, then comparing routes in the system routing table with routes contained in routing protocol advertisements transmitted by the system and observed using a network traffic monitoring tool.

The verification shall be considered successful when all routes other than the default are observed in two successive sets of route advertisements.

> ***Rationale****: Using a network traffic monitoring to measure routing updates and comparing them to elements' routing tables during route establishment and routing updates will verify that only non-default routes via the routing protocols.*

[C3I-89V] The ability of Constellation systems to maintain a default route in the routing tables shall be verified by test.

The test shall consist of configuring a default route in the system under test, then invoking the route query function for a set of destination IP addresses within address blocks not listed elsewhere in the routing table.

The verification shall be considered successful when the route query function returns the default route for each destination IP address tested.

> ***Rationale**: Using a route query functions to show systems' routing tables will verify that a default route is specified.*

[C3I-90V] The fail over to default routes by Constellation systems in the event of a loss of all routing information or the loss of communication to all system network neighbors participating in the routing protocol for more than 20 seconds shall be verified by test.

The test shall consist of blocking network communication between the system under test and the other systems participating in the dynamic routing protocol. After a period of time greater than the routing protocol-specific timeout value, the route query function shall be invoked for a set of destination IP addresses.

The verification shall be considered successful when the route query function returns the default route for each destination IP address tested.

> ***Rationale**: Using a route query functions to show systems' routing tables will verify that a default route is used when there is a loss of all routing information or a loss of communication to all system network neighbors participating in the dynamic routing protocol.*

[C3I-93V] The ability of Constellation systems to resolve symbolic names to IP addresses using a static host table shall be verified by test.

The test shall consist of entering a set of mappings of symbolic names to IP addresses into the static host table, then invoking the symbolic name resolution function for each of the symbolic names entered.

The verification shall be considered successful when the symbolic name resolution function returns the corresponding IP address for each symbolic name specified.

> ***Rationale**: Comparing the symbolic name resolutions to the corresponding IP address will verify resolution of symbolic names.*

[C3I-95V] Modification of the static host table via the network on Constellation systems shall be verified by test.

The test shall consist of sending a set of host table modifications via the network to the system under test, then invoking the symbolic name resolution function for each of the symbolic names contained in the update.

The verification shall be considered successful when the symbolic name resolution function returns the corresponding IP address for each symbolic name specified.

> ***Rationale**: Sending a set of host table modifications via the network will verify that the elements will accept changes to the static host table.*

[C3I-96V] The implementation by Constellation Systems of RFC-2474 shall be verified by test.

The test shall consist of defining a set of per-hop behaviors (PHBs) and a set of traffic classes that map to each PHB. Traffic corresponding to each defined class shall then be introduced to the system under test. Traffic exiting the system under test shall be observed with a network traffic monitoring tool. The DS field for each packet and the flow characteristics (throughput, latency, jitter, loss rate) of aggregate traffic of each class shall be evaluated.

The verification shall be considered successful when the DS field in each packet is set to the corresponding codepoint for the corresponding traffic class, and the flow characteristics of aggregate traffic of each class corresponds with the specified PHB.

> ***Rationale****: Using a test set to analyze the elements' Differentiated Services Field will verify RFC-2474.*

[C3I-97V] The implementation by Constellation systems of RFC 2211 shall be verified by test.

The test shall consist of introducing specified traffic to the system under test in the absence of competing traffic, and observing the test traffic with a network monitoring tool. Flow characteristics (throughput, latency, jitter, loss rate) and parameters needed to specify a TSpec shall be determined from the observed traffic. A TSpec with these parameters shall then be supplied to the system under test, along with both the test traffic and competing traffic sufficient to overload the system. Flow characteristics of the test traffic shall again be observed.

The verification shall be considered successful then the flow characteristics of the test traffic when the system under test is overloaded with competing traffic are equivalent to the flow characteristics of the test traffic in the absence of competing traffic.

> ***Rationale****: Using a network monitoring tool to measure the elements' congested and un-congested data exchanges will verify compliance to the Controlled-Load Network System Service standard.*

[C3I-98V] Constellation systems' implementation of RFC-2205, the Resource Reservation Protocol (RSVP) shall be verified by test.

The test shall consist of endpoint transmission of packets over testbed network links, incorporating RSVP reservations. The test shall include the evaluation of RSVP reservation requests, reservation paths and reservation teardown using a protocol analyzer or equivalent test set on flight or flight-like components.

The verification shall be considered successful when the protocol analysis shows no protocol violations during the RSVP reservation and teardown process utilizing a Government Furnished test set or equivalent.

> ***Rationale****: Using a protocol analyzer or equivalent test set to measure the elements' reserved and best effort data exchanges will verify compliance to the RSVP standard.*

[C3I-99V] The implementation by Constellation SYSTEMS of STD-0062 shall be verified by test.

The test shall consist of invoking each function detailed in the listed standards for the role of the SYSTEM under test (agent or manager) from an external station in the opposite role that is known to comply with the listed standards. The value returned by each function shall be compared with the value returned by an analogous internal, system-specific query for the same variable. Additionally, the traffic transmitted by the SYSTEM under test shall be observed with a network monitoring tool to evaluate the format of the data (request, response, or trap).

The verification shall be complete when each tested function returns a value consistent with the internally available value and no protocol errors are observed.

> ***Rationale**: Using a network monitoring tool to measure the SYSTEMS' data exchanges and comparing the values with SNMP MIB values will verify compliance to the standards.*

[C3I-103V] The implementation by Constellation systems of Internet STD-0007 shall be verified by test.

The test shall consist of establishing TCP connections from the system under test to an external system that is known to comply with the standard and vice versa. Connections shall evolve through the complete cycle of setup, operation, and tear-down, and each TCP option specified in the standard shall be invoked on one or more connections. TCP traffic from the system under test shall be observed with a network monitoring tool. The fields of the TCP headers in the observed traffic shall be evaluated for correctness and protocol compliance.

The verification shall be considered successful when all fields of the observed TCP headers are correct and no protocol errors are observed.

> ***Rationale**: Using a network monitoring tool to measure the elements' TCP data exchanges will verify compliance to the Transmission Control Protocol standard.*

[C3I-104V] The implementation by Constellation SYSTEMS of RFC-1323 shall be evaluated by test.

The test shall consist of establishment of TCP connections from the SYSTEM under test to an external system that is known to comply with RFC-1323 and vice versa. One or more connections shall include each of the Window Scale, Round Trip Time Measurement, and Protection Against Wrapped Sequence Numbers options. TCP traffic from the SYSTEM under test shall be observed with a network monitoring tool. Traffic bandwidth and delays shall be modified during the tests. The fields of the TCP headers shall be evaluated for compliance to the above options.

The verification shall be considered successful when all traffic observed during a test of each option complies with the specification of that option detailed in RFC-1323.

> ***Rationale**: Using a network monitoring tool to measure the SYSTEMS' TCP data exchanges will verify compliance to the RFC-1323 standard.*

[C3I-105V] Constellation systems' implementation of STD-0006, the User Datagram Protocol, shall be verified by test.

The test shall consist of endpoint transmission of UDP packets over testbed network links for SNMP, VoIP, and other packets that use UDP. The test shall include the evaluation of source port, destination port, UDP datagram length and UDP checksum, protocol violations, and errors using a protocol analyzer or equivalent test set. The test shall be performed on flight or flight-like components.

The verification shall be considered successful when the protocol analysis shows no protocol violations during conditions of error and non-error data transmissions utilizing a Government Furnished test set or equivalent.

> ***Rationale****: Using a protocol analyzer tool or equivalent test set to measure the elements' UDP data exchanges will verify compliance to the User Datagram Protocol standard.*

[C3I-106V] Constellation systems' implementation of RFC-3550 (STD-0064), the real-time transport protocol (RTP) shall be verified by test.

The test shall consist of endpoint transmission of RTP packets over testbed network links for VoIP and Motion Imagery packets. The test shall include evaluation of payload type, sequence numbers and timestamps. A test of data exchanges using RTP protocol shall be performed using flight components over simulated networks.

The verification shall be considered successful when the protocol analysis shows no protocol violations using measured test data at the component level utilizing a Government Furnished test set or equivalent.

> ***Rationale****: Using a test set to measure the elements' real-time data exchanges will verify compliance to the RTP standard.*

[C3I-281V] Constellation systems' implementation of RFC-3140, Per Hop Behavior Identification Codes, shall be verified by test.

Testing of per hop behaviors shall be performed in conjunction with Differentiated Services code points, using flight components over simulated networks.

The verification shall be considered successful when the DiffServ analysis is completed, showing no protocol violations, using measured test data at the component level utilizing a Government Furnished test set or equivalent.

> ***Rationale****: Using a test set to analyze the elements' Per Hop Behavior Identification Codes will verify RFC-3140.*

[C3I-282V] Constellation systems' implementation of RFC-3246, An Expedited Forwarding PHB (Per Hop Behavior) shall be verified by test.

Testing of per hop behaviors shall be performed in conjunction with Differentiated Services code points, using flight components over simulated networks.

The verification shall be considered successful when the DiffServ analysis is completed, showing no protocol violations, using measured test data at the component level utilizing a Government Furnished test set or equivalent.

***Rationale**: Using a test set to analyze the elements' Expedited Forwarding will verify RFC-3246.*

[C3I-619V] Constellation systems' implementation of a performance enhancing proxy (PEP) using the SCPS-TP transport layer shall be verified by test.

The test shall consist of connecting the system under test via PEP to other end systems and PEPs known to be compliant with CCSDS 714.0.B-1 over an emulated link with bandwidth*delay product exceeding 1e6 bits and/or a bit error rate equal to or greater than 1e-6. An application-layer TCP connectivity testing tool shall be used to transmit bidirectional TCP traffic between the system under test and the other end systems. A network monitoring tool shall be used to observe traffic from the PEP under test on the emulated link. Observed SCPS-TP headers will be examined for conformance to CCSDS 714.0.B-1.

The verification shall be considered successful when the system under test is are able to transmit bidirectional TCP traffic through the PEP under test, and no protocol errors are observed in traffic from the PEP over the emulated link.

***Rationale**: Exchanging bidirectional TCP traffic with other end systems and observing protocol compliance of traffic transmitted to other known-compliant PEPs will verify the compliance to CCSDS 714.0.B-1 of the system and PEP under test.*

[C3I-620V] Constellation systems' implementation of RFC-2460, the Internet Protocol, Version 6, shall be verified by test.

The test shall consist of endpoint transmission of IPv6 packets over a testbed network link. The packets shall be observed with a network traffic monitoring tool. The test shall include evaluation of fields in the IPv6 headers of packets observed by the monitoring tool.

The verification shall be considered successful when evaluation of the IPv6 header fields shows no protocol violations and correct calculation of length and checksum values for 100% of observed IPv6 packets.

***Rationale**: Using a traffic monitoring tool to measure the elements' IPv6 data exchanges will verify compliance to the IPv6 standards.*

[C3I-621V] Constellation systems' implementation of RFC-792, the Internet Control Message Protocol, shall be verified by test.

The test shall consist of exchanging ICMP messages of each type specified in RFC-792 in both directions between the system under test and an external system known to be compliant with RFC 792. The ICMP traffic shall be observed with a network monitoring tool.

The verification shall be considered successful when there are no protocol errors observed in the messages transmitted by the systems under test.

***Rationale**: Exchanging ICMP traffic with a known-compliant external system will verify that the system under test is itself compliant.*

[C3I-622V] Constellation systems' implementation of RFC-4443, the Internet Control Message Protocol version 6 (ICMPv6), shall be verified by test.

The test shall consist of exchanging ICMPv6 messages of each type specified in RFC-4443 in both directions between the system under test and an external system known to be compliant with RFC-4443. The ICMPv6 traffic shall be observed with a network monitoring tool.

The verification shall be considered successful when there are no protocol errors observed in the messages transmitted by the systems under test.

> ***Rationale****: Exchanging ICMPv6 traffic with a known-compliant external system will verify that the system under test is itself compliant.*

[C3I-654V] Constellations systems' implementation of the Multiprotocol Border Gateway Protocol as specified in RFC-2858 shall be verified by test.

The test shall consist of evaluation of the MBGP implementation with a protocol analyzer, followed by the exchange of MBGP protocol messages between the system under test and one or more external peer systems known to be compliant with the MBGP specification. Protocol-specific routing information shall be observed by examination of the routing tables on the system under test and by observation of exchanged MBGP messages with a network monitoring tool. The test shall be performed on flight or flight-like components using a Government-furnished test set.

The verification shall be considered successful when no protocol errors or errors in the MBGP messages are observed for any transmitted traffic.

> ***Rationale****: Using a protocol analyzer to test MBGP functionality and also testing interoperability with external systems known to be compliant with the MBGP protocol specification will verify that the system under test is compliant.*

[C3I-655V] Constellations systems' implementation of the Multicast Listener Discovery Protocol, version 2 as specified in RFC-3810, shall be verified by test.

The test shall consist of evaluation of the MLD implementation with a protocol analyzer, followed by the exchange of MLD protocol messages between the system under test and an external system known to be compliant with the MLD specification. The protocol operations to be verified shall be specific to the role of the system under test, either a multicast listener or multicast router as defined in the specification. Traffic between the system under test and the external system shall be observed with a network monitoring tool. The test shall be performed on flight or flight-like components using a Government-furnished test set.

The verification shall be considered successful when no protocol errors or errors in the MLD messages are observed for any transmitted traffic.

> ***Rationale****: Using a protocol analyzer to test MLD functionality and also testing interoperability with an external system known to be compliant with the MLD protocol specification will verify that the system under test is compliant.*

[C3I-656V] Constellation systems' implementation of the Multicast Extension to OSPF as specified in RFC-1584 shall be verified by test.

The test shall consist of the evaluation of Multicast Extension to OSPF (MOSPF) route establishment, route changes and the link-state database using by exchanging MOSPF updates between the system under test and one or more external systems known to be compliant with the MOSPF specification. Traffic between the system under test and the external systems shall be observed with a network monitoring tool. The routing tables of the system under test shall then be analyzed and compared with observed MOSPF update messages. The test shall be performed on flight or flight-like components using a Government-furnished test set.

The verification shall be considered successful when the protocol analysis shows no protocol violations and the routing tables show no errors.

> ***Rationale**: Testing interoperability with external systems known to be compliant with the MOSPF specification, along with comparing observed MOSPF routing messages to the routing tables of the system under test during route establishment and routing updates, will verify compliance to the MOSPF standards.*

[C3I-657V] Constellation systems' implementation of the Internet Group Management Protocol (IGMP) as specified in RFC-3376 shall be verified by test.

The test shall consist of the evaluation of IGMP IP multicast group membership updates using a protocol analyzer, followed by the exchange of IGMP messages with one or more external systems known to be compliant with the IGMP specification. The group membership tables of the system under test shall then be analyzed. The test shall be performed on flight or flight-like components using a Government-furnished test set.

The verification shall be considered successful when the protocol analysis shows no protocol violations and the group membership tables show no errors.

> ***Rationale**: Using a protocol analyzer to measure IGMP updates and comparing them to the group membership tables of the system under test, along with testing interoperability with external systems known to be compliant with the IGMP specification, will verify compliance to the IGMP multicast standards.*

4.3.2 Dynamic Routing Between Systems

[C3I-82V] Constellation systems' implementation of RFC-2453, STD-0056 - RIP Version 2 shall be verified by test.

The test shall consist of the evaluation of RIP route establishment, route changes and route updates using a protocol analyzer and analyzing the system routing tables. The test shall be performed on flight or flight-like components.

The verification shall be considered successful when the protocol analysis shows no protocol violations utilizing a Government Furnished test set or equivalent.

> ***Rationale**: Using a protocol analyzer to measure RIP routing updates and comparing them to elements' routing tables during route establishment and routing updates will verify compliance to the RIP standards.*

[C3I-83V] Constellation systems' implementation of RFC-2328, STD-0054 - OSPF Version 2 shall be verified by test.

The test shall consist of the evaluation of OSPF route establishment, route changes and the link-state database using a protocol analyzer and analyzing the system routing tables. The test shall be performed on flight or flight-like components.

The verification shall be considered successful when the protocol analysis shows no protocol violations utilizing a Government Furnished test set or equivalent.

> ***Rationale**: Using a protocol analyzer to measure OSPF routing updates and comparing them to elements' routing tables during route establishment and routing updates will verify compliance to the OSPF standards.*

[C3I-295V] Constellation systems' implementation of RFC-3626 Optimized Link State Routing Protocol (OLSR) shall be verified by test.

The test shall consist of endpoint transmission of packets over testbed network links for mobile ad hoc networks. The test shall include the evaluation of neighbor detection, multipoint relay flooding and topology discovery using a protocol analyzer or equivalent test set. The test shall be performed on flight or flight-like components.

The verification shall be considered successful when the protocol analysis shows no protocol violations utilizing a Government Furnished test set or equivalent.

> ***Rationale**: Using a protocol analyzer to measure OLSR routing updates and comparing them to elements' routing tables during route establishment, neighbor detection and routing updates will verify compliance to the OLSR standards.*

[CLV_GOE] The requirement shall be verified by analysis of lower level test data. The verification shall be considered successful when analysis shows CLV has sent Criticality 3 [TBD-052-010] files to the GS as specified in the [TBD-052-011] File Data Book.

[C3I-663V] Constellation SYSTEMS' implementation of RFC-2740 , OSPF for IPv6 shall be verified by test.

The test shall consist of the evaluation of OSPF route establishment, route changes and the link-state database using a protocol analyzer and analyzing the system routing tables. The test shall be performed on flight or flight-like components.

The verification shall be considered successful when the protocol analysis shows no protocol violations utilizing a Government Furnished test set or equivalent.

> ***Rationale**: Using a protocol analyzer to measure OSPF routing updates and comparing them to SYSTEMS' routing tables during route establishment and routing updates will verify compliance to the OSPF standards or IPv6.*

4.3.3 External Connectivity

[C3I-81V] Constellation SYSTEMS' implementation of RFC-4271 " A Border Gateway Protocol (BGP) Version 4" shall be verified by test.

The test shall consist of manually configuring BGP neighbors on the system under test, then comparing routes in the system routing table with routes contained in routing protocol advertisements transmitted by the system and observed using a network traffic monitoring tool.

The verification shall be considered successful when the protocol analysis shows no protocol violations utilizing a Government Furnished test set or equivalent.

> ***Rationale**: Using a traffic monitoring tool to measure BGP routing updates and comparing them to systems' routing tables during route establishment and routing updates will verify compliance to the Border Gateway Protocol (BGP) Version 4 standards.*

[C3I-280V] The priority usage of external routes learned by BGP shall be verified by test.

The test shall consist of configuring a BGP routes on the system under test, then comparing routes in the system routing table with routes contained in routing protocol advertisements transmitted by the system and observed using a network traffic monitoring tool.

The verification shall be considered successful when external routes learned by BGP are used instead of routes learned via other dynamic routing protocols (RIP, OSPF and OLSR) in two successive sets of route advertisements.

> ***Rationale**: Using a network traffic monitoring to measure routing updates and comparing them to elements' routing tables during route establishment and routing updates will verify external routes are learned by BGP before those learned via other dynamic routing protocols.*

4.3.4 Name Service

[C3I-296V] Constellation systems' implementation of STD-0013 the Domain Name System shall be verified by test.

Testing of DNS functions shall be performed on flight or flight-like components.

The verification shall be considered successful when the analysis of domain name service shows no protocol or naming violations using measured test data at the component level utilizing a Government Furnished test set or equivalent.

> ***Rationale**: Analysis of elements' IP domain names using measured test data will verify compliance to the Domain Name System.*

4.3.5 Disruption Tolerance

[C3I-107V] Constellation systems' implementation of DTN, Delay/Disruption Tolerant Networking Specification, shall be verified by test.

The test shall consist of establishing a network consisting of the system under test and one or more external systems known to be compliant with the DTN Specification. DTN bundle traffic shall be sent to and from the system under test, which shall be partitioned from the network for varying durations of time during the transmissions. During periods of connectivity, traffic from the system under test shall be observed with a network monitoring tool for bundle loss and protocol violations, and bundles queued on the system under test shall be monitored for loss with an appropriate application-layer DTN diagnostic tool.

The verification shall be considered successful when the DTN diagnostic tool detects no bundle loss in violation of the protocol, and no protocol errors are observed in the traffic.

> ***Rationale****: Testing the system by exchanging DTN protocol traffic with external systems known to be compliant with the DTN Specification shall verify that protocol operations are implemented correctly.*

4.3.6 Dynamic Address Assignment

[C3I-67V] Constellation systems' implementation of DHCP Server shall be verified by test.

Testing of DHCP Server functions shall be performed on flight or flight-like components.

The verification shall be considered successful when the protocol analysis of DHCP shows no protocol violations using measured test data at the component level utilizing a Government Furnished test set or equivalent.

> ***Rationale****: Using a test set to measure element data exchanges will verify IP addressing via the Dynamic Host Configuration Protocol.*

4.3.7 Dynamic Address Retrieval

[C3I-69V] Constellation SYSTEMS' implementation of RFC-2131 Dynamic Host Configuration Protocol (DHCP) and update RFC-4361 shall be verified by test.

Testing of self-assigned IP addresses from via DHCP shall be performed on flight or flight-like components.

The verification shall be considered successful when the protocol analysis of DHCP address assignment shows no protocol violations using measured test data at the component level utilizing a Government Furnished test set or equivalent.

> ***Rationale****: Using a test set to measure element data exchanges will verify IP addressing via the Dynamic Host Configuration Protocol.*

[C3I-70V] Constellation systems' implementation of the 'self-assign' an IP addresses, based upon RFC-3927 shall be verified by test.

Testing of self-assigned IP addresses from the 169.254.0.0/16 private address block shall be performed on flight or flight-like components.

The verification shall be considered successful when the self-assignment of IP addresses from the 169.254.0.0/16 address block are completed when the Constellation elements are unable to obtain an IP address from pre-configuration information and/or DHCP.

> ***Rationale**: Using a test set to measure element data exchanges will verify IP private address assignments when unable to obtain an IP address from pre-configuration information and/or DHCP.*

4.3.8 Tunneling (GRE)

[C3I-92V] Constellation systems' implementation of RFC-2784, Generic Routing Encapsulation (GRE), shall be verified by test.

The test shall consist of endpoint transmission of GRE encapsulated packets over testbed network links. The test shall include evaluation of protocol type, sequence numbers, key and checksum, using flight components over simulated networks.

The verification shall be considered successful when the protocol analysis shows no protocol violations using measured test data at the component level utilizing a Government Furnished test set or equivalent.

> ***Rationale**: Protocol analysis will verify compliance to the GRE encapsulation standards.*

[C3I-664V] Constellation SYSTEMS' implementation of RFC-2473, Generic Packet Tunneling in IPv6 Specification., shall be verified by test.

The test shall consist of endpoint transmission of Generic Packet Tunneling encapsulated packets over testbed network links. The test shall include evaluation of protocol type, sequence numbers, key and checksum, using flight components over simulated networks.

The verification shall be considered successful when the protocol analysis shows no protocol violations using measured test data at the component level utilizing a Government Furnished test set or equivalent.

> ***Rationale**: Protocol analysis will verify compliance to the Generic Packet Tunneling encapsulation standards.*

4.3.9 Header Compression

[C3I-307V] Constellation SYSTEMS' implementation of RFC-2507, Compressing TCP/IP headers for low-speed serial links, shall be verified by test.

The test shall consist of the endpoint transmission of data exchanges with compressed TCP and IP headers over a testbed network link. The packets shall be observed with a network traffic monitoring tool. The test shall include evaluation of fields in the TCP and IP headers of packets observed by the monitoring tool.

The verification shall be considered successful when evaluation of the TCP and IP header compression shows no protocol violations for 100% of observed data exchanges.

***Rationale**: Using a network traffic monitoring tool to measure the SYSTEMS' TCP/IP data exchanges will verify compliance to RFC-2507 header compression standard.*

[C3I-588V] Constellation SYSTEMS' implementation of RFC 2508, Compressing IP/UDP/RTP Headers for Low-Speed Serial Links, shall be verified by test.

The test shall consist of exchanging compressed IP/UDP/RTP packets generated with an application-layer RTP tool over a suitable serial link between the SYSTEM under test and an external system known to be compliant with RFC 2508. The headers of packets sent on the link shall be observed with a suitable link monitoring tool.

The verification shall be considered successful when the application-layer RTP tool detects no errors in exchanged packets, and no errors are detected in the headers of packets observed on the serial link.

***Rationale**: Exchanging RTP packets from an application-layer RTP tool with a known-compliant system and observing the headers of packets sent over the serial link will verify the correct implementation of RFC 2508.*

4.3.10 Network Management

[C3I-100V] Constellation systems' implementation of RFC-4293, Management Information Base for Network Management of TCP/IP-based Internets, shall be verified by test.

Testing of the MIB-II Object Identifier (OID) values shall be performed using flight components over simulated networks to demonstrate conformance of the system, interfaces, IP, ICMP, TCP, UDP, EGP, SNMP, transmission and physical addresses group.

The verification shall be considered successful when the MIB-II analysis is completed, showing no MIB violations, using measured test data at the component level using utilizing a Government Furnished test set or equivalent.

***Rationale**: Measuring the MIB Object Identifier (OID) values and comparing them to known data exchanges will verify the MIB compliance.*

[C3I-294V] Constellation systems' implementation of RFC-4292, IP Forwarding MIB, shall be verified by test.

Testing of the IP Forwarding MIB Object Identifier (OID) values shall be performed using flight components over simulated networks to demonstrate MIB conformance for static routes and routes learned by RIP, BGP and OSPF.

The verification shall be considered successful when the routing table MIB analysis is completed, showing no MIB violations, using measured test data at the component level using utilizing a Government Furnished test set or equivalent.

***Rationale**: Measuring the MIB Object Identifier (OID) values and comparing them to known IP data exchanges will verify the MIB compliance.*

[C3I-298V] Constellation systems' implementation of RFC-3747, Differentiated Services Configuration MIB, shall be verified by test.

A test of data exchanges incorporating per hop behaviors shall be performed using flight components over simulated networks. Testing of the per hop behaviors shall be performed in conjunction with various Differentiated Services configuration templates to demonstrate Configuration MIB conformance.

The verification shall be considered successful when the DiffServ configuration table MIB analysis is completed, showing no MIB violations, using measured test data at the component level using utilizing a Government Furnished test set or equivalent.

> ***Rationale****: Measuring the MIB Object Identifier (OID) values and comparing them to known DiffServ configurations will verify the MIB compliance.*

[C3I-299V] Constellation systems' implementation of RFC-3289, MIB for the Differentiated Services Architecture, shall be verified by test.

Testing of the Differentiated Services Architecture MIB Object Identifier (OID) values shall be performed using flight components over simulated networks to demonstrate MIB conformance for data exchanges with marked Differentiated Services Code Points and per hop behaviors.

The verification shall be considered successful when the Differentiated Services Architecture MIB analysis shows no MIB violations, using measured test data at the component level using utilizing a Government Furnished test set or equivalent.

> ***Rationale****: Measuring the MIB Object Identifier (OID) values and comparing them to known UDP data exchanges will verify the MIB compliance.*

[C3I-300V] Constellation systems' implementation of RFC-2213, Integrated Services Management Information Base using SMIv2 shall be verified by test.

Testing of the Integrated Services MIB Object Identifier (OID) values shall be performed using flight components over simulated networks to demonstrate MIB conformance for RSVP reserved data exchanges.

The verification shall be considered successful when the Integrated Services MIB analysis shows no MIB violations, using measured test data at the component level utilizing a Government Furnished test set or equivalent.

> ***Rationale****: Measuring the MIB Object Identifier (OID) values and comparing them to known Integrated Services data exchanges will verify the MIB compliance.*

[C3I-301V] Constellation systems' implementation of RFC-4022, the Management Information Base for the Transmission Control Protocol (TCP) MIB, shall be verified by test.

Testing of the Transmission Control Protocol MIB Object Identifier (OID) values shall be performed using flight components over simulated networks to demonstrate MIB conformance for TCP data exchanges.

The verification shall be considered successful when the TCP MIB analysis shows no MIB violations, using measured test data at the component level using utilizing a Government Furnished test set or equivalent.

> ***Rationale****: Measuring the MIB Object Identifier (OID) values and comparing them to known TCP data exchanges will verify the MIB compliance.*

[C3I-302V] Constellation systems' implementation of RFC-4113, the Management Information Base for the User Datagram Protocol (UDP) MIB, shall be verified by test.

Testing of the User Datagram Protocol MIB Object Identifier (OID) values shall be performed during test data exchanges that use UDP, such as for exchanges utilizing SNMP or Voice Over IP. UDP MIB conformance shall be performed using flight components over simulated networks.

The verification shall be considered successful when the UDP MIB analysis is completed, showing no MIB violations, using measured test data at the component level using utilizing a Government Furnished test set or equivalent.

> ***Rationale****: Measuring the MIB Object Identifier (OID) values and comparing them to understood UDP data exchanges will verify the MIB compliance.*

[C3I-303V] Constellation systems' implementation of RFC-2959, Real-Time Transport Protocol MIB, shall be verified by test.

Testing of the Real-Time Transport Protocol MIB Object Identifier (OID) values shall be performed during test data exchanges that use RTP, such as for exchanges utilizing Voice Over IP and Motion Imagery. RTP MIB conformance shall be performed using flight components over simulated networks.

The verification shall be considered successful when the RTP MIB analysis is completed, showing no MIB violations, using measured test data at the component level using utilizing a Government Furnished test set or equivalent.

> ***Rationale****: Measuring the MIB Object Identifier (OID) values and comparing them to known RTP data exchanges will verify the MIB compliance.*

4.4 Security

4.4.1 Network Layer Security

[C3I-199V] Implementation of RFC-4301, Security Architecture for the IP, on inter-SYSTEM data exchange interfaces using IP shall be verified by Inspection and Test.

An inspection of the design and manufacturing documents (e.g., specifications, drawings, product data sheets) of the network security services shall be performed. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send and receive data in the information base, using network security services to ensure functional operation over the IP. The other SYSTEM may be simulated. Detailed verification objectives shall be developed using RFC 4301 as a guideline. The objectives shall include tests for compatibility between two SYSTEMS and tests for authentication, data integrity, and confidentiality. A range of data values and types shall be tested.

The verification shall be considered successful when (a) the inspection shows that network security services are implemented as specified in RFC-4301, and (b) the test shows that network security services provide the functionality described in RFC 4301 for protecting IP packets passed through the network security services (from an information base) in a manner that meets the detailed verification objectives including authentication, data integrity, confidentiality, and inter-SYSTEM compatibility.

> ***Rationale****: To verify the requirement for IP Security as defined in RFC-4301, both inspection and test must show compliance to meet authentication, data Integrity and confidentiality of IP based communications between Constellation Systems.*

[C3I-200V] Implementation of RFC-4302, Authentication Header for inter-system communications using IPsec, the networking device Authentication and Integrity shall be verified by Inspection and Test.

An inspection of the design and manufacturing documents (e.g., specifications, drawings, product data sheets) of the network security services shall be performed. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send and receive data in the information base, using network security services to ensure functional operation over the IP. The other SYSTEM may be simulated. Detailed verification objectives shall be developed using RFC-4302 as a guideline. The objectives shall include tests for compatibility between two SYSTEMS and tests for authentication and data integrity. A range of data values and types shall be tested.

The verification shall be considered successful when (a) the inspection shows that network IP AH and Integrity security services are implemented as specified in RFC-4302, and (b) the test shows that network security services provide the functionality described in RFC 4302 for protecting IP packets passed through the network security services (from an information base) in a manner that meets the detailed verification objectives including authentication, data integrity, and inter-SYSTEM compatibility.

> ***Rationale****: To verify the requirement for IP AH as defined in RFC 4302, both inspection and test must show compliance to meet authentication and data integrity of IP based communications between Constellation SYSTEMS.*

[C3I-201V] Implementation of RFC-4303, IP Encapsulating Security Payload (ESP) for inter-system communications using IPsec, the networking device encryption of packets shall be verified by Inspection and Test.

An inspection of the design and manufacturing documents (e.g., specifications, drawings, product data sheets) of the network security services shall be performed. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send and receive data in the information base, using network security services to ensure functional operation over the IP. The other SYSTEM may be simulated. Detailed verification objectives shall be developed using RFC 4303 as a guideline. The objectives shall include tests for compatibility between two SYSTEMS and tests for authentication, data integrity, and confidentiality of IP packets. A range of data values and types shall be tested.

The verification shall be considered successful when (a) the inspection shows that network IP ESP security services are implemented as specified in RFC 4303, and (b) the test shows that network security services provide the functionality described in RFC 4303 for the protection of IP packets passed through the security services (from an information base) in a manner that meets the detailed verification objectives including authentication, data integrity, confidentiality, and inter-SYSTEM compatibility.

> ***Rationale****: To verify the requirement for IP ESP as defined in RFC 4303, both inspection and test must show compliance to meet authentication, data integrity, and confidentiality of IP based communications between Constellation SYSTEMS.*

[C3I-204V] Implementation of RFC-4305, Cryptographic Algorithm Implementation Requirements for Encapsulating Security Payload (ESP) and Authentication Header (AH) at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces shall be verified by Inspection and Test.

An inspection of the design and manufacturing documents (e.g., specifications, drawings, product data sheets) of the network security services shall be performed. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send and receive data in the information base, using AH and ESP IPsec security services to ensure that the required algorithms are implemented and function properly. The other SYSTEM may be simulated. Detailed verification objectives shall be developed using RFC 4305 as a guideline. The objectives shall include tests for compatibility between two SYSTEMS and tests for authentication, data integrity, and confidentiality. A range of data values and types shall be tested.

The verification shall be considered successful when (a) the inspection shows that IP AH & ESP security services are implemented as specified in RFC 4305, and (b) when the Tests show that Information Systems' AH and ESP IPsec security services can access and transfer data in a manner that meets the detailed verification objectives including authentication, data integrity, confidentiality and inter-SYSTEM compatibility.

> ***Rationale****: To verify the requirement for Cryptographic Algorithm Implementation Requirements for Encapsulating Security Payload (ESP) and Authentication Header (AH) for inter-system communications using IPsec, as defined in RFC 4305, both Inspection and Test must show compliance to meet approved uses algorithms for data and information communications among Constellation SYSTEMS.*

[C3I-565V] Implementation of RFC-4309, Using Advanced Encryption Standard (AES) CCM Mode with IPsec Encapsulating Security Payload (ESP), in all inter-SYSTEM data and information exchanges shall be verified by Inspection and Test.

An inspection of the SYSTEM's design and manufacturing documentation (e.g., specifications, drawings, product data sheets) for the IPsec mechanisms shall be performed to ensure implementation of AES CCM mode. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send and receive data in the information base, using the AES CCM mode for ESP to ensure proper operation of the required algorithm and inter-SYSTEM interoperability. The test shall include both sending and receiving of AES CCM encrypted data.

The verification shall be considered successful when (a) the inspection shows that the implementation of the AES CCM mode for ESP is as specified in RFC 4309, and when (b) the test shows that successful inter-SYSTEM data exchanges occur using the AES CCM mode with IPsec ESP, as per RFC 4309 for the sending and receiving of encrypted data.

> ***Rationale****: To verify the requirement for IP Security as defined in RFC 4308, both Inspection and Test must be performed.*

4.4.2 Internet Key Exchange (IKE)

[C3I-209V] The implementation of RFC-4306, The INTERNET KEY EXCHANGE (IKEv2), for all inter-SYSTEM management of security associations and keys used by IPSec shall be verified by Inspection and Test.

An inspection of the design and manufacturing documents (e.g., specifications, drawings, product data sheets) of the Constellation SYSTEM shall be performed to ensure that the IKEv2 protocol has been implemented for the negotiation of the security associations (SAs) used by IPsec for inter-SYSTEM information exchanges. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to negotiate IPsec SAs to ensure interoperability. The other SYSTEM may be simulated. A representative set of IPsec security policies shall be used to control the negotiation of SAs.

Verification shall be considered successful when the inspection shows compliance to RFC-4306 and when the test shows that the two systems can successfully negotiate a set of IPsec SAs based upon the relevant IPsec security policies and valid authentication.

> ***Rationale****: To verify the requirement for the Internet Key Exchange (IKEv2) for all inter-system management of security associations and keys used by IPSec as defined in RFC 4306, both Inspection and test must show compliance to meet approved uses for Key Management among Constellation Systems.*

[C3I-568V] The implementation of RFC 4307, Cryptographic Algorithms for use in the Internet Key Exchange Version 2 (IKEv2) for all IKEv2 interfaces shall be verified by Inspection and Test.

An inspection of the SYSTEM's design and manufacturing documentation (e.g., specifications, drawings, product data sheets) for the IKEv2 mechanisms shall be performed to ensure the required algorithms have been implemented. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send and receive IPsec keys to ensure interoperability using the required algorithms. The other SYSTEM may be simulated. A representative sample of security keys shall be exchanged. SYSTEMS shall exchange roles, if applicable.

Verification shall be considered successful when the inspection shows compliance to RFC-4307 and when the test shows that a) security keys are transmitted, b) security keys are received, c) exchanged keys provide expected values, and d) SYSTEM roles are reversed, if applicable.

> ***Rationale****: To verify the requirement for the Internet Key Exchange (IKEv2) for all inter-system management of security associations and keys used by IPSec as defined in RFC-4307, both Inspection and test must show compliance to meet approved uses for Key Management among Constellation SYSTEMS.*

4.4.3 Application Layer Security

[C3I-210V] The compliance with the security mechanisms specified in CxP 70022, Volume 5: Data Exchange Protocol Specification for inter-SYSTEM updated of security processing logic shall be verified by Inspection and Test.

An inspection of the design and manufacturing documents (e.g., specifications, drawings, product data sheets) of the Constellation SYSTEM shall be performed to ensure that security processing logic updates is performed as described in C3I IOS Volume 5. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send and receive updates of security process logic per Vol 5 protocol mechanism. The other SYSTEM may be simulated. The update shall be performed for each device capable of receiving updates.

Verification shall be successful when inspection shows that the required functionality exists and when testing of the security processing logic update mechanisms shows proper operation of the required functionality based upon representative security policies and valid authentication.

> ***Rationale****: Inspection and Test of the updating of security processing logic are performed to show inter-system interoperability. Additional verification is performed in Volume 5.*

[C3I-566V] The compliance with security mechanisms specified in CxP 70022, Volume 5: Data Exchange Protocol Specification for the inter-SYSTEM exchanges of security policy information used by application layer security functions shall be verified by Inspection and Test.

An inspection of the SYSTEM's design and manufacturing documentation (e.g., specifications, drawings, product data sheets) for the IPsec mechanisms shall be performed to ensure implementation of AES CCM mode. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send (if the SYSTEM is responsible for managing the security policies of other SYSTEMs) and receive (if the SYSTEM's security policies are to be managed by another SYSTEM) security policy information per the Vol. 5 Data Exchange (DE) Protocol. The other SYSTEM may be simulated. The test shall be repeated with the SYSTEM performing all applicable roles (send and receive), as appropriate according to the functional requirements specified in 70070-ANX05 Book1.

Verification shall be successful when inspection shows the SYSTEM uses the DE Protocol to exchange the security policy information used by the SYSTEM's application layer security mechanisms and test shows proper operation of the policy exchanges (i.e., policies are sent/received, as appropriate, according to the functional capabilities of the SYSTEM, valid authentication, and authorization). The test will be repeated for various cases to ensure proper results for valid and invalid attempts (e.g., bad authentication, lack of authorization, incorrect format) to update digital security policies.

> ***Rationale****: Inspection and test are used to show inter-system interoperability for the exchange of security policy information. Additional verification is performed in Volume 5.*

[C3I-567V] The compliance with security mechanisms specified in CxP 70022, Volume 5: Data Exchange Protocol Specification for the inter-SYSTEM exchanges of identity data used by application layer security functions shall be verified by Inspection and Test.

An inspection of the SYSTEM's design and manufacturing documentation (e.g., specifications, drawings, product data sheets) for the application layer identity data exchange mechanisms shall be performed to ensure implementation of the required functionality. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send and receive updates to the identity data used by application layer security mechanisms per the Vol. 5 Data Exchange (DE) Protocol. The other SYSTEM may be simulated. The test shall be repeated with the SYSTEM performing all applicable roles (send and receive), and with valid and invalid attempts (e.g., bad authentication, lack of authorization, incorrect format) to update identity data.

Verification shall be successful when inspection shows that the required approach to exchanging identity data is implemented and test shows proper operation of the required functionality (i.e, the exchange of security identity data between systems yields the expected information).

> ***Rationale****: Inspection and test are used to show inter-system interoperability for the exchange of security identity data. Additional verification is performed in Volume 5.*

[C3I-569V] The compliance with security mechanisms specified in CxP 70022, Volume 5: Data Exchange Protocol Specification for the inter-SYSTEM exchanges of authentication and encryption keys used by application layer security functions shall be verified by Inspection and Test.

An inspection of the SYSTEM's design and manufacturing documentation (e.g., specifications, drawings, product data sheets) for the application layer cryptographic key exchange mechanisms shall be performed to ensure the required functionality has been implemented. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send and receive authentication and encryption keys per the Vol. 5 Data Exchange (DE) Protocol mechanism. The other SYSTEM may be simulated. The test shall be repeated with the SYSTEM performing all applicable roles (send and receive) and for valid and invalid attempts (e.g., bad authentication, lack of authorization, incorrect format) to exchange keys.

Verification shall be successful when inspection shows the required functionality has been implemented and test shows that the exchange of authentication and encryption keys between systems yields the expected information.

> ***Rationale**: Inspection and test are used to show inter-system interoperability for the exchange of security keys. Additional verification is performed in Volume 5.*

4.4.4 FIPS Compliant Algorithms

[C3I-203V] The implementation of FIPS PUB 197, ADVANCED ENCRYPTION STANDARD (AES), for encryption security services for all inter-system data exchanges shall be verified by Inspection and Test.

An inspection shall be performed on the design and manufacturing documents (e.g., specifications, drawings, product data sheets) of the Constellation SYSTEM security services involving ENCRYPTION of inter-SYSTEM data exchanges. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send and receive data in the information base, using the encryption mechanisms for inter-SYSTEM information exchanges to verify that the AES algorithm is used and the implementation functions properly. The other SYSTEM may be simulated. Detailed verification objectives shall be developed using FIPS PUB 197 as a guideline. The objectives shall include tests for compatibility between two SYSTEMS and tests for the confidentiality of transmitted information. A range of data values and types shall be tested.

Verification shall be considered successful when inspection and test of the Cx information systems designs show compliance to one of the modes of AES that are acceptable under the FIPS PUB 197 and the implementation functions properly.

> ***Rationale**: Because AES has many forms that can be used and implemented, it is very important to verify that a consistent mode will be used to guarantee inter-operability among Constellation Systems. Using a form of AES that is defined in FIPS PUB 197 is one step to ensure inter-operability. Another step is to verify that the mode and technique used meets the requirement under NASA NPR 2810.1A that states that the security services employing encryption must be an NSA approved method and technique.*

[C3I-206V] The implementation of SHA-1 per FIPS PUB 180-2, Secure Hash Standard, for hash generation performed for inter-SYSTEM data exchanges shall be verified by Inspection and Test.

An inspection of the design and manufacturing documents (e.g., specifications, drawings, product data sheets) of the Constellation SYSTEM implementations of authentication mechanisms shall be performed to ensure that the SHA-1 algorithm has been implemented. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send and receive data in the information base, using the authentication and data integrity mechanisms of the SYSTEMs to ensure that the required algorithm is implemented and functions properly. The other SYSTEM may be simulated. Detailed verification objectives shall be developed using FIPS PUB 180-2 as a guideline. The objectives shall include tests for compatibility between two SYSTEMS and tests for authentication and data integrity.

Verification shall be considered successful when inspection and test of the SYSTEM shows SHA-1 (as described in FIPS PUB 180-2) is implemented and functions properly.

> ***Rationale****: Inspection and Test are required to determine compliance to FIPS PUB 180-2.*

[C3I-207V] The implementation of a compliant Digital Signature Algorithm as defined in FIPS PUB 186-2, Digital Signature Standard (DSS), for all digital signatures exchanged between SYSTEMS shall be verified by Inspection and Test.

An inspection of network security services performing digital signature data exchanges (via software, firmware and/or hardware) shall be performed. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send and receive digital signatures to ensure interoperability. The other SYSTEM may be simulated. A representative sample of digital signatures shall be exchanged. SYSTEMS shall exchange roles, if applicable.

Verification shall be considered successful when the inspection and test shows that the DSA algorithm (as described in FIPS PUB 186-2) has been implemented and functions properly, including verification that a) digital signatures are transmitted, b) digital signatures are received, c) exchanged signatures provide expected values, and d) these operations function in both directions (as applicable).

> ***Rationale****: To verify the requirement for exchanging digital signatures as defined in FIPS PUB 186-2, both inspection and test must be performed to show compliance and to show interoperable communications among Constellation Systems.*

[C3I-208V] The implementation of FIPS PUB 198, Keyed-HASH MESSAGE AUTHENTICATION CODE (HMAC), for all MESSAGE AUTHENTICATION CODES (MACs) exchanged between SYSTEMS shall be verified by Inspection and Test.

An inspection of network security services performing MAC exchanges shall be performed. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send and receive MACs to ensure interoperability. The other SYSTEM may be simulated. A representative sample of MACs shall be exchanged. SYSTEMS shall exchange roles, if applicable.

Verification shall be considered successful when the inspection of the implementation of MAC exchanges show compliance to FIPS PUB 198 and when the test shows that a) MACs are transmitted, b) MACs are received, c) exchanged MACs provide expected values, and d) these operations function in both directions (as applicable).

> ***Rationale****: To verify the requirement for exchanging MACs as defined in FIPS PUB 198, both inspection and test must be performed to show compliance and to show interoperable communications among Constellation SYSTEMS.*

[C3I-665V] The implementation of SHA-256 per FIPS PUB 180-2, Secure Hash Standard, for hash generation performed for inter-SYSTEM data exchanges shall be verified by Inspection and Test.

An inspection of the design and manufacturing documents (e.g., specifications, drawings, product data sheets) of the Constellation SYSTEM implementations of authentication mechanisms shall be performed to ensure that the SHA-256 algorithm has been implemented. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send and receive data in the information base, using the authentication and data integrity mechanisms of the SYSTEMs to ensure that the required algorithm is implemented and functions properly. The other SYSTEM may be simulated. Detailed verification objectives shall be developed using FIPS PUB 180-2 as a guideline. The objectives shall include tests for compatibility between two SYSTEMS and tests for authentication and data integrity.

Verification shall be considered successful when inspection and test of the SYSTEM shows SHA-256 (as described in FIPS PUB 180-2) is implemented and functions properly.

> ***Rationale**: Inspection and Test are required to determine compliance to FIPS PUB 180-2.*

[C3I-666V] The truncation of 160-bit Hash Based Messaged Authentication Codes (HMACs) to 96 bits shall be verified by Inspection and Test.

An inspection of the SYSTEM's design and manufacturing documentation (e.g., specifications, drawings, product data sheets) for authentication and data integrity mechanisms employing HMACs shall be performed to ensure that the required capability has been implemented. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send and receive data in the information base, using HMAC based AUTHENTICATION with, and without, truncation. The other SYSTEM may be simulated. The objectives shall include tests for compatibility between two SYSTEMS and tests for authentication and data integrity.

The verification shall be considered successful when the inspection and test show that inter-SYSTEM AUTHENTICATION results are correct with 160 bit HMACs truncated to 96 bits, and without truncation (as controlled by the relevant digital security policies and other controlling parameters used by the SYSTEM).

> ***Rationale**: Ensuring proper compliance requires inspection of the HMAC related software as well as testing for proper operation of this critical security mechanism.*

[C3I-667V] The truncation of 256-bit Hash Based Messaged Authentication Codes (HMACs) to 128 bits shall be verified by inspection and test.

An inspection of security software implementing HMAC truncation shall be conducted. A test using flight or flight-like equipment (e.g. SIL) interfaced to another SYSTEM shall be performed to send and receive data in the information base, using HMAC based AUTHENTICATION with, and without, truncation. The other SYSTEM may be simulated. The objectives shall include tests for compatibility between two SYSTEMS and tests for authentication and data integrity.

The verification shall be considered successful when the inspection and test show that inter-SYSTEM AUTHENTICATION results are correct with 256 bit HMACs truncated to 128 bits, and without truncation (as controlled by the relevant digital security policies and other controlling parameters used by the SYSTEM).

> ***Rationale****: Ensuring proper compliance requires inspection of the HMAC related software as well as testing for proper operation of this critical security mechanism.*

4.5 Data Exchange

4.5.1 Voice Exchange

[C3I-173V] Constellation SYSTEMS assignment of a delivery priority to voice data sent to another SYSTEM shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM software performing voice data delivery prioritization. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate voice data, assign a delivery priority, and transmit to the receiving SYSTEM. The receiving SYSTEM may be simulated. The test shall be repeated for a range of possible priority values and voice data types, if applicable. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when a) the inspection shows a delivery priority assignment mechanism is implemented for all voice data transmissions, and b) the test shows that the delivery priority of voice data observed by the receiving SYSTEM is identical to the delivery priority assigned by the transmitting SYSTEM for a range of possible priority values and voice data types.

> ***Rationale****: To verify interoperability, testing is performed. To verify functionality, inspection of software is performed..*

[C3I-175V] The transfer of voice data over a one way link shall be verified by Test.

A test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate voice data and transfer over a one way link to the receiving SYSTEM. The test shall be repeated for all applicable SYSTEM roles (send, receive). The cooperating SYSTEM may be simulated. The test shall be repeated for a range of transferred voice data types, if applicable. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the test shows a) voice data is transferred and received over the one-way link, b) applicable mission, phases, states, and modes are tested at least twice, c) the test is repeated for all applicable roles, and d) the receiving SYSTEM confirms voice data packets contains expected values.

> ***Rationale****: To verify interoperability, testing is performed.*

[C3I-176V] The use of ITU G.729, "Coding of speech at 8 kbit/s using conjugate-structure algebraic-code-excited linear prediction (CS-ACELP)" shall be verified by Inspection.

An inspection shall be performed on SYSTEM software for use of ITU G.729 for coding.

The verification shall be considered successful when the inspection of SYSTEM software shows ITU G.729, "Coding of speech at 8 kbit/s using conjugate-structure algebraic-code-excited linear prediction (CS-ACELP)" is used.

> ***Rationale**: Inspection is performed to evaluate the compliance to coding and formatting standards.*

[C3I-555V] The transfer of voice in accordance with IETF RFC 3550, Real-Time Transport Protocol (RTP) shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM software performing the transfer of voice data. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall transfer voice data in accordance with IETF RFC 3550, Real-Time Transport Protocol (RTP) to the receiving SYSTEM. The test shall be repeated for all applicable SYSTEM roles (send, receive). The cooperating SYSTEM may be simulated. The test shall be repeated for a range of voice data types and values, if applicable. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the inspection of SYSTEM software shows the transfer of voice data is in accordance with RFC 3550, Real-Time Transport Protocol (RTP) and when the test shows a) transfer of voice data is successful, b) applicable roles and a range of voice data types and conditions are tested, if applicable, and c) the receiving SYSTEM confirms the voice data packets contain expected values.

> ***Rationale**: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

[C3I-557V] Providing for a mechanism to add voice codecs shall be verified by Inspection and Test.

An inspection shall be conducted on SYSTEM software performing the management of voice codecs. A test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall transmit a new voice codec to the receiving SYSTEM for addition. The test shall be repeated for all applicable SYSTEM roles (send, receive). The cooperating SYSTEM may be simulated. The test shall be repeated for a range of voice codecs types, if applicable. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the inspection of SYSTEMS software shows a mechanism to add voice codecs is present, and when the test shows a) all tested voice codecs are transmitted successfully, b) applicable roles and mission, phases, states, and modes are tested at least twice, and c) the receiving SYSTEM confirms the voice codecs are added and usable.

> ***Rationale**: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

[C3I-558V] Providing for a mechanism to remove voice codecs shall be verified by Inspection and Test.

An inspection shall be conducted on SYSTEM software performing the management of voice codecs. A test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall transmit a request/COMMAND to remove a voice codec to the receiving SYSTEM. The test shall be repeated for all applicable SYSTEM roles (send, receive). The cooperating SYSTEM may be simulated. The test shall be repeated for a range of voice codecs types, if applicable. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the inspection of SYSTEMS software shows a mechanism to remove voice codecs is present, and when the test shows a) all requests/COMMANDs to remove voice codecs are transmitted successfully, b) applicable roles and mission, phases, states, and modes are tested at least twice, and c) the receiving SYSTEM confirms the voice codecs are removed.

> ***Rationale**: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

4.5.2 Motion Imagery Transfer

[C3I-184V] Constellation SYSTEMS assignment of a delivery priority for motion imagery data sent to another SYSTEM shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM software performing motion imagery data delivery prioritization. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate motion imagery data, assign a delivery priority, and transmit to the receiving SYSTEM. The receiving SYSTEM may be simulated. The test shall be repeated for a range of possible priority values and motion imagery data types, if applicable. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when a) the inspection shows a delivery priority assignment mechanism is implemented for all motion imagery data transmissions, and b) the test shows that the delivery priority of motion imagery data observed by the receiving SYSTEM is identical to the delivery priority assigned by the transmitting SYSTEM for a range of possible priority values and motion imagery data types.

> ***Rationale**: To verify interoperability, testing is performed. To verify functionality, inspection of software is performed..*

[C3I-185V] The transfer of motion imagery over a one way link shall be verified by Test.

A test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate motion imagery and transfer over a one way link to the receiving SYSTEM. The test shall be repeated for all applicable SYSTEM roles (send, receive). The cooperating SYSTEM may be simulated. The test shall be repeated for a range of transferred motion imagery types, if applicable. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the test shows a) motion imagery is transferred and received over the one-way link, b) applicable mission, phases, states, and modes are tested at least twice, c) the test is repeated for all applicable roles, and d) the receiving SYSTEM confirms motion imagery packets contain expected values.

> ***Rationale****: To verify interoperability, testing is performed.*

[C3I-186V] The use of ITU H.264, "Advanced Video Coding for Generic Audiovisual Services" shall be verified by Inspection.

An inspection shall be performed on SYSTEM software for the use of ITU H 264 for video coding.

The verification shall be considered successful when the inspection shows ITU H.264, "Advanced Video Coding for Generic Audiovisual Services" is used.

> ***Rationale****: Inspection is performed to evaluate the compliance to coding and formatting standards.*

[C3I-283V] The transfer of motion imagery in accordance with RFC 3550, Real-Time Transport Protocol (RTP) shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM software performing the transfer of motion imagery. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall transfer motion imagery data in accordance with RFC 3550, Real-Time Transport Protocol (RTP) to the receiving SYSTEM. The test shall be repeated for all applicable SYSTEM roles (send, receive). The cooperating SYSTEM may be simulated. The test shall be repeated for a range of motion imagery data types, if applicable. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the inspection shows the transfer of motion imagery is in accordance with RFC 3550, Real-Time Transport Protocol (RTP) and when the test shows a) transfer of motion imagery is performed successfully, b) applicable roles and a range of motion imagery data types and conditions are tested, if applicable, and c) the receiving SYSTEM confirms the transfer of motion imagery packets contain expected values.

> ***Rationale****: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format and protocol specifications.*

[C3I-559V] The use of <TBR 3-13> ISO/IEC 15444-3, "Motion JPEG 2000 (Part 3)" shall be verified by Inspection.

An inspection shall be performed on SYSTEM software performing image compression/decompression for use of <TBR 3-13> ISO/IEC 15444-3, "Motion JPEG 2000 (Part 3)".

The verification shall be considered successful when the inspection of SYSTEM software shows <TBR 3-13> ISO/IEC 15444-3, "Motion JPEG 2000 (Part 3)" is used.

> ***Rationale****: Inspection is performed to evaluate the compliance to format and protocol specifications.*

[C3I-560V] Providing for a mechanism to add MOTION IMAGERY codecs shall be verified by Inspection and Test.

An inspection shall be conducted on SYSTEM software performing the management of MOTION IMAGERY codecs. A test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall transmit a new MOTION IMAGERY codec to the receiving SYSTEM for addition. The test shall be repeated for all applicable SYSTEM roles (send, receive). The cooperating SYSTEM may be simulated. The test shall be repeated for a range of MOTION IMAGERY codecs types, if applicable. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the inspection of SYSTEMS software shows a mechanism to add MOTION IMAGERY codecs is present, and when the test shows a) all tested MOTION IMAGERY codecs are transmitted successfully, b) applicable roles and mission, phases, states, and modes are tested at least twice, and c) the receiving SYSTEM confirms received MOTION IMAGERY codecs are added and usable.

> ***Rationale****: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

[C3I-561V] Providing for a mechanism to remove MOTION IMAGERY codecs shall be verified by Inspection and Test.

An inspection shall be conducted on SYSTEM software performing the management of MOTION IMAGERY codecs. A test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall transmit a request/COMMAND to remove a MOTION IMAGERY codec to the receiving SYSTEM. The test shall be repeated for all applicable SYSTEM roles (send, receive). The cooperating SYSTEM may be simulated. The test shall be repeated for a range of MOTION IMAGERY codecs types, if applicable. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the inspection of SYSTEMS software shows a mechanism to remove MOTION IMAGERY codecs is present, and when the test shows a) all requests/COMMANDs to remove MOTION IMAGERY codecs are transmitted successfully, b) applicable roles and mission, phases, states, and modes are tested at least twice, and c) the receiving SYSTEM confirms the MOTION IMAGERY codecs are removed.

> ***Rationale****: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

4.5.3 Data Exchange Message Formatting and Transmission

[C3I-130V] The transfer of messages over a one way link shall be verified by Test.

A test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate a message and transfer over a one way link to the receiving SYSTEM. The test shall be repeated for all applicable SYSTEM roles (send, receive). The cooperating SYSTEM may be simulated. The test shall be repeated for a range of transferred message values (e.g COMMANDS). Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the test shows a) messages are transferred and received over a one-way link, b) applicable mission, phases, states, and modes are tested at least twice, c) the test is repeated for all applicable roles, and d) the receiving SYSTEM confirms each message contains expected values.

> ***Rationale****: Testing is performed to evaluate interoperability*

[C3I-135V] The use of a common data exchange message format as defined in Appendix C of CxP 70022 Vol 5 shall be verified by Inspection.

An inspection shall be performed on SYSTEM software implementing a common data exchange message format.

The verification shall be considered successful when the inspection shows that the common data exchange message format(s) used by the Constellation SYSTEM is as defined in Appendix C of CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification.

> ***Rationale****: Inspection is performed to evaluate the compliance to format specifications.*

[C3I-659V] Constellation SYSTEM assignment to each data exchange message that is sent to another SYSTEM the priority that was assigned to the Data of that message shall be verified by Test.

The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate a data exchange message, assign the same priority that was assigned to the Data of that data exchange message, and transmit to the receiving SYSTEM. The receiving SYSTEM may be simulated. The test shall be repeated for a range of possible priority values and message types. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the test shows that a) the data exchange message sent has the same priority that was assigned to the Data of that data exchange message observed by the receiving SYSTEM b) the received data exchange message priority is identical to the priority assigned by the transmitting SYSTEM, c) a range of possible priority values and data exchange message types are test, and d) the test is repeated for all applicable mission phases, modes, states, and conditions at least twice.

***Rationale**: Testing is performed to evaluate interoperability.*

4.5.4 File Transfer

[C3I-161V] Constellation SYSTEMS assignment of a delivery priority to each file sent to another SYSTEM shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM software performing file delivery prioritization. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate a data file, assign a delivery priority, and transmit to the receiving SYSTEM. The receiving SYSTEM may be simulated. The test shall be repeated for a range of possible priority values and file types. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when a) the inspection shows a delivery priority assignment mechanism is implemented for all file transmissions, and b) the test shows that the delivery priority of the data file observed by the receiving SYSTEM is identical to the delivery priority assigned by the transmitting SYSTEM for a range of possible priority values and file types.

***Rationale**: To verify interoperability, testing is performed. To verify functionality, inspection of software is performed..*

[C3I-165V] The transfer of files in accordance with CCSDS 727.0-B-3, "CCSDS File Delivery Protocol (CFDP) – Recommended Standard" shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM software performing the transfer of files. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall transfer files to the receiving SYSTEM. The test shall be repeated with each SYSTEM performing all applicable roles. The cooperating SYSTEM may be simulated. The test shall be repeated for a range of files types and sizes. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the inspection shows SYSTEM software is implemented to transfer files in accordance with CCSDS 727.0-B-3, "CCSDS File Delivery Protocol (CFDP) – Recommended Standard" and when the test shows a) files are transferred for all files tested, b) applicable roles and a range of file types, sizes, and conditions are tested, and c) the receiving SYSTEM confirms the transfer of files contain expected values and are usable.

***Rationale**: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

4.5.5 Time Exchange

[C3I-111V] The exchange of time in accordance with IETF RFC 1305, NETWORK TIME PROTOCOL (NTP) Version 3 shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM software implementing the exchange of time. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate time information and provide to the receiving SYSTEM. The test shall be repeated for all applicable SYSTEM roles. The cooperating SYSTEM may be simulated. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the inspection shows the exchange of time complies with IETF RFC 1305, NETWORK TIME PROTOCOL (NTP) Version 3 and when the test shows a) time data is exchanged, b) both roles, mission phases, states, modes, and conditions are tested, if applicable, and c) both SYSTEMs confirms the exchange of time with expected values.

> ***Rationale****: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

4.5.6 Traffic Prioritization

[C3I-660V] Constellation SYSTEM effective observance of the delivery priorities assigned to voice data, motion imagery data, data exchange messages, and files by invoking traffic prioritization mechanisms provided by the underlying network shall be verified by Test.

The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). Detailed verification objectives shall be developed to assess the implementation of delivery priority handling as a traffic prioritization mechanism. The test shall include a series of test configurations and conditions using different delivery priorities and sufficient quantity of data such that lower priority messages are shown to be impacted by the addition of higher priority messages to the data link.

The verification shall be considered successful when the test shows that the detailed verification objectives are met.

> ***Rationale****: A comprehensive test of the effect of delivery priorities on message traffic is required to verify this requirement.*

4.6 Information

4.6.1 Basic Information Definition

[C3I-119V] The use of common COMMAND METADATA as defined by CxP 70022 Volume 4 shall be verified by Test.

The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The SYSTEM shall accept new COMMAND METADATA and demonstrate the use of the METADATA to either send or receive COMMANDs based on the new METADATA. The cooperating SYSTEM may be simulated. The test shall be repeated for a range of COMMAND types at least twice. The SYSTEMS shall exchange roles (send and receive), if applicable.

The verification shall be considered successful when the test shows a) COMMAND METADATA is used for all COMMANDS tested, b) a range of COMMAND types are tested at least twice c) both SYSTEMs confirm tested COMMANDs and COMMAND METADATA contain expected values.

> ***Rationale****: Testing is performed to evaluate interoperability. Inspection of format is performed under separate verification.*

[C3I-140V] The use of common telemetry METADATA as defined by CxP 70022 Volume 4 shall be verified by Test.

The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The SYSTEM shall accept new TELEMETRY METADATA and demonstrate the use of the METADATA to either send or receive TELEMETRY based on the new METADATA. The cooperating SYSTEM may be simulated. The test shall be repeated with different METADATA at least twice. The SYSTEMS shall exchange roles (send and receive), if applicable.

The verification shall be considered successful when the test shows a) TELEMETRY METADATA is used for all TELEMETRY tested, b) tests are repeated at least twice with different METADATA, and c) the both SYSTEMs confirm TELEMETRY and TELEMETRY METADATA contain expected values.

> ***Rationale****: Testing is performed to evaluate interoperability. Inspection of format is performed under separate verification.*

[C3I-157V] The use of a common convention for file formats as defined by CxP 70022 Volume 4 Section 3.3 shall be verified by Inspection and Demonstration.

An inspection shall be performed on SYSTEM software implementing a convention for file formats. The demonstration shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate a COMMAND (request) for a file and transmit to the receiving SYSTEM. The receiving system shall return the requested file. SYSTEMS that provide files and request files shall be tested in both roles. The test shall be repeated for a range of file types including command, telemetry, and reconfiguration-related files. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the inspection shows that the common convention for file formats comply with the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification Section 3.3 and when the demonstration shows a) files received by sending SYSTEMS return expected values and are usable, b) all applicable roles of a SYSTEM are tested, and c) applicable phases, states, modes, and conditions are tested at least twice.

> ***Rationale****: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

[C3I-169V] The use of common voice METADATA as defined by CxP 70022 Volume 4 shall be verified by Test.

The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The SYSTEM shall accept new voice METADATA and demonstrate the use of the METADATA to either send or receive voice packets based on the new METADATA. The cooperating SYSTEM may be simulated. The test shall be repeated with different METADATA at least twice. The SYSTEMS shall exchange roles (send and receive), if applicable.

The verification shall be considered successful when the test shows a) voice METADATA is used for all voice METADATA tested, b) tests are repeated at least twice with different METADATA, and c) both SYSTEMs confirm voice and voice METADATA packets contain expected values.

> ***Rationale****: Testing is performed to evaluate interoperability. Inspection of format is performed under separate verification.*

[C3I-180V] The use of common motion imagery METADATA as defined by CxP 70022 Volume 4 shall be verified by Test.

The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The SYSTEM shall accept new motion imagery METADATA and demonstrate the use of the METADATA to either send or receive motion imagery based on the new METADATA. The cooperating SYSTEM may be simulated. The test shall be repeated with different METADATA at least twice. The SYSTEMS shall exchange roles (send and receive), if applicable.

The verification shall be considered successful when the test shows a) motion imagery METADATA is used for all motion imagery tested, b) tests are repeated at least twice with different METADATA, and c) both SYSTEMs confirm motion imagery and METADATA packets contain expected values.

> ***Rationale****: Testing is performed to evaluate interoperability. Inspection of format is performed under separate verification.*

[C3I-228V] The use of data types as defined by CxP 70022 Volume 4 Section 3.3 shall be verified by Inspection.

An inspection shall be performed on SYSTEM software to assess use of data types.

The verification shall be considered successful when the inspection shows data types are used and are as defined by CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3.

> ***Rationale****: Inspection is performed to evaluate the compliance to data types.*

[C3I-229V] The exchange of METADATA that complies with the CxP 70022 Volume 4 shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM exchange of METADATA formats. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate METADATA and transmit to the receiving SYSTEM. The cooperating SYSTEM may be simulated. The SYSTEMS shall change roles, if applicable. The test shall be repeated for a range of exchanged METADATA values. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the inspection shows the exchange of METADATA complies with the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification and when the test shows a) METADATA is transmitted for all exchanges tested, b) a range of exchanged METADATA and conditions are tested, c) the SYSTEMS perform all applicable roles, and d) both SYTEMS confirm the exchanged METADATA contain expected values.

> ***Rationale***: *Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

[C3I-231V] The use of URIs and namespace constructs using conventions described in RFC3986 shall be verified by Inspection.

An inspection shall be performed on SYSTEM Universal Resource Indicators (URIs) and namespace constructs using conventions described in RFC-3986. A certified parser may be used to demonstrate compliance.

The verification shall be considered successful when the inspection shows the Universal Resource Indicators (URIs) and namespace constructs complies with RFC-3986.

> ***Rationale***: *Inspection is performed to evaluate the compliance to format specifications.*

[C3I-355V] The use of a hierarchical addressing structure as defined by CxP 70022 Volume 4 shall be verified by Inspection.

An inspection shall be performed on SYSTEM software to assess use of a hierarchical addressing structure.

The verification shall be considered successful when the inspection shows a hierarchical addressing structure is used and is as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.

> ***Rationale***: *Inspection is performed to evaluate the compliance to addressing structures.*

[C3I-357V] The use of a common file naming convention as defined by CxP 70022 Volume 4 shall be verified by Inspection.

An inspection shall be performed on SYSTEM software implementing file naming.

The verification shall be considered successful when the inspection shows the use of a common file naming convention and that the implementation is as defined by CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification Section 3.3.

> ***Rationale****: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

[C3I-366V] The issuance of inter-SYSTEM COMMANDS in a format defined by the CxP 70022 Volume 4 shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM formats for inter-SYSTEM COMMANDS. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate inter-SYSTEM COMMANDS and transmit to the receiving SYSTEM. The receiving SYSTEM may be simulated. The test shall be repeated for a range of inter-SYSTEM COMMANDS format types, if applicable, at least twice. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions.

The verification shall be considered successful when the inspection shows that the inter-SYSTEM COMMANDS issued are in the format defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification Section 3.8 and when the test shows a) all inter-SYSTEM COMMANDS issued are received, b) the test is repeated for a range of format types, roles, mission phases, states, modes, and conditions at least twice, as applicable and c) the receiving SYSTEM confirms inter-SYSTEM COMMANDS contain expected values.

> ***Rationale****: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

[C3I-544V] The exchange of application layer security policies between SYSTEMS in a representation that complies with the CxP 70022 Volume 4 shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM software implementing the exchange of application layer security policies between SYSTEMS. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate application layer security policy information and transmit to the receiving SYSTEM. The test shall be repeated with SYSTEMS performing all applicable roles. The cooperating SYSTEM may be simulated. The test shall be repeated for multiple application layer security policies, if applicable. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions.

The verification shall be considered successful when the inspection shows the exchange of application layer security policies between SYSTEMS is in a representation that complies with the CxP 70022, Constellation Command, Control, Communication, and Information (C3I)

Interoperability Standards Book, Volume 4: Information Representation Specification Section 3.12 <TBR 3-26> and when the test shows a) application layer security policies are transmitted, b) multiple application layer security policies, roles, and conditions are tested, if applicable, and c) the receiving SYSTEM confirms the application layer security policies information received contains expected values.

> ***Rationale****: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

[C3I-545V] The exchange of application layer cryptographic keys between SYSTEMS in a representation that complies with the CxP 70022 Volume 4 Section 3.12 shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM software implementing the exchange of application layer cryptographic keys between SYSTEMS. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate application layer cryptographic keys and transmit to the receiving SYSTEM. The test shall be repeated with SYSTEMS performing all applicable roles. The cooperating SYSTEM may be simulated. The test shall be repeated for multiple application layer cryptographic keys and values, if applicable. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions.

The verification shall be considered successful when the inspection shows the exchange of application layer cryptographic keys between SYSTEMS is in a representation that complies with the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification Section 3.12 <TBR 3-26> and when the test shows a) application layer cryptographic keys are transmitted, b) the test is repeated for multiple application layer cryptographic keys, roles, mission phases, states, modes, and conditions, if applicable, and c) the receiving SYSTEM confirms the exchanged information contains expected values.

> ***Rationale****: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

[C3I-546V] The exchange application layer identity information between SYSTEMS in a representation that complies with the CxP 70022 Volume 4 Section 3.12 shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM software implementing the exchange of application layer identity information between SYSTEMS. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate application layer identity information and transmit to the receiving SYSTEM. The test shall be repeated with SYSTEMS performing all applicable roles. The cooperating SYSTEM may be simulated. The test shall be repeated for multiple application layer identity information, if applicable. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions.

The verification shall be considered successful when the inspection shows the exchange of application layer identity information between SYSTEMS is in a representation that complies with the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification Section 3.12 <TBR 3-26> and when the test shows a) application layer identity information is transmitted, b) the test is repeated for multiple application layer identity information values, roles, mission phases, states, modes, and conditions, if applicable, and c) the receiving SYSTEM confirms the exchanged information contains expected values.

> ***Rationale***: *Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

[C3I-652V] The exchange of application layer security audit data between SYSTEMS in a representation that complies with the CxP 70022 Volume 4 Section 3.12 <TBR 3-26> shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM software implementing the exchange of application layer security audit data. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate application layer security audit data and transmit to the receiving SYSTEM. SYSTEMS shall be tested in all applicable roles. The cooperating SYSTEM may be simulated. The test shall be repeated for a range of exchanged application layer security audit data values, if applicable. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the inspection shows application layer security audit data exchanged between SYSTEMS is implemented in a representation that complies with the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification Section 3.12 <TBR 3-26> and when the test shows all data received by both SYSTEMS contains expected values, b) all applicable roles of a SYSTEM are tested, and c) applicable phases, states, modes, and conditions are tested at least twice.

> ***Rationale***: *Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

[C3I-661V] The defining of metadata that complies with the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification shall be verified by Inspection.

An inspection shall be performed on SYSTEM software METADATA formats.

The verification shall be considered successful when the inspection shows METADATA formats comply with the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.

> ***Rationale***: *Inspection is performed to evaluate the compliance to format specifications.*

4.6.2 Adaptive Information Definition

[C3I-215V] The definition of TELEMETRY processing algorithms in accordance with CxP 70022 Volume 4 shall be verified by Inspection.

An inspection shall be performed on SYSTEM software TELEMETRY processing algorithms.

The verification shall be considered successful when the inspection shows TELEMETRY processing algorithms are defined in accordance with CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.

> ***Rationale****: Inspection is performed to evaluate the compliance to algorithm specifications.*

[C3I-222V] The use of a hierarchical naming scheme in accordance with CxP 70022 Volume 4 shall be verified by Inspection.

An inspection shall be performed on SYSTEM software to assess use of a hierarchical naming scheme.

The verification shall be considered successful when the inspection shows a hierarchical naming scheme implementation is used and is in accordance with the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.

> ***Rationale****: Inspection is performed to evaluate the compliance to naming schemes.*

[C3I-547V] The request for data using data identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27>of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM software implementing the request of data. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate a request for data using data identifiers and transmit to the receiving SYSTEM. The receiving system shall return the requested data. SYSTEMS shall be tested in all applicable roles. The cooperating SYSTEM may be simulated. The test shall be repeated for a range of command, telemetry, and reconfiguration-related data files. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the inspection shows that data requests are implemented using data identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27>of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification and when the test shows a) all data received by both SYSTEMS contains expected values, b) all applicable roles of a SYSTEM are tested, and c) applicable phases, states, modes, and conditions are tested at least twice.

> ***Rationale**: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

[C3I-548V] The request for files using file identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27>of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM software implementing the request for files. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall generate a request for files using file identifiers and transmit to the receiving SYSTEM. The receiving system shall return the requested files. SYSTEMS shall be tested in all applicable roles. The cooperating SYSTEM may be simulated. The test shall be repeated for a range of command, telemetry, and reconfiguration-related files. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the inspection shows that the file requests are implemented using file identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27>of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification and when the test shows a) all data received by both SYSTEMS contains expected values, b) all applicable roles of a SYSTEM are tested, and c) applicable phases, states, modes, and conditions are tested at least twice.

> ***Rationale**: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

[C3I-549V] The construction of requests for data using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27>of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM software implementing the construction of requests for data. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall construct requests for data using the protocol and transmit to the receiving SYSTEM. The receiving system shall return the requested information. SYSTEMS shall be tested in all applicable roles. The cooperating SYSTEM may be simulated. The test shall be repeated for a range of requests (e.g. command, telemetry, and reconfiguration-related data files). Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the inspection shows that requests for data are constructed using a protocol as defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27>of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information

Representation Specification and when the test shows a) all data received by both SYSTEMS contains expected values, b) all applicable roles of a SYSTEM are tested, and c) applicable phases, states, modes, and conditions are tested at least twice.

> ***Rationale**: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

[C3I-550V] The construction of requests for file submissions and retrievals using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR), Section

3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification. shall be verified by Inspection and Test.

An inspection shall be performed on SYSTEM software implementing the construction of requests for file submissions and retrievals. The test shall be performed by interfacing flight or flight-like components in simulated mission conditions (e.g. SIL). The sending SYSTEM shall construct requests for file submissions and retrievals using the protocol and transmit to the receiving SYSTEM. The receiving system shall return or store the file, as directed. SYSTEMS shall be tested in all applicable roles. The cooperating SYSTEM may be simulated. The test shall be repeated for a range of files (e.g. command, telemetry, and reconfiguration-related data files). Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The verification shall be considered successful when the inspection shows that constructed requests for file submissions and retrievals are implemented using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27>of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification and when the test shows a) all data received by both SYSTEMS contains expected values, b) all applicable roles of a SYSTEM are tested, and c) applicable phases, states, modes, and conditions are tested at least twice.

> ***Rationale**: Testing is performed to evaluate interoperability. Inspection is performed to evaluate the compliance to format specifications.*

4.7 Command and Control

4.8 Interoperability Requirements Applicability

[C3I-701V] Compliance to the CxP-70022, Volume 1: C3I Interoperability Standards, Appendix D, Table D-1, shall be by inspection.

An inspection shall be performed on a Certificate of Compliance. The Certificate of Compliance shall document that the CEV system has complied with the C3I document as specified for each callout in Table D-1. Records supporting compliance shall be maintained and shall be provided upon request.

The verification shall be considered successful when the inspection shows that the completed and signed Certificate of Compliance is provided.

> ***Rationale****: A Certificate of Compliance is adequate since each row in the table is verified in a separate requirement.*

[C3I-702V] Compliance to the CxP-70022 C3I Interoperability Standards Book Volume 1, Appendix D, Table D-2 shall be by inspection.

An inspection shall be performed on a Certificate of Compliance. The Certificate of Compliance shall document that the CLV system has complied with the C3I document as specified for each callout in Table D-2. Records supporting compliance shall be maintained and shall be provided upon request.

The verification shall be considered successful when the inspection shows that the completed and signed Certificate of Compliance is provided.

> ***Rationale****: A Certificate of Compliance is adequate since each row in the table is verified in a separate requirement.*

[C3I-703V] Compliance to the CxP-70022 C3I Interoperability Standards Book Volume 1, Appendix D, Table D-3 shall be by inspection.

An inspection shall be performed on a Certificate of Compliance. The Certificate of Compliance shall document that the LSAM system has complied with the C3I document as specified for each callout in Table D-3. Records supporting compliance shall be maintained and shall be provided upon request.

The verification shall be considered successful when the inspection shows that the completed and signed Certificate of Compliance is provided.

> ***Rationale****: A Certificate of Compliance is adequate since each row in the table is verified in a separate requirement.*

[C3I-704V] Compliance to the CxP-70022 C3I Interoperability Standards Book Volume 1, Appendix D, Table D-4 shall be by inspection.

An inspection shall be performed on a Certificate of Compliance. The Certificate of Compliance shall document that the CaLV system has complied with the C3I document as specified for each callout in Table D-4. Records supporting compliance shall be maintained and shall be provided upon request.

The verification shall be considered successful when the inspection shows that the completed and signed Certificate of Compliance is provided.

> ***Rationale****: A Certificate of Compliance is adequate since each row in the table is verified in a separate requirement*

[C3I-705V] Compliance to the CxP-70022, Volume 1: C3I Interoperability Standards, Appendix D, Table D-5, shall be by inspection.

An inspection shall be performed on a Certificate of Compliance. The Certificate of Compliance shall document that the GS has complied with the C3I document as specified for each callout in Table D-5. Records supporting compliance shall be maintained and shall be provided upon request.

The verification shall be considered successful when the inspection shows that the completed and signed Certificate of Compliance is provided.

> ***Rationale***: *A Certificate of Compliance is adequate since each row in the table is verified in a separate requirement.*

[C3I-706V] Compliance to the CxP-70022, Volume 1: C3I Interoperability Standards, Appendix D, Table D-6, shall be by inspection.

An inspection shall be performed on a Certificate of Compliance. The Certificate of Compliance shall document that Mission Systems has complied with the C3I document as specified for each callout in Table D-6. Records supporting compliance shall be maintained and shall be provided upon request.

The verification shall be considered successful when the inspection shows that the completed and signed Certificate of Compliance is provided.

> ***Rationale***: *A Certificate of Compliance is adequate since each row in the table is verified in a separate requirement.*

[C3I-707V] Compliance to the CxP-70222, Volume1: C3I Interoperability Standards Book, Appendix D, Table D-7, shall be by inspection.

An inspection shall be performed on a Certificate of Compliance. The Certificate of Compliance shall document that the EVA has complied with the C3I document as specified for each callout in Table D-7. Records supporting compliance shall be maintained and shall be provided upon request.

The verification shall be considered successful when the inspection shows that the completed and signed Certificate of Compliance is provided.

> ***Rationale***: *A Certificate of Compliance is adequate since each row in the table is verified in a separate requirement.*

Appendix A ACRONYMS

Table Appendix A-1 - Acronyms

Acronym	Definition
BER	Bit Error Rate
BGP	Border Gateway Protocol
C&T	Communications & Tracking
C3I	Command, Control, Communications, Information
CaLV	Cargo Launch Vehicle
CARD	Constellation Architecture Requirements Document
CCA	C3I Communications Adapter
CCSDS	Consultative Committee on Space Data Systems
CEV	Crew Exploration Vehicle
CLV	Crew Launch Vehicle
COTS	Commercial Off The Shelf
Cx	Constellation
DAV	Descent Ascent Vehicle
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name System
DTN	Disruption Tolerant Networking
ESMD	Exploration Systems Mission Directorate

Acronym	Definition
EVA	Extravehicular Activity
FEC	Forward Error Correction/Field Engineering Changes
FIPS PUB	Federal Information Processing Standard Publication
HDLC	High-Level Data Link Control
HDTV	High Definition Television
IDAC	Integrated Design Analysis Cycle
IPSec	IP Security
IRD	Interface Requirements Document
ISO	International Standards Organization
ISS	International Space Station
IT	Information Technology
LEO	Low Earth Orbit
LHCP	Left Hand Circular Polarization
LSAM	Lunar Surface Access Module
MEIT	Multi-Element Integrated Testing
MIB	Management Information Base
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NExIOM	NASA Exploration Information Ontology Model

Acronym	Definition
NISN	NASA Integrated Services Network
NTIA	National Telecommunications and Information Administration
NTP	Network Time Protocol
QoS	Quality of Service
RF	Radio Frequency
SBU	Sensitive But Unclassified
SIG	Systems Integration Group
SN	Space Network
SNUG	Space Network Users Guide
T&V	Test and Verification
TBD	To Be Determined
TBR	To Be Resolved
TDRSS	Tracking and Data Relay Satellite System
VOIP	Voice Over IP
XML	Extended Markup Language
dB	Decibel
Hz	Hertz
Mbps	Megabits per second

Appendix B OPEN WORK

Table Appendix B-1 - To Be Determined Items

TBD	Section	Description
TBD 2-1	2.1 Applicable Documents	DTN Version number
TBD-ADL-001	2.1 Applicable Documents	Applicable documents not yet approved.
TBD 3-1	3.1 RF Communication	Category B Frequency for Operational Point-to-Point
TBD 3-2	3.1.4 Multipoint Proximity Links	Protocols for Multipoint Proximity Links
TBD 3-5	3.1 Table 3.1-1 Summary of Link parameters	Hard Line Time Critical Control protocol for the Data Framing Link
TBD 3-15	3.7 Command and Control	Creation of Volume 8 of the Interoperability Standards Book for Command and Control requirements.
TBD 4-1	4.1.2.1 Common Operational Point-to-Point RF Communication	Allowable communications link degradation due to self-interference is TBD dB
TBD 4-2	4.1.2.2 Pont A Operational Point-to-Point RF Communication	TBD Hz band for forward link signal
TBD 4-3	4.1.6.1 Common RF Contingency Voice Communication	Mean Opinion Score (MOS) evaluation methodology required score
TBD E-2	Appendix E C3I Interoperability Requirements Applicability	Deterministic Hard-Line Communications applicability to CLV.
TBD E-3	Appendix E C3I Interoperability Requirements Applicability	Deterministic Hard-Line Communications applicability to the CLV/CEV interface.
TBD E-4	Appendix E C3I Interoperability Requirements Applicability	Deterministic Hard-Line Communications applicability to the CLV/GS interface.
TBD E-5	Appendix E C3I Interoperability Requirements Applicability	Dynamic Address Assignment applicability to the GS/CLV interface.
TBD E-6	Appendix E C3I Interoperability Requirements Applicability	Dynamic Address Retrieval applicability to the GS/CLV interface.
TBD E-7	Appendix E C3I Interoperability Requirements Applicability	Motion Imagery Transfers applicability to the CLV/CEV interface.
TBD E-8	Appendix E C3I Interoperability Requirements Applicability	File Transfers applicability to the CLV/CEV interface.
TBD E-9	Appendix E C3I Interoperability Requirements Applicability	Deterministic Hard-line Communications applicability to CaLV.
TBD E-10	Appendix E C3I Interoperability Requirements Applicability	Deterministic Hard-line Communications applicability to the CaLV/LSAM interface.
TBD E-11	Appendix E C3I Interoperability Requirements Applicability	Deterministic Hard-line Communications applicability to the CaLV/GS interface.
TBD E-12	Appendix E C3I Interoperability Requirements Applicability	Dynamic Address Assignment applicability to the CaLV/GS interface.

TBD E-13	Appendix E C3I Interoperability Requirements Applicability	Deterministic Hard-Line Communications applicability to GS.
TBD E-14	Appendix E C3I Interoperability Requirements Applicability	Deterministic Hard-Line Communications applicability to the GS/CEV interface.
TBD E-15	Appendix E C3I Interoperability Requirements Applicability	Deterministic Hard-Line Communications applicability to the GS/CLV interface.
TBD E-16	Appendix E C3I Interoperability Requirements Applicability	Deterministic Hard-Line Communications applicability to the GS/CaLV interface.
TBD E-17	Appendix E C3I Interoperability Requirements Applicability	Dynamic Routing Between Systems applicability to the GS/CLV interface.
TBD E-18	Appendix E C3I Interoperability Requirements Applicability	Dynamic Address Assignment applicability to GS.
TBD E-19	Appendix E C3I Interoperability Requirements Applicability	Dynamic Address Assignment applicability to the GS/CLVinterface.
TBD E-20	Appendix E C3I Interoperability Requirements Applicability	Dynamic Address Assignment applicability to the GS/CaLV interface.
TBD E-21	Appendix E C3I Interoperability Requirements Applicability	Dynamic Address Retrieval applicability to GS.
TBD E-22	Appendix E C3I Interoperability Requirements Applicability	Dynamic Address Retrieval applicability to the GS/LSAM interface.
TBD E-23	Appendix E C3I Interoperability Requirements Applicability	Dynamic Address Retrieval applicability to the GS/CLV interface.
TBD E-24	Appendix E C3I Interoperability Requirements Applicability	Compression Over Low Bandwidth Links applicability to the GS/LSAM interface.
TBD E-25	Appendix E C3I Interoperability Requirements Applicability	Applicability of the C3I Interoperability Specification to EVA.
TBD E-26	Appendix E C3I Interoperability Requirements Applicability	Name Service applicability to EVA.
TBD E-27	Appendix E C3I Interoperability Requirements Applicability	Dynamic Address Assignment applicability to EVA.

Table Appendix B-2 - To be Resolved Issues

TBR	Section	Description
TBR 3-1	3.1 RF Communication	Table 3, Summary of Link parameters
TBR 3-12	3.3.5 Disruption Tolerance	DTN, Delay/Disruption Tolerance Networking Specification
TBR 3-13	3.5.2 Motion Imagery Transfer	ISO/IEC 15444-3, Motion JPEG 2000 (Part 3)
TBR 3-24	3.3.1 Connectivity	Multicast Listening Discovery protocol v2, RFC-3810
TBR 3-25	3.3.1 Connectivity	Resource ReSerVation Protocol (RSVP) v1, RFC-2205.
TBR 3-26	3.6.1 Basic Information Definition	Section 3.12 Security Representation is

		TBD in Volume 4.
TBR 3-27	3.6.2 Adaptive Information Definition	NExIOM & C3I System of Registries (NCSOR) is TBD in Volume 4.
TBR 4-1	4.1.2.1 Common Operational Point-to-Point RF Communication	Use of IEEE's definition for standard left-hand and right-hand circularly polarized antenna.
TBR 4-6	4.1.2.2 Point A Operational Point-to-Point RF Communication	Verification Requirement C3I-350V test criteria for Non-coherent mode of operation
TBR 4-7	4.1.2.2 Point A Operational Point-to-Point RF Communication	Point B systems emulators
TBR E-1	Appendix E C3I Interoperability Requirements Applicability	RF Contingency Voice Communications applicability to EVA.

Table Appendix B-3 – Open RIDs

Id	Section	Rmt Num	Issue	Recommendation From	Recommendation To
3638	Appendix E-2	N/A	Applicability to CLV of IP protocols	N/A	Affects multiple C3I specified requirements within multiple sections including: 3.3.1, 3.3.4, 3.3.6, 3.3.7, 3.3.10, 3.4, 3.5.x. 3.6.x, etc. Unknown, address potential lack of CLV bidirectional IP comm capabilities within Appendix E-2 Requirements Applicability Matrix. At present the spec makes an entire section applicable without any temporal considerations; which may not be entirely true given some capabilities may exist while others may not within a section depending upon bi-directional communication needs/capabilities and time. Affects multiple C3I specified requirements within multiple sections including: 3.3.1, 3.3.4, 3.3.6, 3.3.7, 3.3.10, 3.4, 3.5.x. 3.6.x, 3.7.x, etc. Some examples include SNMP, RTP/RTCP, TCP, NTP, etc, but there are many/many more. Reconcile these discrepencies with the ETE interfaces for CLV."
3644	Appendix	N/A	Applicability	N/A	Applicable 3.3.1 , 3.5.5Update

	E-2		to CLV of IP protocols		Appendix E-2 Requirements Applicability to eliminate implied SCPS-TP and CFDP requirement need.
3648	Appendix E-2	N/A	Applicability to CLV of IP protocols	N/A	Applicable 3.3.8, 3.3.9 Updated Appendix E-2 Requirements Applicability to eliminate implied GRE and Header Compression Requirements Need.
3710	Appendix E-2	C3I-22	FEC Applicability to CLV	Constellation SYSTEMS shall use Rate ½ <TBR 3-5> LOW DENSITY PARITY CHECK (LDPC) <TBR 3-6> FORWARD ERROR CORRECTION to transmit data streams for operational point-to-point links. [C3I-22]	This requirement not applicable to CLV.
4906	Appendix E-2	N/A	Applicability to CLV of IP protocols	Applicable	Not Applicable
5067	All	N/A	Use of RFCs (EVA)	All RFC References	Delete and replace with specific requirements extracted from applicable RFCs.
6096	3.5.1	C3I-173	QoS	Constellation SYSTEMS shall assign a delivery priority to voice data sent to another SYSTEM. Rationale: Voice conversations may require a greater delivery priority than other data exchanges. SYSTEMS may use quality of service mechanisms available from the underlying network.	TBD
6291	3.3.1	C3I-619	Use ofPEPs/TCP (EVA)	Constellation SYSTEMS shall implement a split-connection TCP Performance Enhancing Proxy (PEP) that implements the SCPS-TP transport layer per CCSDS 714.0.B-1, Space Communications Protocol Specification (SCPS) - Transport Protocol (SCPS-TP), Blue Book, Issue 1, May 1999, on links where the maximum bandwidth*delay product of the link exceeds 1e6 bits and/or whose design bit error rate is	Constellation SYSTEMS shall implement a split-connection TCP Performance Enhancing Proxy (PEP) for non-mission critical links that implements the SCPS-TP transport layer per CCSDS 714.0.B-1, Space Communications Protocol Specification (SCPS) - Transport Protocol (SCPS-TP), Blue Book, Issue 1, May 1999.

				equal to or greater than 1e-6.	
8171	3.5	N/A	-	New requirement	Constellation SYSTEMS shall adhere to the time standards documented in the Navigation Standards Specification document (CxP 70142) [TBR].
8288	N/A	New	-	New requirement	Constellation SYSTEMS shall preserve telemetry parameter rates when routing telemetry.RATIONALE:In order to use telemetry data being received in real-time, flight controllers need to be assured of continuously receiving all telemetry parameters at the rate designated for each parameter, such that 1 Hz data remains received at 1Hz, 10Hz at 10Hz rates, etc..
8461	3.3	New	-	None - new requirement	"Constellation SYSTEMS shall implement a standard Multicast Address Assignment Service (MAAS) for resolution of multicast service names to IP addresses and port per C3I Volume 5.
8665	3.1.4	N/A	RF proximity links	N/A	Errata RIDs from previous release still open.
8679	3.5.2	N/A	JPEG 2000	N/A	Errata RIDs from previous release still open.
8692	Appendix D	N/A	-	N/A	Errata RIDs from previous release still open.
8713	3.5.6	N/A	Time synch	N/A	Errata RIDs from previous release still open.

Appendix C GLOSSARY

Table Appendix C-1 - Glossary Terms

Term	Definition
Architecture	The system of systems that comprise the Constellation Program to achieve the Need, Goals and Objectives of ESMD.
Attitude Determination	The process of determining the rotational state (time tagged attitude and attitude rate) in relation to its direction of motion. Attitude determination may entail estimation of an updated attitude state by incorporation of sensor data or simply a state propagation with environment models.
Automatic	Control or execution of a system or process without human intervention or commanding. Function performed via ground and/or onboard software interaction. This does not exclude the possibility of operator input, but such input is explicitly not required for an automatic function. Automatic may also imply that the function begins without human intervention.
Availability	A measure of the degree to which an item is in an operable state and can be committed for immediate use.
Authentication	The act of establishing or confirming something (or someone) as authentic (i.e., truly what it is claimed to be). For example, verifying an identity claim through the use of a message authentication code (MAC) or digital signature that should only be able to be provided by the individual truly associated with the claimed identity.

Term	Definition
C3I Architecture	The collection of communications, network, software, information, and security systems that must function together to provide command and control of all Constellation Systems.
Caution and Warning	Alert notification system for flight crew and ground that includes Emergencies, Cautions, Warnings, and Advisories.
Command	Directive to a processor or system to perform a particular action or function. Parameters can be specified at the time of command initiation.
Element	Physical entities that have functional capabilities allocated to them necessary to satisfy system-level mission objectives within the Constellation Architecture. Elements can perform all allocated system functions within a mission phase, or through mated operations with other Constellation elements or systems (e.g. Crew Module, Upper Stage).
End Item Response (EIR)	A telemetry indication, from the destination hardware device or destination software location (i.e. "end item") of a specific command, which provides feedback that the command has nominally executed at the end item with the anticipated effect on that end item.
Encryption	The transformation of data into unintelligible data (sometimes called ciphertext) to help maintain the secrecy and integrity of the data.
Flight Vehicle	A vehicle, which is generally composed of multiple elements, used to transport

Term	Definition
	persons or things to and/or from a location outside of the Earth's atmosphere.
Health and Status	Information on subsystem performance and flight performance, including configuration data, vehicle state data, subsystem status, failures, hazards and measured parameters outside of normal limits.
Information Model	Describes how data and information is denoted and used by humans, software and systems in a complete and consistent way. Extends the common data representations (e.g. parameter lists) by including a richer, more descriptive set of relational and contextual information. Its goal is to establish unambiguous data, information, and knowledge structures for uniform use across mission and system lifecycles, using a common form that is both human and machine intelligible.
Identifier	A reference (such as a unique name, number, or any other set of bits) assigned to an individual person, system, device, process, group, role, file, etc.
Metadata	Data about data, including information describing aspects of actual data items, such as name, type, format, content, and other descriptive information. In a data exchange context, it can be a set of descriptive properties about a specific data exchange topic. These properties are typically values that do not change very often.
Mission	A flight to a destination in space, intended to accomplish specific scientific and technical objectives. Mission phases

Term	Definition
	include TBS.
Mission Critical	An event, system, subsystem or process that must function properly in order to prevent loss of mission, launch scrub, or major facility damage.
Motion Imagery	Transient imagery and sound captured via electronic sensors and converted to data for retention and observation. Motion imagery may utilize portions of what is currently referred to as traditional video or television architectures and systems. Future television or motion imagery distribution will be required to be in a digital format that is compliant with the Advanced Television Standards Committee (ATSC) standard.
Network Management	The ability to manage parameters of network elements (nodes) such as routing tables, class of service mappings, transport layer options, etc. Network management also includes the ability where appropriate to read information such as the current settings and audit data.
Rendezvous	Mission phase during which the maneuvering vehicle approaches the target vehicle using a series of coarse maneuvers targeted to move the maneuvering vehicle into the proximity of the target vehicle.
Requirement	A necessary, quantifiable, and verifiable capability, function, property, characteristic, or behavior that a product must exhibit to solve a real world problem, or a constraint that it must satisfy or be satisfied.

Term	Definition
Safety Critical	An event, system, subsystem or process, which if lost or degraded, would result in a critical or catastrophic hazard.
Space Network	The collection of systems, facilities, services and capabilities that comprise NASA's Earth-orbiting tracking and telecommunications relay system. The Space Network (SN) currently consists of the Tracking and Data Relay Satellite System (TDRSS), the White Sands Complex (WSC) and the SN Network Control Center (NCC).
System	Physical entities that have functional capabilities allocated to them necessary to satisfy Architecture-level mission objectives. Systems can perform all allocated functions within a mission phase, or through mated operations with other Constellation systems (e.g. Crew Exploration Vehicle (CEV), Lunar Surface Access Module.)
Telemetry	The measurement and transmission of data by radio or other means from remote sources to receiving stations for recording and analysis.

Appendix D RESERVED

Appendix E C3I Interoperability Requirements Applicability

Table Appendix E-1 - C3I Interoperability Requirements Applicability to CEV

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
3.1	**RF Communication**				
3.1.1	***Common RF Communication***				***Compliance with this section is required for interoperable communications between CEV and GS (for checkout testing), LSAM , ISS, and C&T Networks.***
C3I-3	Constellation SYSTEMS shall comply with spectrum selection/allocation, certification and usage restriction policies set forth in NASA Policy Directive (NPD) 2570.5D, NASA Electromagnetic (EM) Spectrum Management.	X	X	X	
C3I-5	Constellation SYSTEMS shall use transmit/receive frequency assignments and spectrum characteristics as defined in CxP 70022 Constellation Command, Control, Communications and Information (C3I) Interoperability Standards Book, Volume 2: Constellation Spectrum and Channel Plan.	X	X	X	
C3I-584	Constellation SYSTEMS shall comply with radio frequency allocation and conditions of assignment for frequency spectrum usage approved by the National Telecommunications & Information Administration (NTIA).	X	X	X	
3.1.2	**Operational Pt-to-Pt RF Communication**				
3.1.2.1	***Common Operational Pt-to-Pt RF Communication***				***Compliance with this section is required for interoperable communications between CEV and GS (for checkout testing), LSAM, ISS, and C&T Networks.***

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-6	Constellation SYSTEMS shall transmit using LEFT-HAND CIRCULAR POLARIZATION for operational point-to-point links.	X	X	X	
C3I-7	Constellation SYSTEMS shall receive using LEFT-HAND CIRCULAR POLARIZATION for operational point-to-point links.	X	X	X	
C3I-11	Constellation SYSTEMS shall communicate using at least two independent transmit/receive frequency pairs within the near Earth S-band spectrum allocation for multi-SYSTEM, simultaneous operational point-to-point communications.	X	X	X	
C3I-22	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1.O-1, Section 3 to transmit data streams for operational point-to-point links.	X	X	X	
C3I-23	Constellation SYSTEMS shall use bit randomization techniques in accordance with CCSDS 131.0-B-1 for randomization of transmitted data streams for operational point-to-point links.	X	X	X	
C3I-590	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3 for decoding received data streams using FORWARD ERROR CORRECTION for operational point-to-point links.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-592	Constellation SYSTEMS shall use bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-randomization of received data streams for operational point-to-point links.	X	X	X	
C3I-594	Constellation SYSTEMS shall apply the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 as specified in CCSDS 131.1-O-1, Section 3.5 transmitted FEC code block frames for operational point-to-point links.	X	X	X	
C3I-596	Constellation SYSTEMS shall comply with the specifications for service access points as defined in section 3 of the AOS Space Data Link Protocol 732.0.B-2 for reception of Multiprotocol Interconnect over Frame Relay using the CCSDS AOS Virtual Channel Access (VCA) service over operational point-to-point links.	X	X	X	
C3I-612	Constellation SYSTEMS shall transmit Multiprotocol Interconnect over Frame Relay (MPoFR) as serial octet-aligned streams per CCSDS recommendation “IP over CCSDS Space Links”, CCSDS 702.1-R-1, using the Virtual Channel Access (VCA) service of CCSDS Advanced Orbiting Systems (AOS) Space Link Protocol as specified in CCSDS 732.0-B-2 for operational point-to-point links.	X	X	X	
C3I-653	Constellation SYSTEMS shall enable and disable communication link forward	X	X	X	

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	error correction (FEC) upon receipt of COMMAND for operational point-to-point links.				
C3I-668	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for transmission of IP packets for operational point-to-point links.	X	X	X	
C3I-669	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for reception of IP packets for operational point-to-point links.	X	X	X	
C3I-670	Constellation SYSTEMS shall use the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 for synchronization of received FEC code block frames as specified in CCSDS 131.1-O-1 for operational point-to-point links.	X	X	X	
C3I-671	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for transmission of non-FEC coded data streams for operational point-to-point links.	X	X	X	
C3I-672	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for resolution of symbol phase ambiguity of non-FEC coded data streams for operational point-to-point links.	X	X	X	
3.1.2.2	***Point A Operational Pt-to-Pt RF Communication***				***Compliance with this section is required to support the Point A Role in communication while using the Operational Point-to-Point Communication link. The Point A Role provides for coherent ranging for tracking, and assumes the role of target during rendezvous.***
C3I-308	Constellation point A SYSTEMS shall coherently re-	X	X	X	

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	transmit the received carrier with a turn-around ratio of 240/221(transmit/receive) for coherent point-to-point link operation.				
C3I-314	Constellation point A SYSTEMS shall coherently re-transmit the received range channel data to point B SYSTEM.	X	X	X	
C3I-350	Constellation point A SYSTEMS shall provide a non-coherent mode of operation for operational point-to-point links.	X	X	X	
C3I-573	Constellation point A SYSTEMS shall use transmit signals with modulation schemes in accordance with Table 3.1-2 for operational point-to-point links.	X	X	X	
C3I-574	Constellation point A SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-3 for operational point-to-point links.	X	X	X	
C3I-633	Constellation point A SYSTEMS shall transmit independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 (DG1).	X	X	X	
3.1.2.3	***Point B Operational Pt-to-Pt RF Communication***				***Compliance with this section is required to support the Point B Role in communication while using the Operational Point-to-Point Communication link. The Point B role provides for the capabilities of space communications infrastructure (eg. GN, SN, DSN) as well as originating the ranging signals for tracking and rendezvous operations.***
C3I-315	Constellation point B SYSTEMS shall process the coherent turn-around carrier to make radiometric measurements of	X	X	X	

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	range rate data (two-way Doppler data) for operational point-to-point links.				
C3I-572	Constellation point B SYSTEMS shall process coherent turn-around ranging channel data to provide radiometric measurements of range data for operational point-to-point links.	X	X	X	
C3I-575	Constellation point B SYSTEMS shall transmit signals with modulation schemes in accordance with Table 3.1-3 for operational point-to-point links.	X	X	X	
C3I-576	Constellation point B SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-2 for operational point-to-point links.	X	X	X	
C3I-591	Constellation Point B SYSTEMS shall generate and modulate the range channel (Q channel) with the Forward Link Range Channel PN code as defined in the Space Network Interoperable PN Code Libraries, Rev. 1 (451-PN CODE-SNIP).	X	X	X	
C3I-634	Constellation point B SYSTEMS shall receive independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 (DG1).	X	X	X	
3.1.3	**High-Rate Pt-to-Pt RF Communication**				
3.1.3.1	***Common High Rate RF Communication***				***Compliance with this section is required for CEV high rate communications between CEV and GS (for checkout testing), LSAM, and C&T Networks.***
C3I-30	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR	X	X	X	

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	CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3, to transmit data streams for high rate point-to-point links.				
C3I-31	Constellation SYSTEMS shall use bit randomization techniques in accordance with CCSDS 131.0-B-1 for randomization of transmitted data streams for high rate point-to-point links.	X	X	X	
C3I-581	Constellation SYSTEMS shall transmit using Right-hand Circular polarization for high rate point-to-point links.	X	X	X	
C3I-583	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3, for decoding of received data streams using FEC for high rate point-to-point links.	X	X	X	
C3I-589	Constellation SYSTEMS shall receive using Right-hand Circular polarization for high-rate point-to-point links.	X	X	X	
C3I-598	Constellation SYSTEMS shall use bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-randomization of received data streams for high rate point-to-point links.	X	X	X	
C3I-600	Constellation SYSTEMS shall apply the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 as specified in CCSDS 131.1-O-1, Section 3.5, to transmit FEC code blocks for high rate point-to-point links.	X	X	X	
C3I-601	Constellation SYSTEMS shall	X	X	X	

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	comply with the specifications for service access points as defined in section 3 of AOS Space Data Link Protocol 732.0.B-2 for reception of Multiprotocol Interconnect over Frame Relay using the CCSDS AOS Virtual Channel Access service over high rate point-to-point links.				
C3I-603	Constellation SYSTEMS shall transmit Multiprotocol Interconnect over Frame Relay (MPoFR) as serial octet-aligned streams per CCSDS recommendation “IP over CCSDS Space Links”, CCSDS 702.1-R-1, using the Virtual Channel Access (VCA) service of CCSDS Advanced Orbiting Systems (AOS) Space Link Protocol as specified in CCSDS 732.0-B-2 for High Rate point-to-point links.	X	X	X	
C3I-632	Constellation SYSTEMS shall enable and disable communication link forward error correction (FEC) upon receipt of COMMAND for high rate point-to-point links.	X	X	X	
C3I-673	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for transmission of IP packets for high rate point-to-point links.	X	X	X	
C3I-674	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for reception of IP packets for high rate point-to-point links.	X	X	X	
C3I-675	Constellation SYSTEMS shall	X	X	X	

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	use the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 for synchronization of received FEC code block frames as specified in CCSDS 131.1-O-1 for high rate point-to-point links.				
C3I-676	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for transmission of non-FEC coded data streams for high rate point-to-point links.	X	X	X	
C3I-677	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for resolution of symbol phase ambiguity of non-FEC coded data streams for high rate point-to-point links.	X	X	X	
3.1.3.2	***Point A High-rate Pt-to-Pt RF Communication***				***Compliance with this section is required to support high rate communication with space communications infrastructure (eg. GN, SN, DSN).***
C3I-577	Constellation point A SYSTEMS shall use transmit signals with modulation schemes in accordance with Table 3.1-4 for high rate point-to-point links.	X	X	X	
C3I-578	Constellation point A SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-5 for high rate point-to-point links.	X	X	X	
3.1.3.3	***Point B High-rate Pt-to-Pt RF Communication***				***This requirement is not applicable to CEV. No current requirement for CEV to support the Point B role for high rate communications.***
C3I-579	Constellation point B SYSTEMS shall transmit signals with modulation schemes in accordance with Table 3.1-5 for high rate point-to-point links.				
C3I-580	Constellation point B SYSTEMS shall receive signals with modulation schemes in				

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	accordance with Table 3.1-4 for high rate point-to-point links.				
3.1.4	***Multipoint Proximity RF Communication***				***These requirements are not applicable to CEV since CEV-EVA communication is via umbilical.***
	RESERVED				
3.1.5	**Recovery RF Communication**				
3.1.5.1	***Common Recovery RF Communication***				***Compliance with this section is required for interoperable recovery communications interfaces between GS recovery forces and CEV.***
C3I-347	Constellation SYSTEMS shall transmit to the COSPAS/SARSAT system using the spectrum guidelines provided by ITU-R Recommendation M.633.	X	X	X	
C3I-362	Constellation SYSTEMS shall use amplitude modulation (AM) for analog voice communication with US and international search and rescue forces.	X	X	X	
C3I-363	Constellation SYSTEMS shall transmit to the COSPAS/SARSAT system per COSPAS/SARSAT document C/S T.001 Sections 2 and 3.	X	X	X	
C3I-678	Constellation SYSTEMS shall use narrowband frequency modulation (FM) for analog voice communication with US and international maritime search and rescue forces.	X	X	X	
C3I-679	Constellation SYSTEMS shall communicate using the US UHF SATCOM system per MIL-STD-188-181.	X	X	X	
3.1.6	**RF Contingency Voice Communication**				
3.1.6.1	***Common RF Contingency Voice Communication***				***Compliance with this section is required for interoperable contingency RF communications interfaces between CEV and MS, GS, and LSAM, as well as possible interfaces between DSS and ISS***
C3I-385	Constellation SYSTEMS shall	X	X	X	

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	modulate the transmitted carrier using amplitude modulation for analog, half-duplex Contingency Voice links.				
C3I-680	Constellation SYSTEMS shall receive an amplitude modulated carrier for Contingency Voice links.	X	X	X	
3.1.7	**Future High Rate Link Class**				
	RESERVED	TBD	TBD	TBD	
3.1.8	**Vehicle Internal Wireless Link Class**				
C3I-681	Constellation SYSTEMS shall use IEEE 802.11g on non-critical internal local area wireless data networks.	X	X	X	
3.2	**Hard-Line Communication**				
3.2.1	***High-Rate, Hard-Line Communication***				***Compliance with this section is required for interoperable hard-line communications between CEV and GO, LSAM, CLV, and CaLV.***
C3I-58	Constellation SYSTEMS shall use IEEE Std 1394b™-2002 and SAE-AS5643/1 with RFC-2734 for high data volume, hard-line connections between Constellation SYSTEMS.	X	X	X	
3.2.2	***High-Rate, Ground Hard-Line Communication***				***This section is not applicable to CEV. This section specifies non-time-critical hard-line communication between and within Constellation ground systems.***
C3I-336	Constellation SYSTEMS shall use ground institutional IP routed networks.				
3.2.3	***Deterministic Hard-Line Communication***				
C3I-682	Constellation SYSTEMS shall use SAE-AS5643 and AS5643/1 standards for	X	X	X	

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	deterministic rate based hard-line connections between Constellation SYSTEMS.				
3.3	**Network**				
3.3.1	***Connectivity***				***Compliance with this section is required for interoperable IP network communications between CEV and MS, GS, LSAM, CLV, and CaLV.***
C3I-61	Constellation SYSTEMS shall implement version 4 of the Internet Protocol (IPv4) as specified in STD-0005.	X			IPv4 is for ISS Missions only.
C3I-62	Constellation SYSTEMS shall use unicast addresses as defined in RFC-1918, Address Allocation for Private Internets.	X			IPv4 is for ISS Missions only.
C3I-63	Constellation SYSTEMS shall use multicast addresses as defined in RFC-3171, IANA Guidelines for IPv4 Multicast Address Assignments.	X			IPv4 is for ISS Missions only.
C3I-64	Constellation SYSTEMS shall provide a mechanism to manually configure the addresses of all IP-addressable interfaces.	X	X	X	
C3I-72	Constellation SYSTEMS shall provide IP network address to data link layer address mappings for IP addresses external to the SYSTEM.	X	X	X	
C3I-73	Constellation SYSTEMS shall use managed associations to map IP addresses to data link layer addresses for IP addresses external to the SYSTEM.	X	X	X	
C3I-74	Constellation SYSTEMS shall accept modifications to the IP address to data-link layer address mapping information via the network for IP addresses external to the SYSTEM.	X	X	X	
C3I-75	Constellation SYSTEMS shall	X			IPv4 is for ISS Missions only.

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	perform multi-hop routing as specified in RFC-1812, Requirements for IP Version 4 Routers as updated by RFC-2644.				
C3I-76	Constellation SYSTEMS shall comply with RFC-1122 (STD-0003), Requirements for Internet Hosts – Communications Layers.	X			IPv4 is for ISS Missions only.
C3I-78	Constellation SYSTEMS shall use manually configured routes instead of dynamically learned ones when there is an exact match in the prefix length for a given destination external to the SYSTEM.	X	X	X	
C3I-79	Constellation SYSTEMS shall use static routing table entries.	X	X	X	
C3I-80	Constellation SYSTEMS shall accept changes to the routing tables via the network.	X	X	X	
C3I-87	Constellation SYSTEMS shall advertise only non-default routes via the routing protocols.	X	X	X	
C3I-89	Constellation SYSTEMS shall have a default route specified in the routing tables.	X	X	X	
C3I-90	Constellation SYSTEMS shall fail over to default routes when there is a loss of all routing information or a loss of communication to all SYSTEM network neighbors participating in the dynamic routing protocol for more than 20 seconds.	X	X	X	
C3I-93	Constellation SYSTEMS shall resolve symbolic names to IP addresses using static host table.	X	X	X	
C3I-95	Constellation SYSTEMS shall accept changes to the static host table via the network.	X	X	X	

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C3I-96	Constellation SYSTEMS shall implement RFC-2474, Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers.	X	X	X	
C3I-97	Constellation SYSTEMS shall implement RFC-2211, Specification of the Controlled-Load Network System Service.	X	X	X	
C3I-98	Constellation SYSTEMS shall implement <TBR 3-25> RFC-2205, Resource ReSerVation Protocol (RSVP) Version 1 Functional Specification.	X	X	X	
C3I-99	Constellation SYSTEMS shall implement the Simple Network Management Protocol version 3 as defined in STD0062.	X	X	X	
C3I-103	Constellation SYSTEMS shall implement Internet STD-0007: TRANSMISSION CONTROL PROTOCOL (TCP).	X	X	X	
C3I-104	Constellation SYSTEMS shall implement RFC-1323 - TCP Extensions for High Performance.	X	X	X	
C3I-105	Constellation SYSTEMS shall implement STD-0006 - UDP, USER DATAGRAM PROTOCOL, for communication with all IP-addressable endpoints.	X	X	X	
C3I-106	Constellation SYSTEMS shall implement RFC-3550 (STD-0064), RTP: A Transport Protocol for Real-Time Applications.	X	X	X	
C3I-281	Constellation SYSTEMS shall implement RFC-3140, Per Hop Behavior Identification Codes.	X	X	X	

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C3I-282	Constellation SYSTEMS shall implement RFC-3246, An Expedited Forwarding PHB (PER HOP BEHAVIOR).	X	X	X	
C3I-619	Constellation SYSTEMS shall implement a split-connection TCP Performance Enhancing Proxy (PEP) that implements the SCPS-TP transport layer per CCSDS 714.0.B-1, Space Communications Protocol Specification (SCPS) - Transport Protocol (SCPS-TP), Blue Book, Issue 1, May 1999, on links where the maximum bandwidth*delay product of the link exceeds 1e6 bits and/or whose design bit error rate is equal to or greater than 1e-6.		X	X	This requirement will be phased in by CEV for Lunar Missions as agreed to by CEV/L2 Splinter team.
C3I-620	Constellation SYSTEMS shall implement Internet Protocol version 6 (IPv6) per RFC 2460 Internet Protocol, Version 6 (IPv6) Specification.		X	X	IPv6 Lunar Missions
C3I-621	Constellation SYSTEMS shall implement the Internet Control Messaging Protocol (ICMP) per RFC 792, Internet Control Message Protocol.	X			IPv4 Lunar Missions
C3I-622	Constellation SYSTEMS shall implement the Internet Control Messaging Protocol version 6 (ICMPv6) per RFC 4443 Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification.		X	X	IPv6 Lunar Missions
C3I-654	Constellation SYSTEMS shall implement the Multiprotocol Border Gateway Protocol (MBGP) as specified in RFC-2858.				CEV will not act as a routing network border for the Cx Program. Therefore, CEV will have no need to implement BGP or MBGP.
C3I-655	Constellation SYSTEMS shall		X	X	This protocol is required to join end systems to

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	implement the Multicast Listener Discovery protocol, version 2, as specified in RFC-3810 <TBR 3-24>.				multicast groups in IPv6. CEV will need to join multicast groups for various applications, including voice and telemetry reception from other systems.
C3I-656	Constellation SYSTEMS shall implement Multicast Extension to OSPF as specified in RFC-1584.				MOSPF is IPv4 specific. Since CEV will not use dynamic routing protocols during the IPv4 phase of Cx operations (CEV-ISS), CEV will never run MOSPF.
C3I-657	Constellation SYSTEMS shall implement the Internet Group Management Protocol (IGMP) as specified in RFC-3376.	X			This protocol is required to join end systems to multicast groups in IPv4. CEV will need to join multicast groups for various applications, including voice.
3.3.2	***Dynamic Routing Between Systems***				***Compliance with this section is required for interoperable IP network dynamic routing between CEV and MS, GS, LSAM, and CaLV. This requirement is phased for Lunar Sortie.***
C3I-82	Constellation SYSTEMS shall implement RFC-2453, STD-0056 - RIP Version 2.				Not applicable to CEV since CEV is not doing Dynamic routing for ISS under IPv4.
C3I-83	Constellation SYSTEMS shall implement RFC-2328 (STD-0054), OPEN SHORTEST PATH FIRST (OSPF) Version 2.				Not applicable to CEV since CEV is not doing Dynamic routing for ISS under IPv4.
C3I-295	Constellation SYSTEMS shall implement RFC-3626 Optimized Link State Routing Protocol (OLSR).		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
C3I-662	Constellation SYSTEMS shall implement RFC-2080, RIPng for IPv6 .		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
C3I-663	Constellation SYSTEMS shall implement RFC-2740 , OSPF for IPv6.		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
3.3.3	***External Connectivity***				
C3I-81	Constellation SYSTEMS shall implement RFC-4271-A BORDER GATEWAY PROTOCOL (BGP) Version 4, as specified in RFC4271 "A BORDER GATEWAY PROTOCOL 4 (BGP-4)				This requirement is not applicable to CEV. The CEV does not interface with external networks.

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C3I-280	Constellation SYSTEMS shall use external routes learned by Border Gateway Protocol Version 4, as specified in RFC4271 "A Border Gateway Protocol 4 (BGP-4), before those learned via other dynamic routing protocols.				Requirement not applicable to CEV. BGP not needed for CEV since CEV will not be interfacing with non-trusted sources.
3.3.4	***Name Service***				***Compliance with this section is required for IP network name services used for network communications between CEV and MS, GS, LSAM, CLV or CaLV. This is required to reduce systems management overhead associated with IP address management.***
C3I-296	Constellation SYSTEMS shall implement IETF STD-0013, Domain Name SYSTEM.	X	X	X	
3.3.5	***Disruption Tolerance***				***Compliance with this section is required to enable efficient communications during delayed or intermittent communications (especially through intermittent multi-hop communications paths). This is required for interoperable DTN communications between CEV and MS or LSAM. Note that this section is phased in at Lunar Sortie.***
C3I-107	Constellation SYSTEMS shall implement <TBR 3-12> DTN, DELAY/DISRUPTION TOLERANT NETWORKING Specifications, http://www.ietf.org/internet-drafts/draft-irtf-dtnrg-bundle-spec-05.txt.		X	X	
3.3.6	***Dynamic Address Assignment***				***Compliance with this section is required to support the connection of GSE test control systems.***
C3I-67	Constellation SYSTEMS shall implement the DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP) Server functions as specified in RFC-2131 and updated by RFC-4361.	X	X	X	Support for mobile IP end-points such as suits, laptops, and hand-helds.

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3.3.7	***Dynamic Address Retrieval***				***Compliance with this section is not required since the CEV does not dynamically connect to multiple network segments.***
C3I-69	Constellation SYSTEMS shall obtain network addresses via the DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP) as specified in RFC-2131 and updated by RFC-4361.				
C3I-70	Constellation SYSTEMS shall 'self-assign' an IP address from the 169.254.0.0/16 private address block as specified in RFC-3927, Dynamic Configuration of IPv4 Link-Local Addresses of IPv4 interfaces when unable to obtain an IP address from pre-configuration information and/or DHCP.				
3.3.8	***Tunneling***				***Compliance with this section is required for network tunneling on interfaces between CEV and MS, LSAM, and C&T Networks. Tunneling is necessary to support Mobile IP and allows controllers to perform traffic engineering and to force traffic to follow particular paths in the network that are different from the routes that might be 'default' or learned via dynamic routing protocols.***
C3I-92	Constellation SYSTEMS shall implement RFC-2784, GENERIC ROUTING ENCAPSULATION (GRE).				
C3I-664	Constellation SYSTEMS shall implement RFC-2473, Generic Packet Tunneling in IPv6 Specification.		X	X	IPv6 version for Lunar Missions
3.3.9	***Header Compression***				***Compliance with this section is required for interoperable communications between CEV and GS (test), LSAM, CaLV (EDS) or C&T Networks***

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					over low bandwidth links.
C3I-307	Constellation SYSTEMS shall implement RFC-2507 IP Header Compression.	X	X	X	
C3I-588	Constellation SYSTEMS shall implement RFC 2508 Compressing IP/UDP/RTP Headers for Low-Speed Serial Links.	X	X	X	
3.3.10	***Network Management***				***Compliance with this section is required for network management interfaces between CEV and MS, GS, CLV, CaLV (EDS) or C&T Networks.***
C3I-100	Constellation SYSTEMS shall implement RFC-4293 Management Information Base for the Internet Protocol (IP).	X	X	X	
C3I-294	Constellation SYSTEMS shall implement RFC-4292, IP Forwarding Table MIB.	X	X	X	
C3I-298	Constellation SYSTEMS shall implement RFC-3747, Differentiated Services Configuration MIB.	X	X	X	
C3I-299	Constellation SYSTEMS shall implement RFC-3289, MIB for the Differentiated Services Architecture.	X	X	X	
C3I-300	Constellation SYSTEMS shall implement RFC-2213, Integrated Services Management Information Base using SMIv2.	X	X	X	
C3I-301	Constellation SYSTEMS shall implement RFC-4022, Management Information Base for TRANSMISSION CONTROL PROTOCOL (TCP).	X	X	X	
C3I-302	Constellation SYSTEMS shall implement RFC-4113, Management Information Base for USER DATAGRAM PROTOCOL (UDP).	X	X	X	
C3I-303	Constellation SYSTEMS shall	X	X	X	

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	implement RFC-2959, Real Time Protocol MIB.				
3.4	**Security**				Compliance with this section is required for secure, interoperable communications between CEV and MS, CEV, LSAM, CLV, and CaLV.
3.4.1	***Network Layer Security***				
C3I-199	Constellation SYSTEMS shall implement RFC 4301, Security architecture for the Internet Protocol, at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-200	Constellation SYSTEMS shall implement RFC-4302, IP AUTHENTICATION HEADER (AH), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-201	Constellation SYSTEMS shall implement RFC-4303, IP ENCAPSULATING SECURITY PAYLOAD (ESP), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-204	Constellation SYSTEMS shall implement RFC 4305, Cryptographic Algorithm Implementation Requirements for Encapsulating Security Payload (ESP) and Authentication Header (AH), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-565	Constellation SYSTEMS shall implement RFC 4309, Using Advanced Encryption Standard (AES) CCM Mode with IPsec Encapsulating Security Payload (ESP), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
3.4.2	***Internet Key Exchange***				
C3I-209	Constellation SYSTEMS shall implement RFC-4306, The INTERNET KEY EXCHANGE (IKEv2), for all inter-SYSTEM management of security associations and keys used by IPSec.	X	X	X	
C3I-568	Constellation SYSTEMS shall implement RFC-4307, Cryptographic Algorithms for use in the Internet Key Exchange Version 2 (IKEv2).	X	X	X	
3.4.3	***Application Layer Security***				
C3I-210	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for inter-SYSTEM updates of security processing logic.	X	X	X	
C3I-566	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for all inter-system exchanges of the security policy information used by application layer security functions.	X	X	X	
C3I-567	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification and described in the for all inter-SYSTEM exchanges of the identity data used by application layer security functions.				
C3I-569	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for all inter-SYSTEM exchanges of the authentication keys and encryption keys used by application layer security functions.	X	X	X	
3.4.4	***FIPS Compliant Algorithms***				
C3I-203	Constellation SYSTEMS shall implement FIPS PUB 197, ADVANCED ENCRYPTION STANDARD (AES), for all ENCRYPTION of inter-SYSTEM data exchanges.	X	X	X	
C3I-206	Constellation SYSTEMS shall implement SHA-1 per FIPS PUB 180-2, Secure Hash Standard, for hash generation performed for inter-SYSTEM data exchanges.	X	X	X	
C3I-207	Constellation SYSTEMS shall implement FIPS PUB 186-2, DIGITAL SIGNATURE STANDARD (DSS) using the DIGITAL SIGNATURE ALGORITHM (DSA) for all digital signatures exchanged between SYSTEMS.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-208	Constellation SYSTEMS shall implement FIPS PUB 198, Keyed-HASH MESSAGE AUTHENTICATION CODE (HMAC), for all MESSAGE AUTHENTICATION CODES (MACs) exchanged between SYSTEMS.	X	X	X	
C3I-665	Constellation SYSTEMS shall implement SHA-256 per FIPS PUB 180-2, Secure Hash Standard, for hash generation performed for inter-SYSTEM data exchanges.	X	X	X	
C3I-666	Constellation SYSTEMS shall implement truncation of SHA-1 based 160-bit Hash Based Messaged Authentication Codes (HMACs) to 96 bits.	X	X	X	
C3I-667	Constellation SYSTEMS shall implement truncation of SHA-256 based 256-bit Hash Based Messaged Authentication Codes (HMACs) to 128 bits.	X	X	X	
3.5	**Data Exchange**				
3.5.1	***Voice Exchange***				***Compliance with this section is required for interoperable voice communications between CEV and MS, GS, LSAM, and ISS.***
C3I-173	Constellation SYSTEMS shall assign a delivery priority to voice data sent to another SYSTEM.	X	X	X	
C3I-175	Constellation SYSTEMS shall transfer voice data over a one way link.	X	X	X	
C3I-176	Constellation SYSTEMS shall use ITU G.729, "Coding of speech at 8 kbit/s using conjugate-structure algebraic-code-excited linear prediction (CS-ACELP)".	X	X	X	
C3I-555	Constellation SYSTEMS shall	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	transfer voice in accordance with IETF RFC 3550, Real-Time Transport Protocol (RTP).				
C3I-557	Constellation SYSTEMS shall provide a mechanism to add voice codecs.	X	X	X	
C3I-558	Constellation SYSTEMS shall provide a mechanism to remove voice codecs.	X	X	X	
3.5.2	***Motion Imagery Transfer***				***Compliance with this section is required for interoperable motion imagery transfer between CEV and MS, GS, LSAM, CLV, and CaLV.***
C3I-184	Constellation SYSTEMS shall assign a delivery priority for motion imagery data sent to another SYSTEM.	X	X	X	
C3I-185	Constellation SYSTEMS shall transfer motion imagery over a one way link.	X	X	X	
C3I-186	Constellation SYSTEMS shall use ITU H.264, "Advanced Video Coding for Generic Audiovisual Services".	X	X	X	
C3I-283	Constellation SYSTEMS shall transfer motion imagery in accordance with RFC 3550, Real-Time Transport Protocol (RTP).	X	X	X	
C3I-559	Constellation SYSTEMS shall use <TBR 3-13> ISO/IEC 15444-3, "Motion JPEG 2000 (Part 3)".		X	X	Based on Splinter team phased for Lunar missions for CEV.
C3I-560	Constellation SYSTEMS shall provide a mechanism to add MOTION IMAGERY codecs.	X	X	X	
C3I-561	Constellation SYSTEMS shall provide a mechanism to remove MOTION IMAGERY codecs.	X	X	X	
3.5.3	***Data Exchange Message Formatting and Transmission***				***Compliance with this section is required for interoperable message exchange between CEV and GS, LSAM, CLV, and CaLV.***

Section/ Req #	Section/Requirement	Phasing ISS	Phasing Sortie	Phasing Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
C3I-130	Constellation SYSTEMS shall transfer data exchange messages over a one way link.	X	X	X	
C3I-135	Constellation SYSTEMS shall use a common data exchange message format as defined in Appendix C of CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5:	X	X	X	
C3I-659	Constellation SYSTEMS shall assign to each data exchange message that is sent to another SYSTEM the priority that was assigned to the Data of that data exchange message.	X	X	X	
3.5.4	***File Transfer***				***Compliance with this section is required for interoperable file transfer between CEV and MS, GS, LSAM, CLV, and CaLV.***
C3I-161	Constellation SYSTEMS shall assign a delivery priority to each file sent to another SYSTEM.	X	X	X	
C3I-165	Constellation SYSTEMS shall transfer files in accordance with CCSDS 727.0-B-3, "CCSDS File Delivery Protocol (CFDP) – Recommended Standard".	X	X	X	
3.5.5	***Time Exchange***				***Compliance with this section is required for time exchange/sync interfaces between CEV and C&T Networks, GS, LSAM, and CaLV (EDS).***
C3I-111	Constellation SYSTEMS shall exchange time in accordance with IETF RFC 1305, NETWORK TIME PROTOCOL (NTP) Version 3.		X	X	Based on Splinter team agreed to phase for Lunar missions for CEV.
3.5.6	***Traffic Prioritization***				
C3I-660	Constellation SYSTEMS shall effect observance of the delivery priorities assigned to voice data,	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	motion imagery data, data exchange messages, and files by invoking traffic prioritization mechanisms provided by the underlying network.				
3.6	**Information**				
3.6.1	***Basic Information Definition***				***Compliance with this section is required for interoperable information definition for information exchanged between CEV and MS, GS, LSAM, CLV, and CaLV.***
C3I-119	Constellation SYSTEMS shall use common COMMAND METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-140	Constellation SYSTEMS shall use common telemetry METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-157	Constellation SYSTEMS shall use a common convention for file formats as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-169	Constellation SYSTEMS shall use common voice METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-180	Constellation SYSTEMS shall use common motion imagery METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-228	Constellation SYSTEMS shall use data types as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3.	X	X	X	
C3I-229	Constellation SYSTEMS shall exchange METADATA that complies with the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	Based on Splinter team, agreed to phase for Lunar missions for CEV.
C3I-231	Constellation SYSTEMS shall use Universal Resource Indicators (URIs) and	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	namespace constructs using conventions described in RFC3986.				
C3I-355	Constellation SYSTEMS shall use a hierarchical addressing structure as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-357	Constellation SYSTEMS shall use a common file naming convention as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Sec 3.3.	X	X	X	
C3I-366	Constellation SYSTEMS shall issue inter-SYSTEM COMMANDS in the format defined by the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Sec 3.8.	X	X	X	
C3I-544	Constellation SYSTEMS shall exchange application layer security policies between SYSTEMS in a representation that complies with CxP 70022, Constellation Command, Control, Communications, and Information (C3I)	X	X	X	

Section/ Req #	Section/Requirement	Phasing ISS	Sortie	Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
	Interoperability Standards Book, Volume				
C3I-545	Constellation SYSTEMS shall exchange application layer cryptographic keys between SYSTEMS in a representation that complies with the CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-546	Constellation SYSTEMS shall exchange application layer identity information between SYSTEMS in a representation that complies with CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-652	Constellation SYSTEMS shall exchange application layer security audit data between SYSTEMS in a representation that complies with the CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-661	Constellation Systems shall define METADATA that complies with the CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
3.6.2	***Adaptive Information***				***Compliance with this section is required for more***

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Definition				***adaptive (ad-hoc) interoperable information definition for information exchanged between CEV and MS, GS, LSAM, CLV, CaLV. Note that this functionality is not phased in until lunar sortie.***
C3I-215	Constellation SYSTEMS shall define TELEMETRY processing algorithms in accordance with CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-222	Constellation SYSTEMS shall use a hierarchical naming scheme in accordance with the CXP-70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-547	Constellation SYSTEMS shall request data using data identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-548	Constellation SYSTEMS shall request files using file identifiers defined in the NExIOM & C3I System Of Registries (NCSOR),		X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Section 3.13 <TBR 3-27>of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.				
C3I-549	Constellation SYSTEMS shall construct requests for data using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR) Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-550	Constellation SYSTEMS shall construct requests for file submissions and retrievals using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR) Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	

Table Appendix E-2 - C3I Interoperability Requirements Applicability to CLV

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
3.1	**RF Communication**				
3.1.1	***Common RF Communication***				***Compliance with this section is required for interoperable communications between CLV and GS and C&T Networks.***
C3I-3	Constellation SYSTEMS shall comply with spectrum selection/allocation, certification and usage restriction policies set forth in NASA Policy Directive (NPD) 2570.5D, NASA Electromagnetic (EM) Spectrum Management.	X	X	X	
C3I-5	Constellation SYSTEMS shall use transmit/receive frequency assignments and spectrum characteristics as defined in CxP 70022 Constellation Command, Control, Communications and Information (C3I) Interoperability Standards Book, Volume 2: Constellation Spectrum and Channel Plan.	X	X	X	
C3I-584	Constellation SYSTEMS shall comply with radio frequency allocation and conditions of assignment for frequency spectrum usage approved by the National Telecommunications & Information Administration (NTIA).	X	X	X	
3.1.2	**Operational Pt-to-Pt RF Communication**				**Compliance with this section is required for interoperable communications between CLV and GS and C&T Networks.**
3.1.2.1	***Common Operational Pt-to-Pt RF Communication***				***Compliance with this section is required to support the Operational Point-to-Point Communication link class.***
C3I-6	Constellation SYSTEMS shall transmit using LEFT-HAND CIRCULAR POLARIZATION for operational point-to-point	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	links.				
C3I-7	Constellation SYSTEMS shall receive using LEFT-HAND CIRCULAR POLARIZATION for operational point-to-point links.	X	X	X	
C3I-11	Constellation SYSTEMS shall communicate using at least two independent transmit/receive frequency pairs within the near Earth S-band spectrum allocation for multi-SYSTEM, simultaneous operational point-to-point communications.	X	X	X	
C3I-22	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1.O-1, Section 3 to transmit data streams for operational point-to-point links.	X	X	X	
C3I-23	Constellation SYSTEMS shall use bit randomization techniques in accordance with CCSDS 131.0-B-1 for randomization of transmitted data streams for operational point-to-point links.	X	X	X	
C3I-590	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3 for decoding received data streams using FORWARD ERROR CORRECTION for operational point-to-point links.	X	X	X	
C3I-592	Constellation SYSTEMS shall use bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	randomization of received data streams for operational point-to-point links.				
C3I-594	Constellation SYSTEMS shall apply the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 as specified in CCSDS 131.1-O-1, Section 3.5 transmitted FEC code block frames for operational point-to-point links.	X	X	X	
C3I-596	Constellation SYSTEMS shall comply with the specifications for service access points as defined in section 3 of the AOS Space Data Link Protocol 732.0.B-2 for reception of Multiprotocol Interconnect over Frame Relay using the CCSDS AOS Virtual Channel Access (VCA) service over operational point-to-point links.	X	X	X	
C3I-612	Constellation SYSTEMS shall transmit Multiprotocol Interconnect over Frame Relay (MPoFR) as serial octet-aligned streams per CCSDS recommendation “IP over CCSDS Space Links”, CCSDS 702.1-R-1, using the Virtual Channel Access (VCA) service of CCSDS Advanced Orbiting Systems (AOS) Space Link Protocol as specified in CCSDS 732.0-B-2 for operational point-to-point links.	X	X	X	
C3I-653	Constellation SYSTEMS shall enable and disable communication link forward error correction (FEC) upon receipt of COMMAND for operational point-to-point links.	X	X	X	
C3I-668	Constellation SYSTEMS shall	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for transmission of IP packets for operational point-to-point links.				
C3I-669	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for reception of IP packets for operational point-to-point links.	X	X	X	
C3I-670	Constellation SYSTEMS shall use the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 for synchronization of received FEC code block frames as specified in CCSDS 131.1-O-1 for operational point-to-point links.	X	X	X	
C3I-671	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for transmission of non-FEC coded data streams for operational point-to-point links.	X	X	X	
C3I-672	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for resolution of symbol phase ambiguity of non-FEC coded data streams for operational point-to-point links.	X	X	X	
3.1.2.2	***Point A Operational Pt-to-Pt RF Communication***				***Compliance with this section is required to support the Point A Role in communication while using the Operational Point-to-Point Communication link. CLV assumes the Point A Role to support its telemetry downlink during ascent.***
C3I-308	Constellation point A SYSTEMS shall coherently re-transmit the received carrier with a turn-around ratio of 240/221(transmit/receive) for coherent point-to-point link operation.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-314	Constellation point A SYSTEMS shall coherently re-transmit the received range channel data to point B SYSTEM.	X	X	X	
C3I-350	Constellation point A SYSTEMS shall provide a non-coherent mode of operation for operational point-to-point links.	X	X	X	
C3I-573	Constellation point A SYSTEMS shall use transmit signals with modulation schemes in accordance with Table 3.1-2 for operational point-to-point links.	X	X	X	
C3I-574	Constellation point A SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-3 for operational point-to-point links.	X	X	X	
C3I-633	Constellation point A SYSTEMS shall transmit independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 (DG1).	X	X	X	
3.1.2.3	***Point B Operational Pt-to-Pt RF Communication***				***No current requirement for CLV to act as the Point B Role for this class of communication.***
C3I-315	Constellation point B SYSTEMS shall process the coherent turn-around carrier to make radiometric measurements of range rate data (two-way Doppler data) for operational point-to-point links.				
C3I-572	Constellation point B SYSTEMS shall process coherent turn-around ranging channel data to provide radiometric measurements of range data for operational point-to-point links.				
C3I-575	Constellation point B SYSTEMS				

Phasing					
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	shall transmit signals with modulation schemes in accordance with Table 3.1-3 for operational point-to-point links.				
C3I-576	Constellation point B SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-2 for operational point-to-point links.				
C3I-591	Constellation Point B SYSTEMS shall generate and modulate the range channel (Q channel) with the Forward Link Range Channel PN code as defined in the Space Network Interoperable PN Code Libraries, Rev. 1 (451-PN CODE-SNIP).				
C3I-634	Constellation point B SYSTEMS shall receive independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 (DG1).				
3.1.3	**High-Rate Pt-to-Pt RF Communication**				**CLV does not have high rate RF links required.**
3.1.3.1	***Common High Rate RF Communication***				***No current requirement for this class of communications on CLV.***
C3I-30	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3, to transmit data streams for high rate point-to-point links.				
C3I-31	Constellation SYSTEMS shall use bit randomization techniques in accordance with CCSDS 131.0-B-1 for randomization of transmitted data streams for high				

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	rate point-to-point links.				
C3I-581	Constellation SYSTEMS shall transmit using Right-hand Circular polarization for high rate point-to-point links.				
C3I-583	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3, for decoding of received data streams using FEC for high rate point-to-point links.				
C3I-589	Constellation SYSTEMS shall receive using Right-hand Circular polarization for high-rate point-to-point links.				
C3I-598	Constellation SYSTEMS shall use bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-randomization of received data streams for high rate point-to-point links.				
C3I-600	Constellation SYSTEMS shall apply the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 as specified in CCSDS 131.1-O-1, Section 3.5, to transmit FEC code blocks for high rate point-to-point links.				
C3I-601	Constellation SYSTEMS shall comply with the specifications for service access points as defined in section 3 of AOS Space Data Link Protocol 732.0.B-2 for reception of Multiprotocol Interconnect over Frame Relay using the CCSDS AOS Virtual Channel Access service over high rate point-to-point links.				

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-603	Constellation SYSTEMS shall transmit Multiprotocol Interconnect over Frame Relay (MPoFR) as serial octet-aligned streams per CCSDS recommendation "IP over CCSDS Space Links", CCSDS 702.1-R-1, using the Virtual Channel Access (VCA) service of CCSDS Advanced Orbiting Systems (AOS) Space Link Protocol as specified in CCSDS 732.0-B-2 for High Rate point-to-point links.				
C3I-632	Constellation SYSTEMS shall enable and disable communication link forward error correction (FEC) upon receipt of COMMAND for high rate point-to-point links.				
C3I-673	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for transmission of IP packets for high rate point-to-point links.				
C3I-674	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for reception of IP packets for high rate point-to-point links.				
C3I-675	Constellation SYSTEMS shall use the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 for synchronization of received FEC code block frames as specified in CCSDS 131.1-O-1 for high rate point-to-point links.				
C3I-676	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for				

		Phasing			
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	transmission of non-FEC coded data streams for high rate point-to-point links.				
C3I-677	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for resolution of symbol phase ambiguity of non-FEC coded data streams for high rate point-to-point links.				
3.1.3.2	***Point A High-rate Pt-to-Pt RF Communication***				***No current requirement for this class of communications on CLV.***
C3I-577	Constellation point A SYSTEMS shall use transmit signals with modulation schemes in accordance with Table 3.1-4 for high rate point-to-point links.				
C3I-578	Constellation point A SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-5 for high rate point-to-point links.				
3.1.3.3	***Point B High-rate Pt-to-Pt RF Communication***				***No current requirement for this class of communications on CLV.***
C3I-579	Constellation point B SYSTEMS shall transmit signals with modulation schemes in accordance with Table 3.1-5 for high rate point-to-point links.				
C3I-580	Constellation point B SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-4 for high rate point-to-point links.				
3.1.4	***Multipoint Proximity RF Communication***				***CLV does not have a requirement to support multipoint proximity RF communication.***
	RESERVED				
3.1.5	**Recovery RF Communication**				***CLV does not have a requirement to support recovery RF communication.***
3.1.5.1	***Common Recovery RF Communication***				
C3I-347	Constellation SYSTEMS shall transmit to the				

		Phasing			
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	COSPAS/SARSAT system using the spectrum guidelines provided by ITU-R Recommendation M.633.				
C3I-362	Constellation SYSTEMS shall use amplitude modulation (AM) for analog voice communication with US and international search and rescue forces.				
C3I-363	Constellation SYSTEMS shall transmit to the COSPAS/SARSAT system per COSPAS/SARSAT document C/S T.001 Sections 2 and 3.				
C3I-678	Constellation SYSTEMS shall use narrowband frequency modulation (FM) for analog voice communication with US and international maritime search and rescue forces.				
C3I-679	Constellation SYSTEMS shall communicate using the US UHF SATCOM system per MIL-STD-188-181.				
3.1.6	**RF Contingency Voice Communication**				***CLV does not have a requirement to support voice communication.***
3.1.6.1	***Common RF Contingency Voice Communication***				
C3I-385	Constellation SYSTEMS shall modulate the transmitted carrier using amplitude modulation for analog, half-duplex Contingency Voice links.				
C3I-680	Constellation SYSTEMS shall receive an amplitude modulated carrier for Contingency Voice links.				
3.1.7	**Future High Rate Link Class**				
	RESERVED	TBD	TBD	TBD	

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3.1.8	**Vehicle Internal Wireless Link Class**				
C3I-681	Constellation SYSTEMS shall use IEEE 802.11g on non-critical internal local area wireless data networks.				
3.2	**Hard-Line Communication**				
3.2.1	***High-Rate, Hard-Line Communication***				***Compliance with this section is required for interoperable hard-line communications between CLV and GS and CEV.***
C3I-58	Constellation SYSTEMS shall use IEEE Std 1394b™-2002 and SAE-AS5643/1 with RFC-2734 for high data volume, hard-line connections between Constellation SYSTEMS.	X	X	X	
3.2.2	***High-Rate, Ground Hard-Line Communication***				
C3I-336	Constellation SYSTEMS shall use ground institutional IP routed networks.				
3.2.3	***Deterministic Hard-Line Communication***				Compliance with this section is pending determination of any need for any interfaces requiring deterministic closed-loop control with CEV <TBD E-3>, and GS <TBD E-4>.
C3I-682	Constellation SYSTEMS shall use SAE-AS5643 and AS5643/1 standards for deterministic rate based hard-line connections between Constellation SYSTEMS.	X	X	X	
3.3	**Network**				
3.3.1	***Connectivity***				***Compliance with this section is required for interoperable IP network communications between CLV and GS, MS, CEV and C&T Networks.***
C3I-61	Constellation SYSTEMS shall implement version 4 of the Internet Protocol (IPv4) as specified in STD-0005.	X			IPv4 is for ISS Missions only.
C3I-62	Constellation SYSTEMS shall use unicast addresses as defined	X			IPv4 is for ISS Missions only.

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	in RFC-1918, Address Allocation for Private Internets.				
C3I-63	Constellation SYSTEMS shall use multicast addresses as defined in RFC-3171, IANA Guidelines for IPv4 Multicast Address Assignments.	X			IPv4 is for ISS Missions only.
C3I-64	Constellation SYSTEMS shall provide a mechanism to manually configure the addresses of all IP-addressable interfaces.	X	X	X	
C3I-72	Constellation SYSTEMS shall provide IP network address to data link layer address mappings for IP addresses external to the SYSTEM.	X	X	X	
C3I-73	Constellation SYSTEMS shall use managed associations to map IP addresses to data link layer addresses for IP addresses external to the SYSTEM.	X	X	X	
C3I-74	Constellation SYSTEMS shall accept modifications to the IP address to data-link layer address mapping information via the network for IP addresses external to the SYSTEM.	X	X	X	
C3I-75	Constellation SYSTEMS shall perform multi-hop routing as specified in RFC-1812, Requirements for IP Version 4 Routers as updated by RFC-2644.	X			IPv4 is for ISS Missions only.
C3I-76	Constellation SYSTEMS shall comply with RFC-1122 (STD-0003), Requirements for Internet Hosts – Communications Layers.	X			IPv4 is for ISS Missions only.
C3I-78	Constellation SYSTEMS shall use manually configured routes instead of dynamically learned ones when there is an exact	X	X	X	

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	match in the prefix length for a given destination external to the SYSTEM.				
C3I-79	Constellation SYSTEMS shall use static routing table entries.	X	X	X	
C3I-80	Constellation SYSTEMS shall accept changes to the routing tables via the network.	X	X	X	
C3I-87	Constellation SYSTEMS shall advertise only non-default routes via the routing protocols.	X	X	X	
C3I-89	Constellation SYSTEMS shall have a default route specified in the routing tables.	X	X	X	
C3I-90	Constellation SYSTEMS shall fail over to default routes when there is a loss of all routing information or a loss of communication to all SYSTEM network neighbors participating in the dynamic routing protocol for more than 20 seconds.	X	X	X	
C3I-93	Constellation SYSTEMS shall resolve symbolic names to IP addresses using static host table.	X	X	X	
C3I-95	Constellation SYSTEMS shall accept changes to the static host table via the network.	X	X	X	
C3I-96	Constellation SYSTEMS shall implement RFC-2474, Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers.	X	X	X	
C3I-97	Constellation SYSTEMS shall implement RFC-2211, Specification of the Controlled-Load Network System Service.	X	X	X	
C3I-98	Constellation SYSTEMS shall implement <TBR 3-25> RFC-2205, Resource ReSerVation Protocol (RSVP) Version 1	X	X	X	

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	Functional Specification.				
C3I-99	Constellation SYSTEMS shall implement the Simple Network Management Protocol version 3 as defined in STD0062.	X	X	X	
C3I-103	Constellation SYSTEMS shall implement Internet STD-0007: TRANSMISSION CONTROL PROTOCOL (TCP).	X	X	X	
C3I-104	Constellation SYSTEMS shall implement RFC-1323 - TCP Extensions for High Performance.	X	X	X	
C3I-105	Constellation SYSTEMS shall implement STD-0006 - UDP, USER DATAGRAM PROTOCOL, for communication with all IP-addressable endpoints.	X	X	X	
C3I-106	Constellation SYSTEMS shall implement RFC-3550 (STD-0064), RTP: A Transport Protocol for Real-Time Applications.	X	X	X	
C3I-281	Constellation SYSTEMS shall implement RFC-3140, Per Hop Behavior Identification Codes.	X	X	X	
C3I-282	Constellation SYSTEMS shall implement RFC-3246, An Expedited Forwarding PHB (PER HOP BEHAVIOR).	X	X	X	
C3I-619	Constellation SYSTEMS shall implement a split-connection TCP Performance Enhancing Proxy (PEP) that implements the SCPS-TP transport layer per CCSDS 714.0.B-1, Space Communications Protocol Specification (SCPS) - Transport Protocol (SCPS-TP), Blue Book, Issue 1, May 1999, on links	X	X	X	

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	where the maximum bandwidth*delay product of the link exceeds 1e6 bits and/or whose design bit error rate is equal to or greater than 1e-6.				
C3I-620	Constellation SYSTEMS shall implement Internet Protocol version 6 (IPv6) per RFC 2460 Internet Protocol, Version 6 (IPv6) Specification.		X	X	IPv6 Lunar Missions
C3I-621	Constellation SYSTEMS shall implement the Internet Control Messaging Protocol (ICMP) per RFC 792, Internet Control Message Protocol.	X			IPv4 Lunar Missions
C3I-622	Constellation SYSTEMS shall implement the Internet Control Messaging Protocol version 6 (ICMPv6) per RFC 4443 Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification.		X	X	IPv6 Lunar Missions
C3I-654	Constellation SYSTEMS shall implement the Multiprotocol Border Gateway Protocol (MBGP) as specified in RFC-2858.	X	X	X	
C3I-655	Constellation SYSTEMS shall implement the Multicast Listener Discovery protocol, version 2, as specified in RFC-3810 <TBR 3-24>.		X	X	This protocol is required to join end systems to multicast groups in IPv6.
C3I-656	Constellation SYSTEMS shall implement Multicast Extension to OSPF as specified in RFC-1584.	X			MOSPF is IPv4 specific.
C3I-657	Constellation SYSTEMS shall implement the Internet Group Management Protocol (IGMP) as specified in RFC-3376.	X			This protocol is required to join end systems to multicast groups in IPv4.
3.3.2	***Dynamic Routing Between Systems***				***Dynamic routing is not required since static routes will be sufficient to support the network***

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					configurations for CLV operations.
C3I-82	Constellation SYSTEMS shall implement RFC-2453, STD-0056 - RIP Version 2.				
C3I-83	Constellation SYSTEMS shall implement RFC-2328 (STD-0054), OPEN SHORTEST PATH FIRST (OSPF) Version 2.				
C3I-295	Constellation SYSTEMS shall implement RFC-3626 Optimized Link State Routing Protocol (OLSR).				.
C3I-662	Constellation SYSTEMS shall implement RFC-2080, RIPng for IPv6 .				
C3I-663	Constellation SYSTEMS shall implement RFC-2740 , OSPF for IPv6.				
3.3.3	***External Connectivity***				***The CLV does not interface with external networks.***
C3I-81	Constellation SYSTEMS shall implement RFC-4271-A BORDER GATEWAY PROTOCOL (BGP) Version 4, as specified in RFC4271 "A BORDER GATEWAY PROTOCOL 4 (BGP-4)				
C3I-280	Constellation SYSTEMS shall use external routes learned by Border Gateway Protocol Version 4, as specified in RFC4271 “A Border Gateway Protocol 4 (BGP-4), before those learned via other dynamic routing protocols.				
3.3.4	***Name Service***				***Compliance with this section is required for IP network name services used for network communications between CLV and GS or C&T Networks. This is required to reduce systems management overhead associated with IP address management.***
C3I-296	Constellation SYSTEMS shall	X	X	X	

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	implement IETF STD-0013, Domain Name SYSTEM.				
3.3.5	***Disruption Tolerance***				***CLV does not interface with systems under conditions where disruption and delay are issues.***
C3I-107	Constellation SYSTEMS shall implement <TBR 3-12> DTN, DELAY/DISRUPTION TOLERANT NETWORKING Specifications, http://www.ietf.org/internet-drafts/draft-irtf-dtnrg-bundle-spec-05.txt.		X	X	
3.3.6	***Dynamic Address Assignment***				***Compliance with this section is pending determination of any need for GS GSE interfaces with CLV <TBD E-5> that would require dynamic address assignment.***
C3I-67	Constellation SYSTEMS shall implement the DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP) Server functions as specified in RFC-2131 and updated by RFC-4361.	TBD	TBD	TBD	
3.3.7	***Dynamic Address Retrieval***				***Compliance with this section is pending determination of any need for GS GSE interfaces with CLV <TBD E-6> that would require dynamic address retrieval functions.***
C3I-69	Constellation SYSTEMS shall obtain network addresses via the DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP) as specified in RFC-2131 and updated by RFC-4361.	TBD	TBD	TBD	
C3I-70	Constellation SYSTEMS shall 'self-assign' an IP address from the 169.254.0.0/16 private address block as specified in RFC-3927, Dynamic Configuration of IPv4 Link-Local Addresses of IPv4	TBD	TBD	TBD	

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	interfaces when unable to obtain an IP address from pre-configuration information and/or DHCP.				
3.3.8	***Tunneling***				***Compliance with this section is required for network tunneling on interfaces between CLV and MS and GS. Tunneling is necessary to support Mobile IP and allows controllers to perform traffic engineering and to force traffic to follow particular paths in the network that are different from the routes that might be 'default' or learned via dynamic routing protocols.***
C3I-92	Constellation SYSTEMS shall implement RFC-2784, GENERIC ROUTING ENCAPSULATION (GRE).	TBD	TBD	TBD	
C3I-664	Constellation SYSTEMS shall implement RFC-2473, Generic Packet Tunneling in IPv6 Specification.	TBD	TBD	TBD	IPv6 version for Lunar Missions
3.3.9	***Header Compression***				***Compliance with this section is required for test and checkout of compressed network communications between CLV and C&T Networks***
C3I-307	Constellation SYSTEMS shall implement RFC-2507 IP Header Compression.	X	X	X	
C3I-588	Constellation SYSTEMS shall implement RFC 2508 Compressing IP/UDP/RTP Headers for Low-Speed Serial Links.	X	X	X	
3.3.10	***Network Management***				***Compliance with this section is required for network management interfaces between CLV and MS and GS.***
C3I-100	Constellation SYSTEMS shall implement RFC-4293 Management Information Base for the Internet Protocol (IP).	X	X	X	
C3I-294	Constellation SYSTEMS shall	X	X	X	

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	implement RFC-4292, IP Forwarding Table MIB.				
C3I-298	Constellation SYSTEMS shall implement RFC-3747, Differentiated Services Configuration MIB.	X	X	X	
C3I-299	Constellation SYSTEMS shall implement RFC-3289, MIB for the Differentiated Services Architecture.	X	X	X	
C3I-300	Constellation SYSTEMS shall implement RFC-2213, Integrated Services Management Information Base using SMIv2.	X	X	X	
C3I-301	Constellation SYSTEMS shall implement RFC-4022, Management Information Base for TRANSMISSION CONTROL PROTOCOL (TCP).	X	X	X	
C3I-302	Constellation SYSTEMS shall implement RFC-4113, Management Information Base for USER DATAGRAM PROTOCOL (UDP).	X	X	X	
C3I-303	Constellation SYSTEMS shall implement RFC-2959, Real Time Protocol MIB.	X	X	X	
3.4	**Security**				***Compliance with this section is required for secure, interoperable communications between CLV and MS, GS, CEV and C&T Networks.***
3.4.1	***Network Layer Security***				
C3I-199	Constellation SYSTEMS shall implement RFC 4301, Security architecture for the Internet Protocol, at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-200	Constellation SYSTEMS shall implement RFC-4302, IP AUTHENTICATION HEADER (AH), at all Internet Protocol (IP) based inter-SYSTEM data	X	X	X	

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	exchange interfaces.				
C3I-201	Constellation SYSTEMS shall implement RFC-4303, IP ENCAPSULATING SECURITY PAYLOAD (ESP), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-204	Constellation SYSTEMS shall implement RFC 4305, Cryptographic Algorithm Implementation Requirements for Encapsulating Security Payload (ESP) and Authentication Header (AH), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-565	Constellation SYSTEMS shall implement RFC 4309, Using Advanced Encryption Standard (AES) CCM Mode with IPsec Encapsulating Security Payload (ESP), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
3.4.2	***Internet Key Exchange***				
C3I-209	Constellation SYSTEMS shall implement RFC-4306, The INTERNET KEY EXCHANGE (IKEv2), for all inter-SYSTEM management of security associations and keys used by IPSec.	X	X	X	
C3I-568	Constellation SYSTEMS shall implement RFC-4307, Cryptographic Algorithms for use in the Internet Key Exchange Version 2 (IKEv2).	X	X	X	
3.4.3	***Application Layer Security***				
C3I-210	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP	X	X	X	

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	70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for inter-SYSTEM updates of security processing logic.				
C3I-566	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for all inter-system exchanges of the security policy information used by application layer security functions.	X	X	X	
C3I-567	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification and described in the for all inter-SYSTEM exchanges of the identity data used by application layer security functions.	X	X	X	
C3I-569	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for all	X	X	X	

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	inter-SYSTEM exchanges of the authentication keys and encryption keys used by application layer security functions.				
3.4.4	***FIPS Compliant Algorithms***				
C3I-203	Constellation SYSTEMS shall implement FIPS PUB 197, ADVANCED ENCRYPTION STANDARD (AES), for all ENCRYPTION of inter-SYSTEM data exchanges.	X	X	X	
C3I-206	Constellation SYSTEMS shall implement SHA-1 per FIPS PUB 180-2, Secure Hash Standard, for hash generation performed for inter-SYSTEM data exchanges.	X	X	X	
C3I-207	Constellation SYSTEMS shall implement FIPS PUB 186-2, DIGITAL SIGNATURE STANDARD (DSS) using the DIGITAL SIGNATURE ALGORITHM (DSA) for all digital signatures exchanged between SYSTEMS.	X	X	X	
C3I-208	Constellation SYSTEMS shall implement FIPS PUB 198, Keyed-HASH MESSAGE AUTHENTICATION CODE (HMAC), for all MESSAGE AUTHENTICATION CODES (MACs) exchanged between SYSTEMS.	X	X	X	
C3I-665	Constellation SYSTEMS shall implement SHA-256 per FIPS PUB 180-2, Secure Hash Standard, for hash generation performed for inter-SYSTEM data exchanges.	X	X	X	
C3I-666	Constellation SYSTEMS shall implement truncation of SHA-1 based 160-bit Hash Based	X	X	X	

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	Messaged Authentication Codes (HMACs) to 96 bits.				
C3I-667	Constellation SYSTEMS shall implement truncation of SHA-256 based 256-bit Hash Based Messaged Authentication Codes (HMACs) to 128 bits.	X	X	X	
3.5	**Data Exchange**				
3.5.1	***Voice Exchange***				***Voice communications are not required for CLV*.**
C3I-173	Constellation SYSTEMS shall assign a delivery priority to voice data sent to another SYSTEM.				
C3I-175	Constellation SYSTEMS shall transfer voice data over a one way link.				
C3I-176	Constellation SYSTEMS shall use ITU G.729, "Coding of speech at 8 kbit/s using conjugate-structure algebraic-code-excited linear prediction (CS-ACELP)".				
C3I-555	Constellation SYSTEMS shall transfer voice in accordance with IETF RFC 3550, Real-Time Transport Protocol (RTP).				
C3I-557	Constellation SYSTEMS shall provide a mechanism to add voice codecs.				
C3I-558	Constellation SYSTEMS shall provide a mechanism to remove voice codecs.				
3.5.2	***Motion Imagery Transfer***				***Compliance with this section is required for interoperable motion imagery transfer between CLV and MS, GS and CEV <TBD E-7>.***
C3I-184	Constellation SYSTEMS shall assign a delivery priority for motion imagery data sent to another SYSTEM.	X	X	X	
C3I-185	Constellation SYSTEMS shall transfer motion imagery over a one way link.	X	X	X	

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C3I-186	Constellation SYSTEMS shall use ITU H.264, "Advanced Video Coding for Generic Audiovisual Services".	X	X	X	
C3I-283	Constellation SYSTEMS shall transfer motion imagery in accordance with RFC 3550, Real-Time Transport Protocol (RTP).	X	X	X	
C3I-559	Constellation SYSTEMS shall use <TBR 3-13> ISO/IEC 15444-3, "Motion JPEG 2000 (Part 3)".	X	X	X	
C3I-560	Constellation SYSTEMS shall provide a mechanism to add MOTION IMAGERY codecs.	X	X	X	
C3I-561	Constellation SYSTEMS shall provide a mechanism to remove MOTION IMAGERY codecs.	X	X	X	
3.5.3	***Data Exchange Message Formatting and Transmission***				***Compliance with this section is required for interoperable message exchange between CLV and MS, GS, and CEV.***
C3I-130	Constellation SYSTEMS shall transfer data exchange messages over a one way link.	X	X	X	
C3I-135	Constellation SYSTEMS shall use a common data exchange message format as defined in Appendix C of CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5:	X	X	X	
C3I-659	Constellation SYSTEMS shall assign to each data exchange message that is sent to another SYSTEM the priority that was assigned to the Data of that data exchange message.	X	X	X	
3.5.4	***File Transfer***				***Compliance with this section is required for interoperable file transfer between CLV and MS,***

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					GS, and CEV <TBD E-8>.
C3I-161	Constellation SYSTEMS shall assign a delivery priority to each file sent to another SYSTEM.	X	X	X	
C3I-165	Constellation SYSTEMS shall transfer files in accordance with CCSDS 727.0-B-3, "CCSDS File Delivery Protocol (CFDP) – Recommended Standard".	X	X	X	
3.5.5	***Time Exchange***				***Compliance with this section is required for time exchange/sync interfaces between CLV and MS, GS, CEV, and C&T Networks.***
C3I-111	Constellation SYSTEMS shall exchange time in accordance with IETF RFC 1305, NETWORK TIME PROTOCOL (NTP) Version 3.	X	X	X	
3.5.6	***Traffic Prioritization***				
C3I-660	Constellation SYSTEMS shall effect observance of the delivery priorities assigned to voice data, motion imagery data, data exchange messages, and files by invoking traffic prioritization mechanisms provided by the underlying network.	X	X	X	
3.6	**Information**				
3.6.1	***Basic Information Definition***				***Compliance with this section is required for interoperable information definition for information exchanged between CLV and MS, GS, and CEV***
C3I-119	Constellation SYSTEMS shall use common COMMAND METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book,	X	X	X	

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	Volume 4: Information Representation Specification.				
C3I-140	Constellation SYSTEMS shall use common telemetry METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-157	Constellation SYSTEMS shall use a common convention for file formats as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3.	X	X	X	
C3I-169	Constellation SYSTEMS shall use common voice METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-180	Constellation SYSTEMS shall use common motion imagery METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book,	X	X	X	

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	Volume 4: Information Representation Specification.				
C3I-228	Constellation SYSTEMS shall use data types as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3.	X	X	X	
C3I-229	Constellation SYSTEMS shall exchange METADATA that complies with the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-231	Constellation SYSTEMS shall use Universal Resource Indicators (URIs) and namespace constructs using conventions described in RFC3986.	X	X	X	
C3I-355	Constellation SYSTEMS shall use a hierarchical addressing structure as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-357	Constellation SYSTEMS shall use a common file naming convention as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and	X	X	X	

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	Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Sec 3.3.				
C3I-366	Constellation SYSTEMS shall issue inter-SYSTEM COMMANDS in the format defined by the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Sec 3.8.	X	X	X	
C3I-544	Constellation SYSTEMS shall exchange application layer security policies between SYSTEMS in a representation that complies with CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-545	Constellation SYSTEMS shall exchange application layer cryptographic keys between SYSTEMS in a representation that complies with the CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-546	Constellation SYSTEMS shall exchange application layer identity information between SYSTEMS in a representation that complies with CxP 70022, Constellation Command, Control, Communications, and	X	X	X	

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	Information (C3I) Interoperability Standards Book, Volume				
C3I-652	Constellation SYSTEMS shall exchange application layer security audit data between SYSTEMS in a representation that complies with the CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-661	Constellation Systems shall define METADATA that complies with the CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
3.6.2	***Adaptive Information Definition***				***Compliance with this section is required for more adaptive (ad-hoc) interoperable information definition for information exchanged between CLV and MS and GS. Note that this functionality is not phased in until lunar sortie.***
C3I-215	Constellation SYSTEMS shall define TELEMETRY processing algorithms in accordance with CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-222	Constellation SYSTEMS shall use a hierarchical naming scheme in accordance with the CXP-70022, Constellation		X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.				
C3I-547	Constellation SYSTEMS shall request data using data identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-548	Constellation SYSTEMS shall request files using file identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27>of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-549	Constellation SYSTEMS shall construct requests for data using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR) Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book,		X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Volume 4: Information Representation Specification.				
C3I-550	Constellation SYSTEMS shall construct requests for file submissions and retrievals using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR) Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	

Table Appendix E-3 - C3I Interoperability Requirements Applicability to LSAM

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
3.1	**RF Communication**				
3.1.1	***Common RF Communication***				***Compliance with this section is required for interoperable communications between LSAM and GS (for checkout testing), CEV, and C&T Networks.***
C3I-3	Constellation SYSTEMS shall comply with spectrum selection/allocation, certification and usage restriction policies set forth in NASA Policy Directive (NPD) 2570.5D, NASA Electromagnetic (EM) Spectrum	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Management.				
C3I-5	Constellation SYSTEMS shall use transmit/receive frequency assignments and spectrum characteristics as defined in CxP 70022 Constellation Command, Control, Communications and Information (C3I) Interoperability Standards Book, Volume 2: Constellation Spectrum and Channel Plan.	X	X	X	
C3I-584	Constellation SYSTEMS shall comply with radio frequency allocation and conditions of assignment for frequency spectrum usage approved by the National Telecommunications & Information Administration (NTIA).	X	X	X	
3.1.2	**Operational Pt-to-Pt RF Communication**				***Compliance with this section is required for interoperable communications between LSAM and GS (for checkout testing), CEV, and C&T Networks.***
3.1.2.1	***Common Operational Pt-to-Pt RF Communication***				***Compliance with this section is required to support the Operational Point-to-Point Communication link class.***
C3I-6	Constellation SYSTEMS shall transmit using LEFT-HAND CIRCULAR POLARIZATION for operational point-to-point links.	X	X	X	
C3I-7	Constellation SYSTEMS shall receive using LEFT-HAND CIRCULAR POLARIZATION for operational point-to-point links.	X	X	X	
C3I-11	Constellation SYSTEMS shall communicate using at least two independent transmit/receive frequency pairs within the near Earth S-band spectrum allocation for multi-SYSTEM,	X	X	X	

		Phasing			
Section/ Req #	Section/Requirement	ISS	Sortie	Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
	simultaneous operational point-to-point communications.				
C3I-22	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1.O-1, Section 3 to transmit data streams for operational point-to-point links.	X	X	X	
C3I-23	Constellation SYSTEMS shall use bit randomization techniques in accordance with CCSDS 131.0-B-1 for randomization of transmitted data streams for operational point-to-point links.	X	X	X	
C3I-590	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3 for decoding received data streams using FORWARD ERROR CORRECTION for operational point-to-point links.	X	X	X	
C3I-592	Constellation SYSTEMS shall use bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-randomization of received data streams for operational point-to-point links.	X	X	X	
C3I-594	Constellation SYSTEMS shall apply the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 as specified in CCSDS 131.1-O-1, Section 3.5 transmitted FEC code block frames for operational point-to-point links.	X	X	X	
C3I-596	Constellation SYSTEMS shall	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	comply with the specifications for service access points as defined in section 3 of the AOS Space Data Link Protocol 732.0.B-2 for reception of Multiprotocol Interconnect over Frame Relay using the CCSDS AOS Virtual Channel Access (VCA) service over operational point-to-point links.				
C3I-612	Constellation SYSTEMS shall transmit Multiprotocol Interconnect over Frame Relay (MPoFR) as serial octet-aligned streams per CCSDS recommendation “IP over CCSDS Space Links”, CCSDS 702.1-R-1, using the Virtual Channel Access (VCA) service of CCSDS Advanced Orbiting Systems (AOS) Space Link Protocol as specified in CCSDS 732.0-B-2 for operational point-to-point links.	X	X	X	
C3I-653	Constellation SYSTEMS shall enable and disable communication link forward error correction (FEC) upon receipt of COMMAND for operational point-to-point links.	X	X	X	
C3I-668	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for transmission of IP packets for operational point-to-point links.	X	X	X	
C3I-669	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for reception of IP packets for operational point-to-point links.	X	X	X	
C3I-670	Constellation SYSTEMS shall	X	X	X	

Section/ Req #	Section/Requirement	Phasing ISS	Sortie	Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
	use the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 for synchronization of received FEC code block frames as specified in CCSDS 131.1-O-1 for operational point-to-point links.				
C3I-671	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for transmission of non-FEC coded data streams for operational point-to-point links.	X	X	X	
C3I-672	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for resolution of symbol phase ambiguity of non-FEC coded data streams for operational point-to-point links.	X	X	X	
3.1.2.2	***Point A Operational Pt-to-Pt RF Communication***				***Compliance with this section is required to support the Point A Role in communication while using the Operational Point-to-Point Communication link. The Point A Role provides for coherent ranging for tracking, and assumes the role of target during rendezvous.***
C3I-308	Constellation point A SYSTEMS shall coherently re-transmit the received carrier with a turn-around ratio of 240/221(transmit/receive) for coherent point-to-point link operation.	X	X	X	
C3I-314	Constellation point A SYSTEMS shall coherently re-transmit the received range channel data to point B SYSTEM.	X	X	X	
C3I-350	Constellation point A SYSTEMS shall provide a non-coherent mode of operation for operational point-to-point links.	X	X	X	
C3I-573	Constellation point A SYSTEMS shall use transmit	X	X	X	

Section/ Req #	Section/Requirement	Phasing ISS	Phasing Sortie	Phasing Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
	signals with modulation schemes in accordance with Table 3.1-2 for operational point-to-point links.				
C3I-574	Constellation point A SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-3 for operational point-to-point links.	X	X	X	
C3I-633	Constellation point A SYSTEMS shall transmit independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 (DG1).	X	X	X	
3.1.2.3	***Point B Operational Pt-to-Pt RF Communication***				***Compliance with this section is required to support the Point B Role in communication while using the Operational Point-to-Point Communication link. The Point B role provides for the capabilities of space communications infrastructure (eg. GN, SN, DSN) as well as originating the ranging signals for tracking and rendezvous operations.***
C3I-315	Constellation point B SYSTEMS shall process the coherent turn-around carrier to make radiometric measurements of range rate data (two-way Doppler data) for operational point-to-point links.	X	X	X	
C3I-572	Constellation point B SYSTEMS shall process coherent turn-around ranging channel data to provide radiometric measurements of range data for operational point-to-point links.	X	X	X	
C3I-575	Constellation point B SYSTEMS shall transmit signals with modulation schemes in accordance with Table 3.1-3 for operational point-to-point links.	X	X	X	
C3I-576	Constellation point B SYSTEMS	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	shall receive signals with modulation schemes in accordance with Table 3.1-2 for operational point-to-point links.				
C3I-591	Constellation Point B SYSTEMS shall generate and modulate the range channel (Q channel) with the Forward Link Range Channel PN code as defined in the Space Network Interoperable PN Code Libraries, Rev. 1 (451-PN CODE-SNIP).	X	X	X	
C3I-634	Constellation point B SYSTEMS shall receive independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 (DG1).	X	X	X	
3.1.3	**High-Rate Pt-to-Pt RF Communication**				***Compliance with this section is required for LSAM high rate communications between LSAM and GS (for checkout testing), CEV, and C&T Networks.***
3.1.3.1	***Common High Rate RF Communication***				***Compliance with this section is required to support the frequencies and modulation to enable high rate communication.***
C3I-30	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3, to transmit data streams for high rate point-to-point links.	X	X	X	
C3I-31	Constellation SYSTEMS shall use bit randomization techniques in accordance with CCSDS 131.0-B-1 for randomization of transmitted data streams for high rate point-to-point links.	X	X	X	
C3I-581	Constellation SYSTEMS shall	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	transmit using Right-hand Circular polarization for high rate point-to-point links.				
C3I-583	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3, for decoding of received data streams using FEC for high rate point-to-point links.	X	X	X	
C3I-589	Constellation SYSTEMS shall receive using Right-hand Circular polarization for high-rate point-to-point links.	X	X	X	
C3I-598	Constellation SYSTEMS shall use bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-randomization of received data streams for high rate point-to-point links.	X	X	X	
C3I-600	Constellation SYSTEMS shall apply the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 as specified in CCSDS 131.1-O-1, Section 3.5, to transmit FEC code blocks for high rate point-to-point links.	X	X	X	
C3I-601	Constellation SYSTEMS shall comply with the specifications for service access points as defined in section 3 of AOS Space Data Link Protocol 732.0.B-2 for reception of Multiprotocol Interconnect over Frame Relay using the CCSDS AOS Virtual Channel Access service over high rate point-to-point links.	X	X	X	
C3I-603	Constellation SYSTEMS shall transmit Multiprotocol	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Interconnect over Frame Relay (MPoFR) as serial octet-aligned streams per CCSDS recommendation “IP over CCSDS Space Links”, CCSDS 702.1-R-1, using the Virtual Channel Access (VCA) service of CCSDS Advanced Orbiting Systems (AOS) Space Link Protocol as specified in CCSDS 732.0-B-2 for High Rate point-to-point links.				
C3I-632	Constellation SYSTEMS shall enable and disable communication link forward error correction (FEC) upon receipt of COMMAND for high rate point-to-point links.	X	X	X	
C3I-673	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for transmission of IP packets for high rate point-to-point links.	X	X	X	
C3I-674	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for reception of IP packets for high rate point-to-point links.	X	X	X	
C3I-675	Constellation SYSTEMS shall use the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 for synchronization of received FEC code block frames as specified in CCSDS 131.1-O-1 for high rate point-to-point links.	X	X	X	
C3I-676	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for transmission of non-FEC coded data streams for high rate point-	X	X	X	

Section/ Req #	Section/Requirement	Phasing ISS	Phasing Sortie	Phasing Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
	to-point links.				
C3I-677	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for resolution of symbol phase ambiguity of non-FEC coded data streams for high rate point-to-point links.	X	X	X	
3.1.3.2	***Point A High-rate Pt-to-Pt RF Communication***				***Compliance with this section is required to support high rate communication with space communications infrastructure (eg. GN, SN, DSN).***
C3I-577	Constellation point A SYSTEMS shall use transmit signals with modulation schemes in accordance with Table 3.1-4 for high rate point-to-point links.	X	X	X	
C3I-578	Constellation point A SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-5 for high rate point-to-point links.	X	X	X	
3.1.3.3	***Point B High-rate Pt-to-Pt RF Communication***				***No current requirement for LSAM to support the Point B role for high rate communications.***
C3I-579	Constellation point B SYSTEMS shall transmit signals with modulation schemes in accordance with Table 3.1-5 for high rate point-to-point links.				
C3I-580	Constellation point B SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-4 for high rate point-to-point links.				
3.1.4	***Multipoint Proximity RF Communication***				***Compliance with this section is required for interoperable communications between LSAM and EVA/surface systems or GS (for checkout testing).***
	RESERVED	TBD	TBD	TBD	
3.1.5	**Recovery RF Communication**				***Not required since LSAM is not recovered.***

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
3.1.5.1	***Common Recovery RF Communication***				
C3I-347	Constellation SYSTEMS shall transmit to the COSPAS/SARSAT system using the spectrum guidelines provided by ITU-R Recommendation M.633.				
C3I-362	Constellation SYSTEMS shall use amplitude modulation (AM) for analog voice communication with US and international search and rescue forces.				
C3I-363	Constellation SYSTEMS shall transmit to the COSPAS/SARSAT system per COSPAS/SARSAT document C/S T.001 Sections 2 and 3.				
C3I-678	Constellation SYSTEMS shall use narrowband frequency modulation (FM) for analog voice communication with US and international maritime search and rescue forces.				
C3I-679	Constellation SYSTEMS shall communicate using the US UHF SATCOM system per MIL-STD-188-181.				
3.1.6	**RF Contingency Voice Communication**				***Compliance with this section is required for interoperable contingency RF communications interfaces between LSAM and MS, GS, and CEV.***
3.1.6.1	***Common RF Contingency Voice Communication***				
C3I-385	Constellation SYSTEMS shall modulate the transmitted carrier using amplitude modulation for analog, half-duplex Contingency Voice links.	X	X	X	
C3I-680	Constellation SYSTEMS shall receive an amplitude modulated	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	carrier for Contingency Voice links.				
3.1.7	**Future High Rate Link Class**				
	RESERVED	TBD	TBD	TBD	
3.1.8	**Vehicle Internal Wireless Link Class**				
C3I-681	Constellation SYSTEMS shall use IEEE 802.11g on non-critical internal local area wireless data networks.	X	X	X	
3.2	**Hard-Line Communication**				
3.2.1	***High-Rate, Hard-Line Communication***				***Compliance with this section is required for interoperable hard-line communications between LSAM and GS, CEV, EVA, and CaLV.***
C3I-58	Constellation SYSTEMS shall use IEEE Std 1394b™-2002 and SAE-AS5643/1 with RFC-2734 for high data volume, hard-line connections between Constellation SYSTEMS.	X	X	X	
3.2.2	***High-Rate, Ground Hard-Line Communication***				
C3I-336	Constellation SYSTEMS shall use ground institutional IP routed networks.				
3.2.3	***Deterministic Hard-Line Communication***				***No real-time, deterministic control loop interfaces with other systems have been identified.***
C3I-682	Constellation SYSTEMS shall use SAE-AS5643 and AS5643/1 standards for deterministic rate based hard-line connections between Constellation SYSTEMS.				
3.3	**Network**				
3.3.1	***Connectivity***				***Compliance with this section is required for interoperable IP network communications between LSAM and MS, GS (testing), CEV, EVA, and***

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
					CaLV.
C3I-61	Constellation SYSTEMS shall implement version 4 of the Internet Protocol (IPv4) as specified in STD-0005.	X			IPv4 is for ISS Missions only.
C3I-62	Constellation SYSTEMS shall use unicast addresses as defined in RFC-1918, Address Allocation for Private Internets.	X			IPv4 is for ISS Missions only.
C3I-63	Constellation SYSTEMS shall use multicast addresses as defined in RFC-3171, IANA Guidelines for IPv4 Multicast Address Assignments.	X			IPv4 is for ISS Missions only.
C3I-64	Constellation SYSTEMS shall provide a mechanism to manually configure the addresses of all IP-addressable interfaces.	X	X	X	
C3I-72	Constellation SYSTEMS shall provide IP network address to data link layer address mappings for IP addresses external to the SYSTEM.	X	X	X	
C3I-73	Constellation SYSTEMS shall use managed associations to map IP addresses to data link layer addresses for IP addresses external to the SYSTEM.	X	X	X	
C3I-74	Constellation SYSTEMS shall accept modifications to the IP address to data-link layer address mapping information via the network for IP addresses external to the SYSTEM.	X	X	X	
C3I-75	Constellation SYSTEMS shall perform multi-hop routing as specified in RFC-1812, Requirements for IP Version 4 Routers as updated by RFC-2644.	X			IPv4 is for ISS Missions only.

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-76	Constellation SYSTEMS shall comply with RFC-1122 (STD-0003), Requirements for Internet Hosts – Communications Layers.	X			IPv4 is for ISS Missions only.
C3I-78	Constellation SYSTEMS shall use manually configured routes instead of dynamically learned ones when there is an exact match in the prefix length for a given destination external to the SYSTEM.	X	X	X	
C3I-79	Constellation SYSTEMS shall use static routing table entries.	X	X	X	
C3I-80	Constellation SYSTEMS shall accept changes to the routing tables via the network.	X	X	X	
C3I-87	Constellation SYSTEMS shall advertise only non-default routes via the routing protocols.	X	X	X	
C3I-89	Constellation SYSTEMS shall have a default route specified in the routing tables.	X	X	X	
C3I-90	Constellation SYSTEMS shall fail over to default routes when there is a loss of all routing information or a loss of communication to all SYSTEM network neighbors participating in the dynamic routing protocol for more than 20 seconds.	X	X	X	
C3I-93	Constellation SYSTEMS shall resolve symbolic names to IP addresses using static host table.	X	X	X	
C3I-95	Constellation SYSTEMS shall accept changes to the static host table via the network.	X	X	X	
C3I-96	Constellation SYSTEMS shall implement RFC-2474, Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-97	Constellation SYSTEMS shall implement RFC-2211, Specification of the Controlled-Load Network System Service.	X	X	X	
C3I-98	Constellation SYSTEMS shall implement <TBR 3-25> RFC-2205, Resource ReSerVation Protocol (RSVP) Version 1 Functional Specification.	X	X	X	
C3I-99	Constellation SYSTEMS shall implement the Simple Network Management Protocol version 3 as defined in STD0062.	X	X	X	
C3I-103	Constellation SYSTEMS shall implement Internet STD-0007: TRANSMISSION CONTROL PROTOCOL (TCP).	X	X	X	
C3I-104	Constellation SYSTEMS shall implement RFC-1323 - TCP Extensions for High Performance.	X	X	X	
C3I-105	Constellation SYSTEMS shall implement STD-0006 - UDP, USER DATAGRAM PROTOCOL, for communication with all IP-addressable endpoints.	X	X	X	
C3I-106	Constellation SYSTEMS shall implement RFC-3550 (STD-0064), RTP: A Transport Protocol for Real-Time Applications.	X	X	X	
C3I-281	Constellation SYSTEMS shall implement RFC-3140, Per Hop Behavior Identification Codes.	X	X	X	
C3I-282	Constellation SYSTEMS shall implement RFC-3246, An Expedited Forwarding PHB (PER HOP BEHAVIOR).	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-619	Constellation SYSTEMS shall implement a split-connection TCP Performance Enhancing Proxy (PEP) that implements the SCPS-TP transport layer per CCSDS 714.0.B-1, Space Communications Protocol Specification (SCPS) - Transport Protocol (SCPS-TP), Blue Book, Issue 1, May 1999, on links where the maximum bandwidth*delay product of the link exceeds 1e6 bits and/or whose design bit error rate is equal to or greater than 1e-6.	X	X	X	
C3I-620	Constellation SYSTEMS shall implement Internet Protocol version 6 (IPv6) per RFC 2460 Internet Protocol, Version 6 (IPv6) Specification.		X	X	IPv6 Lunar Missions
C3I-621	Constellation SYSTEMS shall implement the Internet Control Messaging Protocol (ICMP) per RFC 792, Internet Control Message Protocol.	X			IPv4 Lunar Missions
C3I-622	Constellation SYSTEMS shall implement the Internet Control Messaging Protocol version 6 (ICMPv6) per RFC 4443 Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification.		X	X	IPv6 Lunar Missions
C3I-654	Constellation SYSTEMS shall implement the Multiprotocol Border Gateway Protocol (MBGP) as specified in RFC-2858.	X	X	X	
C3I-655	Constellation SYSTEMS shall implement the Multicast Listener Discovery protocol, version 2, as specified in RFC-3810 <TBR 3-24>.		X	X	This protocol is required to join end systems to multicast groups in IPv6.

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-656	Constellation SYSTEMS shall implement Multicast Extension to OSPF as specified in RFC-1584.	X			MOSPF is IPv4 specific.
C3I-657	Constellation SYSTEMS shall implement the Internet Group Management Protocol (IGMP) as specified in RFC-3376.	X			This protocol is required to join end systems to multicast groups in IPv4.
3.3.2	***Dynamic Routing Between Systems***				***Compliance with this section is required for interoperable IP network dynamic routing between LSAM and MS, GS (testing),, CEV, and CaLV. This requirement is phased for Lunar Sortie.***
C3I-82	Constellation SYSTEMS shall implement RFC-2453, STD-0056 - RIP Version 2.	X			
C3I-83	Constellation SYSTEMS shall implement RFC-2328 (STD-0054), OPEN SHORTEST PATH FIRST (OSPF) Version 2.	X			
C3I-295	Constellation SYSTEMS shall implement RFC-3626 Optimized Link State Routing Protocol (OLSR).		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
C3I-662	Constellation SYSTEMS shall implement RFC-2080, RIPng for IPv6 .		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
C3I-663	Constellation SYSTEMS shall implement RFC-2740 , OSPF for IPv6.		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
3.3.3	***External Connectivity***				***The LSAM does not interface with external networks.***
C3I-81	Constellation SYSTEMS shall implement RFC-4271-A BORDER GATEWAY PROTOCOL (BGP) Version 4, as specified in RFC4271 "A BORDER GATEWAY PROTOCOL 4 (BGP-4)				
C3I-280	Constellation SYSTEMS shall				

Section/ Req #	Section/Requirement	Phasing ISS	Sortie	Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
	use external routes learned by Border Gateway Protocol Version 4, as specified in RFC4271 "A Border Gateway Protocol 4 (BGP-4), before those learned via other dynamic routing protocols.				
3.3.4	***Name Service***				***Compliance with this section is required for IP network name services used for network communications between LSAM and MS, GS (testing), CEV, EVA or CaLV. This is required to reduce systems management overhead associated with IP address management.***
C3I-296	Constellation SYSTEMS shall implement IETF STD-0013, Domain Name SYSTEM.	X	X	X	
3.3.5	***Disruption Tolerance***				***Compliance with this section is required to enable efficient communications during delayed or intermittent communications (especially through intermittent multi-hop communications paths). This is required for interoperable DTN communications between LSAM and MS, EVA/surface systems, and CEV. Note that this section is phased in at Lunar Sortie.***
C3I-107	Constellation SYSTEMS shall implement <TBR 3-12> DTN, DELAY/DISRUPTION TOLERANT NETWORKING Specifications, http://www.ietf.org/internet-drafts/draft-irtf-dtnrg-bundle-spec-05.txt.		X	X	
3.3.6	***Dynamic Address Assignment***				***Compliance with this section is required to supportthe connection of EVA or surface systems to the LSAM.***
C3I-67	Constellation SYSTEMS shall implement the DYNAMIC HOST CONFIGURATION	X	X	X	Support for mobile IP end-points such as suits, laptops, and hand-helds.

Section/ Req #	Section/Requirement	Phasing ISS	Phasing Sortie	Phasing Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
	PROTOCOL (DHCP) Server functions as specified in RFC-2131 and updated by RFC-4361.				
3.3.7	***Dynamic Address Retrieval***				***Compliance with this section is not required since the LSAM does not dynamically connect to multiple network segments.***
C3I-69	Constellation SYSTEMS shall obtain network addresses via the DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP) as specified in RFC-2131 and updated by RFC-4361.				
C3I-70	Constellation SYSTEMS shall 'self-assign' an IP address from the 169.254.0.0/16 private address block as specified in RFC-3927, Dynamic Configuration of IPv4 Link-Local Addresses of IPv4 interfaces when unable to obtain an IP address from pre-configuration information and/or DHCP.				
3.3.8	***Tunneling***				***Compliance with this section is required for network tunneling on interfaces between LSAM and MS, CEV, EVA/surface systems, and C&T Networks. Tunneling is necessary to support Mobile IP and allows controllers to perform traffic engineering and to force traffic to follow particular paths in the network that are different from the routes that might be 'default' or learned via dynamic routing protocols.***
C3I-92	Constellation SYSTEMS shall implement RFC-2784, GENERIC ROUTING ENCAPSULATION (GRE).	X			
C3I-664	Constellation SYSTEMS shall implement RFC-2473, Generic		X	X	IPv6 version for Lunar Missions

Section/ Req #	Section/Requirement	Phasing ISS	Phasing Sortie	Phasing Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
	Packet Tunneling in IPv6 Specification.				
3.3.9	***Header Compression***				***Compliance with this section is required for interoperable communications between LSAM and GS (test), CEV, EVA/surface systems, CaLV (EDS) or C&T Networks over low bandwidth links.***
C3I-307	Constellation SYSTEMS shall implement RFC-2507 IP Header Compression.	X	X	X	
C3I-588	Constellation SYSTEMS shall implement RFC 2508 Compressing IP/UDP/RTP Headers for Low-Speed Serial Links.	X	X	X	
3.3.10	***Network Management***				***Compliance with this section is required for network management interfaces between LSAM and MS, GS (test), EVA/surface systems, CaLV (EDS) or C&T Networks.***
C3I-100	Constellation SYSTEMS shall implement RFC-4293 Management Information Base for the Internet Protocol (IP).	X	X	X	
C3I-294	Constellation SYSTEMS shall implement RFC-4292, IP Forwarding Table MIB.	X	X	X	
C3I-298	Constellation SYSTEMS shall implement RFC-3747, Differentiated Services Configuration MIB.	X	X	X	
C3I-299	Constellation SYSTEMS shall implement RFC-3289, MIB for the Differentiated Services Architecture.	X	X	X	
C3I-300	Constellation SYSTEMS shall implement RFC-2213, Integrated Services Management Information Base using SMIv2.	X	X	X	
C3I-301	Constellation SYSTEMS shall implement RFC-4022, Management Information Base	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	for TRANSMISSION CONTROL PROTOCOL (TCP).				
C3I-302	Constellation SYSTEMS shall implement RFC-4113, Management Information Base for USER DATAGRAM PROTOCOL (UDP).	X	X	X	
C3I-303	Constellation SYSTEMS shall implement RFC-2959, Real Time Protocol MIB.	X	X	X	
3.4	**Security**				***Compliance with this section is required for secure, interoperable communications between LSAM and MS, GS (test) , CEV, EVA/surface systems, and CaLV (EDS).***
3.4.1	***Network Layer Security***				
C3I-199	Constellation SYSTEMS shall implement RFC 4301, Security architecture for the Internet Protocol, at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-200	Constellation SYSTEMS shall implement RFC-4302, IP AUTHENTICATION HEADER (AH), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-201	Constellation SYSTEMS shall implement RFC-4303, IP ENCAPSULATING SECURITY PAYLOAD (ESP), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-204	Constellation SYSTEMS shall implement RFC 4305, Cryptographic Algorithm Implementation Requirements for Encapsulating Security Payload (ESP) and Authentication Header (AH), at all Internet Protocol (IP) based	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	inter-SYSTEM data exchange interfaces.				
C3I-565	Constellation SYSTEMS shall implement RFC 4309, Using Advanced Encryption Standard (AES) CCM Mode with IPsec Encapsulating Security Payload (ESP), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
3.4.2	***Internet Key Exchange***				
C3I-209	Constellation SYSTEMS shall implement RFC-4306, The INTERNET KEY EXCHANGE (IKEv2), for all inter-SYSTEM management of security associations and keys used by IPSec.	X	X	X	
C3I-568	Constellation SYSTEMS shall implement RFC-4307, Cryptographic Algorithms for use in the Internet Key Exchange Version 2 (IKEv2).	X	X	X	
3.4.3	***Application Layer Security***				
C3I-210	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for inter-SYSTEM updates of security processing logic.	X	X	X	
C3I-566	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Protocol Specification for all inter-system exchanges of the security policy information used by application layer security functions.				
C3I-567	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification and described in the for all inter-SYSTEM exchanges of the identity data used by application layer security functions.	X	X	X	
C3I-569	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for all inter-SYSTEM exchanges of the authentication keys and encryption keys used by application layer security functions.	X	X	X	
3.4.4	***FIPS Compliant Algorithms***				
C3I-203	Constellation SYSTEMS shall implement FIPS PUB 197, ADVANCED ENCRYPTION STANDARD (AES), for all ENCRYPTION of inter-SYSTEM data exchanges.	X	X	X	
C3I-206	Constellation SYSTEMS shall implement SHA-1 per FIPS PUB 180-2, Secure Hash Standard, for hash generation	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	performed for inter-SYSTEM data exchanges.				
C3I-207	Constellation SYSTEMS shall implement FIPS PUB 186-2, DIGITAL SIGNATURE STANDARD (DSS) using the DIGITAL SIGNATURE ALGORITHM (DSA) for all digital signatures exchanged between SYSTEMS.	X	X	X	
C3I-208	Constellation SYSTEMS shall implement FIPS PUB 198, Keyed-HASH MESSAGE AUTHENTICATION CODE (HMAC), for all MESSAGE AUTHENTICATION CODES (MACs) exchanged between SYSTEMS.	X	X	X	
C3I-665	Constellation SYSTEMS shall implement SHA-256 per FIPS PUB 180-2, Secure Hash Standard, for hash generation performed for inter-SYSTEM data exchanges.	X	X	X	
C3I-666	Constellation SYSTEMS shall implement truncation of SHA-1 based 160-bit Hash Based Messaged Authentication Codes (HMACs) to 96 bits.	X	X	X	
C3I-667	Constellation SYSTEMS shall implement truncation of SHA-256 based 256-bit Hash Based Messaged Authentication Codes (HMACs) to 128 bits.	X	X	X	
3.5	**Data Exchange**				
3.5.1	***Voice Exchange***				***Compliance with this section is required for interoperable voice communications between LSAM and MS, GS (test), CEV, and EVA/surface systems.***
C3I-173	Constellation SYSTEMS shall assign a delivery priority to voice data sent to another SYSTEM.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-175	Constellation SYSTEMS shall transfer voice data over a one way link.	X	X	X	
C3I-176	Constellation SYSTEMS shall use ITU G.729, "Coding of speech at 8 kbit/s using conjugate-structure algebraic-code-excited linear prediction (CS-ACELP)".	X	X	X	
C3I-555	Constellation SYSTEMS shall transfer voice in accordance with IETF RFC 3550, Real-Time Transport Protocol (RTP).	X	X	X	
C3I-557	Constellation SYSTEMS shall provide a mechanism to add voice codecs.	X	X	X	
C3I-558	Constellation SYSTEMS shall provide a mechanism to remove voice codecs.	X	X	X	
3.5.2	***Motion Imagery Transfer***				***Compliance with this section is required for interoperable motion imagery transfer between LSAM and MS, GS (test), CEV, EVA/surface systems, and CaLV (EDS).***
C3I-184	Constellation SYSTEMS shall assign a delivery priority for motion imagery data sent to another SYSTEM.	X	X	X	
C3I-185	Constellation SYSTEMS shall transfer motion imagery over a one way link.	X	X	X	
C3I-186	Constellation SYSTEMS shall use ITU H.264, "Advanced Video Coding for Generic Audiovisual Services".	X	X	X	
C3I-283	Constellation SYSTEMS shall transfer motion imagery in accordance with RFC 3550, Real-Time Transport Protocol (RTP).	X	X	X	
C3I-559	Constellation SYSTEMS shall use <TBR 3-13> ISO/IEC 15444-3, "Motion JPEG 2000	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	(Part 3)".				
C3I-560	Constellation SYSTEMS shall provide a mechanism to add MOTION IMAGERY codecs.	X	X	X	
C3I-561	Constellation SYSTEMS shall provide a mechanism to remove MOTION IMAGERY codecs.	X	X	X	
3.5.3	***Data Exchange Message Formatting and Transmission***				***Compliance with this section is required for interoperable message exchange between LSAM and GS (tests), CEV, EVA/surface systems, and CaLV (EDS).***
C3I-130	Constellation SYSTEMS shall transfer data exchange messages over a one way link.	X	X	X	
C3I-135	Constellation SYSTEMS shall use a common data exchange message format as defined in Appendix C of CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5:	X	X	X	
C3I-659	Constellation SYSTEMS shall assign to each data exchange message that is sent to another SYSTEM the priority that was assigned to the Data of that data exchange message.	X	X	X	
3.5.4	***File Transfer***				***Compliance with this section is required for interoperable file transfer between LSAM and MS, GS (test), CEV, EVA/surface systems, and CaLV.***
C3I-161	Constellation SYSTEMS shall assign a delivery priority to each file sent to another SYSTEM.	X	X	X	
C3I-165	Constellation SYSTEMS shall transfer files in accordance with CCSDS 727.0-B-3, "CCSDS File Delivery Protocol (CFDP) – Recommended Standard".	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
3.5.5	***Time Exchange***				***Compliance with this section is required for time exchange/sync interfaces between LSAM and C&T Networks, GS (test), CEV, EVA/surface systems, and CaLV (EDS).***
C3I-111	Constellation SYSTEMS shall exchange time in accordance with IETF RFC 1305, NETWORK TIME PROTOCOL (NTP) Version 3.	X	X	X	
3.5.6	***Traffic Prioritization***				
C3I-660	Constellation SYSTEMS shall effect observance of the delivery priorities assigned to voice data, motion imagery data, data exchange messages, and files by invoking traffic prioritization mechanisms provided by the underlying network.	X	X	X	
3.6	**Information**				
3.6.1	***Basic Information Definition***				***Compliance with this section is required for interoperable information definition for information exchanged between LSAM and MS, GS (test), CEV, EVA/surface systems, and CaLV (EDS).***
C3I-119	Constellation SYSTEMS shall use common COMMAND METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-140	Constellation SYSTEMS shall use common telemetry METADATA as defined by the CxP 70022, Constellation Command, Control,	X	X	X	

Phasing					
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.				
C3I-157	Constellation SYSTEMS shall use a common convention for file formats as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3.	X	X	X	
C3I-169	Constellation SYSTEMS shall use common voice METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-180	Constellation SYSTEMS shall use common motion imagery METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-228	Constellation SYSTEMS shall use data types as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and	X	X	X	

		Phasing			
Section/ Req #	Section/Requirement	ISS	Sortie	Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
	Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3.				
C3I-229	Constellation SYSTEMS shall exchange METADATA that complies with the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-231	Constellation SYSTEMS shall use Universal Resource Indicators (URIs) and namespace constructs using conventions described in RFC3986.	X	X	X	
C3I-355	Constellation SYSTEMS shall use a hierarchical addressing structure as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-357	Constellation SYSTEMS shall use a common file naming convention as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Sec 3.3.	X	X	X	
C3I-366	Constellation SYSTEMS shall issue inter-SYSTEM	X	X	X	

Phasing					
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	COMMANDS in the format defined by the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Sec 3.8.				
C3I-544	Constellation SYSTEMS shall exchange application layer security policies between SYSTEMS in a representation that complies with CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-545	Constellation SYSTEMS shall exchange application layer cryptographic keys between SYSTEMS in a representation that complies with the CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-546	Constellation SYSTEMS shall exchange application layer identity information between SYSTEMS in a representation that complies with CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-652	Constellation SYSTEMS shall exchange application layer security audit data between SYSTEMS in a representation	X	X	X	

Phasing					
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	that complies with the CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume				
C3I-661	Constellation Systems shall define METADATA that complies with the CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
3.6.2	***Adaptive Information Definition***				***Compliance with this section is required for more adaptive (ad-hoc) interoperable information definition for information exchanged between LSAM and MS, GS (test), CEV, EVA/surface systems, CaLV (EDS). Note that this functionality is not phased in until lunar sortie.***
C3I-215	Constellation SYSTEMS shall define TELEMETRY processing algorithms in accordance with CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-222	Constellation SYSTEMS shall use a hierarchical naming scheme in accordance with the CXP-70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information		X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Representation Specification.				
C3I-547	Constellation SYSTEMS shall request data using data identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-548	Constellation SYSTEMS shall request files using file identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27>of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-549	Constellation SYSTEMS shall construct requests for data using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR) Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-550	Constellation SYSTEMS shall construct requests for file submissions and retrievals using		X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	a protocol defined in the NExIOM & C3I System Of Registries (NCSOR) Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.				

Table Appendix E-4 - C3I Interoperability Requirements Applicability to CaLV

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
3.1	**RF Communication**				
3.1.1	***Common RF Communication***				***Compliance with this section is required for interoperable communications between CaLV and GS (test), CEV, and C&T Networks.***
C3I-3	Constellation SYSTEMS shall comply with spectrum selection/allocation, certification and usage restriction policies set forth in NASA Policy Directive (NPD) 2570.5D, NASA Electromagnetic (EM) Spectrum Management.	X	X	X	
C3I-5	Constellation SYSTEMS shall use transmit/receive frequency assignments and spectrum characteristics as defined in CxP 70022 Constellation Command, Control, Communications and	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Information (C3I) Interoperability Standards Book, Volume 2: Constellation Spectrum and Channel Plan.				
C3I-584	Constellation SYSTEMS shall comply with radio frequency allocation and conditions of assignment for frequency spectrum usage approved by the National Telecommunications & Information Administration (NTIA).	X	X	X	
3.1.2	**Operational Pt-to-Pt RF Communication**				***Compliance with this section is required for interoperable communications between CaLV and GS (test), CEV, and C&T Networks.***
3.1.2.1	***Common Operational Pt-to-Pt RF Communication***				***Compliance with this section is required to support the Operational Point-to-Point Communication link class.***
C3I-6	Constellation SYSTEMS shall transmit using LEFT-HAND CIRCULAR POLARIZATION for operational point-to-point links.	X	X	X	
C3I-7	Constellation SYSTEMS shall receive using LEFT-HAND CIRCULAR POLARIZATION for operational point-to-point links.	X	X	X	
C3I-11	Constellation SYSTEMS shall communicate using at least two independent transmit/receive frequency pairs within the near Earth S-band spectrum allocation for multi-SYSTEM, simultaneous operational point-to-point communications.	X	X	X	
C3I-22	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	specified by CCSDS 131.1.O-1, Section 3 to transmit data streams for operational point-to-point links.				
C3I-23	Constellation SYSTEMS shall use bit randomization techniques in accordance with CCSDS 131.0-B-1 for randomization of transmitted data streams for operational point-to-point links.	X	X	X	
C3I-590	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3 for decoding received data streams using FORWARD ERROR CORRECTION for operational point-to-point links.	X	X	X	
C3I-592	Constellation SYSTEMS shall use bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-randomization of received data streams for operational point-to-point links.	X	X	X	
C3I-594	Constellation SYSTEMS shall apply the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 as specified in CCSDS 131.1-O-1, Section 3.5 transmitted FEC code block frames for operational point-to-point links.	X	X	X	
C3I-596	Constellation SYSTEMS shall comply with the specifications for service access points as defined in section 3 of the AOS Space Data Link Protocol 732.0.B-2 for reception of Multiprotocol Interconnect over Frame Relay using the CCSDS	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	AOS Virtual Channel Access (VCA) service over operational point-to-point links.				
C3I-612	Constellation SYSTEMS shall transmit Multiprotocol Interconnect over Frame Relay (MPoFR) as serial octet-aligned streams per CCSDS recommendation "IP over CCSDS Space Links", CCSDS 702.1-R-1, using the Virtual Channel Access (VCA) service of CCSDS Advanced Orbiting Systems (AOS) Space Link Protocol as specified in CCSDS 732.0-B-2 for operational point-to-point links.	X	X	X	
C3I-653	Constellation SYSTEMS shall enable and disable communication link forward error correction (FEC) upon receipt of COMMAND for operational point-to-point links.	X	X	X	
C3I-668	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for transmission of IP packets for operational point-to-point links.	X	X	X	
C3I-669	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for reception of IP packets for operational point-to-point links.	X	X	X	
C3I-670	Constellation SYSTEMS shall use the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 for synchronization of received FEC code block frames as specified in CCSDS 131.1-O-1 for operational point-to-point links.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-671	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for transmission of non-FEC coded data streams for operational point-to-point links.	X	X	X	
C3I-672	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for resolution of symbol phase ambiguity of non-FEC coded data streams for operational point-to-point links.	X	X	X	
3.1.2.2	***Point A Operational Pt-to-Pt RF Communication***				***Compliance with this section is required to support the Point A Role in communication while using the Operational Point-to-Point Communication link. CaLV assumes the Point A Role to support its telemetry downlink during ascent.***
C3I-308	Constellation point A SYSTEMS shall coherently re-transmit the received carrier with a turn-around ratio of 240/221(transmit/receive) for coherent point-to-point link operation.	X	X	X	
C3I-314	Constellation point A SYSTEMS shall coherently re-transmit the received range channel data to point B SYSTEM.	X	X	X	
C3I-350	Constellation point A SYSTEMS shall provide a non-coherent mode of operation for operational point-to-point links.	X	X	X	
C3I-573	Constellation point A SYSTEMS shall use transmit signals with modulation schemes in accordance with Table 3.1-2 for operational point-to-point links.	X	X	X	
C3I-574	Constellation point A SYSTEMS shall receive signals with modulation schemes in	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	accordance with Table 3.1-3 for operational point-to-point links.				
C3I-633	Constellation point A SYSTEMS shall transmit independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 (DG1).	X	X	X	
3.1.2.3	***Point B Operational Pt-to-Pt RF Communication***				***No current requirement for CaLV to act as the Point B Role for this class of communication.***
C3I-315	Constellation point B SYSTEMS shall process the coherent turn-around carrier to make radiometric measurements of range rate data (two-way Doppler data) for operational point-to-point links.				
C3I-572	Constellation point B SYSTEMS shall process coherent turn-around ranging channel data to provide radiometric measurements of range data for operational point-to-point links.				
C3I-575	Constellation point B SYSTEMS shall transmit signals with modulation schemes in accordance with Table 3.1-3 for operational point-to-point links.				
C3I-576	Constellation point B SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-2 for operational point-to-point links.				
C3I-591	Constellation Point B SYSTEMS shall generate and modulate the range channel (Q channel) with the Forward Link Range Channel PN code as defined in the Space Network Interoperable PN Code Libraries, Rev. 1 (451-PN				

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	CODE-SNIP).				
C3I-634	Constellation point B SYSTEMS shall receive independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 (DG1).				
3.1.3	**High-Rate Pt-to-Pt RF Communication**				***CaLV does not have high rate RF links required.***
3.1.3.1	***Common High Rate RF Communication***				***No current requirement for this class of communications on CaLV.***
C3I-30	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3, to transmit data streams for high rate point-to-point links.				
C3I-31	Constellation SYSTEMS shall use bit randomization techniques in accordance with CCSDS 131.0-B-1 for randomization of transmitted data streams for high rate point-to-point links.				
C3I-581	Constellation SYSTEMS shall transmit using Right-hand Circular polarization for high rate point-to-point links.				
C3I-583	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3, for decoding of received data streams using FEC for high rate point-to-point links.				
C3I-589	Constellation SYSTEMS shall receive using Right-hand Circular polarization for high-				

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	rate point-to-point links.				
C3I-598	Constellation SYSTEMS shall use bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-randomization of received data streams for high rate point-to-point links.				
C3I-600	Constellation SYSTEMS shall apply the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 as specified in CCSDS 131.1-O-1, Section 3.5, to transmit FEC code blocks for high rate point-to-point links.				
C3I-601	Constellation SYSTEMS shall comply with the specifications for service access points as defined in section 3 of AOS Space Data Link Protocol 732.0.B-2 for reception of Multiprotocol Interconnect over Frame Relay using the CCSDS AOS Virtual Channel Access service over high rate point-to-point links.				
C3I-603	Constellation SYSTEMS shall transmit Multiprotocol Interconnect over Frame Relay (MPoFR) as serial octet-aligned streams per CCSDS recommendation “IP over CCSDS Space Links”, CCSDS 702.1-R-1, using the Virtual Channel Access (VCA) service of CCSDS Advanced Orbiting Systems (AOS) Space Link Protocol as specified in CCSDS 732.0-B-2 for High Rate point-to-point links.				
C3I-632	Constellation SYSTEMS shall enable and disable communication link forward				

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	error correction (FEC) upon receipt of COMMAND for high rate point-to-point links.				
C3I-673	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for transmission of IP packets for high rate point-to-point links.				
C3I-674	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for reception of IP packets for high rate point-to-point links.				
C3I-675	Constellation SYSTEMS shall use the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 for synchronization of received FEC code block frames as specified in CCSDS 131.1-O-1 for high rate point-to-point links.				
C3I-676	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for transmission of non-FEC coded data streams for high rate point-to-point links.				
C3I-677	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for resolution of symbol phase ambiguity of non-FEC coded data streams for high rate point-to-point links.				
3.1.3.2	***Point A High-rate Pt-to-Pt RF Communication***				***No current requirement for this class of communications on CaLV.***
C3I-577	Constellation point A SYSTEMS shall use transmit signals with modulation schemes in accordance with Table 3.1-4 for high rate point-to-point links.				

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C3I-578	Constellation point A SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-5 for high rate point-to-point links.				
3.1.3.3	***Point B High-rate Pt-to-Pt RF Communication***				***No current requirement for this class of communications on CaLV.***
C3I-579	Constellation point B SYSTEMS shall transmit signals with modulation schemes in accordance with Table 3.1-5 for high rate point-to-point links.				
C3I-580	Constellation point B SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-4 for high rate point-to-point links.				
3.1.4	***Multipoint Proximity RF Communication***				***CaLV does not have a requirement to support multipoint proximity RF communication.***
	RESERVED				
3.1.5	**Recovery RF Communication**				***CaLV does not have a requirement to support recovery RF communication since it is not recovered.***
3.1.5.1	***Common Recovery RF Communication***				
C3I-347	Constellation SYSTEMS shall transmit to the COSPAS/SARSAT system using the spectrum guidelines provided by ITU-R Recommendation M.633.				
C3I-362	Constellation SYSTEMS shall use amplitude modulation (AM) for analog voice communication with US and international search and rescue forces.				
C3I-363	Constellation SYSTEMS shall transmit to the COSPAS/SARSAT system per				

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	COSPAS/SARSAT document C/S T.001 Sections 2 and 3.				
C3I-678	Constellation SYSTEMS shall use narrowband frequency modulation (FM) for analog voice communication with US and international maritime search and rescue forces.				
C3I-679	Constellation SYSTEMS shall communicate using the US UHF SATCOM system per MIL-STD-188-181.				
3.1.6	**RF Contingency Voice Communication**				***CaLV does not have a requirement to support voice communication.***
3.1.6.1	***Common RF Contingency Voice Communication***				
C3I-385	Constellation SYSTEMS shall modulate the transmitted carrier using amplitude modulation for analog, half-duplex Contingency Voice links.				
C3I-680	Constellation SYSTEMS shall receive an amplitude modulated carrier for Contingency Voice links.				
3.1.7	**Future High Rate Link Class**				
	RESERVED	TBD	TBD	TBD	
3.1.8	**Vehicle Internal Wireless Link Class**				
C3I-681	Constellation SYSTEMS shall use IEEE 802.11g on non-critical internal local area wireless data networks.				
3.2	**Hard-Line Communication**				
3.2.1	***High-Rate, Hard-Line Communication***				***Compliance with this section is required for interoperable hard-line communications between CaLV and GS (test), and LSAM.***

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C3I-58	Constellation SYSTEMS shall use IEEE Std 1394b™-2002 and SAE-AS5643/1 with RFC-2734 for high data volume, hard-line connections between Constellation SYSTEMS.	X	X	X	
3.2.2	***High-Rate, Ground Hard-Line Communication***				
C3I-336	Constellation SYSTEMS shall use ground institutional IP routed networks.	X	X	X	
3.2.3	***Deterministic Hard-Line Communication***				***Compliance with this section is pending determination of any need for any interfaces requiring deterministic closed-loop control with LSAM <TBD E-10> (joint control) , and GS <TBD E-11> (servicing).***
C3I-682	Constellation SYSTEMS shall use SAE-AS5643 and AS5643/1 standards for deterministic rate based hard-line connections between Constellation SYSTEMS.	X	X	X	
3.3	**Network**				
3.3.1	***Connectivity***				***Compliance with this section is required for interoperable IP network communications between CaLV and GS (test), MS, LSAM, CEV or C&T Networks.***
C3I-61	Constellation SYSTEMS shall implement version 4 of the Internet Protocol (IPv4) as specified in STD-0005.	X			IPv4 is for ISS Missions only.
C3I-62	Constellation SYSTEMS shall use unicast addresses as defined in RFC-1918, Address Allocation for Private Internets.	X			IPv4 is for ISS Missions only.
C3I-63	Constellation SYSTEMS shall use multicast addresses as defined in RFC-3171, IANA Guidelines for IPv4 Multicast	X			IPv4 is for ISS Missions only.

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	Address Assignments.				
C3I-64	Constellation SYSTEMS shall provide a mechanism to manually configure the addresses of all IP-addressable interfaces.	X	X	X	
C3I-72	Constellation SYSTEMS shall provide IP network address to data link layer address mappings for IP addresses external to the SYSTEM.	X	X	X	
C3I-73	Constellation SYSTEMS shall use managed associations to map IP addresses to data link layer addresses for IP addresses external to the SYSTEM.	X	X	X	
C3I-74	Constellation SYSTEMS shall accept modifications to the IP address to data-link layer address mapping information via the network for IP addresses external to the SYSTEM.	X	X	X	
C3I-75	Constellation SYSTEMS shall perform multi-hop routing as specified in RFC-1812, Requirements for IP Version 4 Routers as updated by RFC-2644.	X			IPv4 is for ISS Missions only.
C3I-76	Constellation SYSTEMS shall comply with RFC-1122 (STD-0003), Requirements for Internet Hosts – Communications Layers.	X			IPv4 is for ISS Missions only.
C3I-78	Constellation SYSTEMS shall use manually configured routes instead of dynamically learned ones when there is an exact match in the prefix length for a given destination external to the SYSTEM.	X	X	X	
C3I-79	Constellation SYSTEMS shall use static routing table entries.	X	X	X	

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C3I-80	Constellation SYSTEMS shall accept changes to the routing tables via the network.	X	X	X	
C3I-87	Constellation SYSTEMS shall advertise only non-default routes via the routing protocols.	X	X	X	
C3I-89	Constellation SYSTEMS shall have a default route specified in the routing tables.	X	X	X	
C3I-90	Constellation SYSTEMS shall fail over to default routes when there is a loss of all routing information or a loss of communication to all SYSTEM network neighbors participating in the dynamic routing protocol for more than 20 seconds.	X	X	X	
C3I-93	Constellation SYSTEMS shall resolve symbolic names to IP addresses using static host table.	X	X	X	
C3I-95	Constellation SYSTEMS shall accept changes to the static host table via the network.	X	X	X	
C3I-96	Constellation SYSTEMS shall implement RFC-2474, Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers.	X	X	X	
C3I-97	Constellation SYSTEMS shall implement RFC-2211, Specification of the Controlled-Load Network System Service.	X	X	X	
C3I-98	Constellation SYSTEMS shall implement <TBR 3-25> RFC-2205, Resource ReSerVation Protocol (RSVP) Version 1 Functional Specification.	X	X	X	
C3I-99	Constellation SYSTEMS shall implement the Simple Network Management Protocol version 3	X	X	X	

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	as defined in STD0062.				
C3I-103	Constellation SYSTEMS shall implement Internet STD-0007: TRANSMISSION CONTROL PROTOCOL (TCP).	X	X	X	
C3I-104	Constellation SYSTEMS shall implement RFC-1323 - TCP Extensions for High Performance.	X	X	X	
C3I-105	Constellation SYSTEMS shall implement STD-0006 - UDP, USER DATAGRAM PROTOCOL, for communication with all IP-addressable endpoints.	X	X	X	
C3I-106	Constellation SYSTEMS shall implement RFC-3550 (STD-0064), RTP: A Transport Protocol for Real-Time Applications.	X	X	X	
C3I-281	Constellation SYSTEMS shall implement RFC-3140, Per Hop Behavior Identification Codes.	X	X	X	
C3I-282	Constellation SYSTEMS shall implement RFC-3246, An Expedited Forwarding PHB (PER HOP BEHAVIOR).	X	X	X	
C3I-619	Constellation SYSTEMS shall implement a split-connection TCP Performance Enhancing Proxy (PEP) that implements the SCPS-TP transport layer per CCSDS 714.0.B-1, Space Communications Protocol Specification (SCPS) - Transport Protocol (SCPS-TP), Blue Book, Issue 1, May 1999, on links where the maximum bandwidth*delay product of the link exceeds 1e6 bits and/or whose design bit error rate is equal to or greater than 1e-6.	X	X	X	

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C3I-620	Constellation SYSTEMS shall implement Internet Protocol version 6 (IPv6) per RFC 2460 Internet Protocol, Version 6 (IPv6) Specification.		X	X	IPv6 Lunar Missions
C3I-621	Constellation SYSTEMS shall implement the Internet Control Messaging Protocol (ICMP) per RFC 792, Internet Control Message Protocol.	X			IPv4 Lunar Missions
C3I-622	Constellation SYSTEMS shall implement the Internet Control Messaging Protocol version 6 (ICMPv6) per RFC 4443 Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification.		X	X	IPv6 Lunar Missions
C3I-654	Constellation SYSTEMS shall implement the Multiprotocol Border Gateway Protocol (MBGP) as specified in RFC-2858.	X	X	X	
C3I-655	Constellation SYSTEMS shall implement the Multicast Listener Discovery protocol, version 2, as specified in RFC-3810 <TBR 3-24>.		X	X	This protocol is required to join end systems to multicast groups in IPv6.
C3I-656	Constellation SYSTEMS shall implement Multicast Extension to OSPF as specified in RFC-1584.	X			MOSPF is IPv4 specific.
C3I-657	Constellation SYSTEMS shall implement the Internet Group Management Protocol (IGMP) as specified in RFC-3376.	X			This protocol is required to join end systems to multicast groups in IPv4.
3.3.2	***Dynamic Routing Between Systems***				***Compliance with this section is required for interoperable IP network dynamic routing between CaLV and MS, GS (test), LSAM, and CEV. This requirement is phased for Lunar Sortie.***
C3I-82	Constellation SYSTEMS shall implement RFC-2453, STD-	X			

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	0056 - RIP Version 2.				
C3I-83	Constellation SYSTEMS shall implement RFC-2328 (STD-0054), OPEN SHORTEST PATH FIRST (OSPF) Version 2.	X			
C3I-295	Constellation SYSTEMS shall implement RFC-3626 Optimized Link State Routing Protocol (OLSR).		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
C3I-662	Constellation SYSTEMS shall implement RFC-2080, RIPng for IPv6 .		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
C3I-663	Constellation SYSTEMS shall implement RFC-2740 , OSPF for IPv6.		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
3.3.3	***External Connectivity***				***The CaLV does not interface with external networks.***
C3I-81	Constellation SYSTEMS shall implement RFC-4271-A BORDER GATEWAY PROTOCOL (BGP) Version 4, as specified in RFC4271 "A BORDER GATEWAY PROTOCOL 4 (BGP-4)				
C3I-280	Constellation SYSTEMS shall use external routes learned by Border Gateway Protocol Version 4, as specified in RFC4271 “A Border Gateway Protocol 4 (BGP-4), before those learned via other dynamic routing protocols.				
3.3.4	***Name Service***				***Compliance with this section is required for IP network name services used for network communications between CaLV and GS (test), CEV, LSAM, and C&T Networks. This is required to reduce systems management overhead associated with IP address management.***
C3I-296	Constellation SYSTEMS shall	X	X	X	

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	implement IETF STD-0013, Domain Name SYSTEM.				
3.3.5	***Disruption Tolerance***				***Compliance with this section is required to enable efficient communications during delayed or intermittent communications (especially through intermittent multi-hop communications paths). This is required for interoperable DTN communications between CaLV (EDS) and MS, CEV, and LSAM. Note that this section is phased in at Lunar Sortie.***
C3I-107	Constellation SYSTEMS shall implement <TBR 3-12> DTN, DELAY/DISRUPTION TOLERANT NETWORKING Specifications, http://www.ietf.org/internet-drafts/draft-irtf-dtnrg-bundle-spec-05.txt.		X	X	
3.3.6	***Dynamic Address Assignment***				***Compliance with this section is pending determination of any need for GS GSE interfaces with CaLV <TBD E-12> that would require dynamic address assignment.***
C3I-67	Constellation SYSTEMS shall implement the DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP) Server functions as specified in RFC-2131 and updated by RFC-4361.	X	X	X	Support for mobile IP end-points such as suits, laptops, and hand-helds.
3.3.7	***Dynamic Address Retrieval***				***Compliance with this section is not required since the CaLV (EDS) does not dynamically connect to multiple network segments.***
C3I-69	Constellation SYSTEMS shall obtain network addresses via the DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP) as specified in RFC-2131 and				

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	updated by RFC-4361.				
C3I-70	Constellation SYSTEMS shall 'self-assign' an IP address from the 169.254.0.0/16 private address block as specified in RFC-3927, Dynamic Configuration of IPv4 Link-Local Addresses of IPv4 interfaces when unable to obtain an IP address from pre-configuration information and/or DHCP.				
3.3.8	***Tunneling***				***Compliance with this section is required for network tunneling on interfaces between CaLV (EDS) and MS, LSAM, CEV or GS (test). Tunneling is necessary to support Mobile IP and allows controllers to perform traffic engineering and to force traffic to follow particular paths in the network that are different from the routes that might be 'default' or learned via dynamic routing protocols.***
C3I-92	Constellation SYSTEMS shall implement RFC-2784, GENERIC ROUTING ENCAPSULATION (GRE).	X			
C3I-664	Constellation SYSTEMS shall implement RFC-2473, Generic Packet Tunneling in IPv6 Specification.		X	X	IPv6 version for Lunar Missions
3.3.9	***Header Compression***				***Compliance with this section is required for test and checkout of compressed network communications between CaLV (EDS) and C&T Networks or CEV over low bandwidth links.***
C3I-307	Constellation SYSTEMS shall implement RFC-2507 IP Header Compression.	X	X	X	
C3I-588	Constellation SYSTEMS shall implement RFC 2508 Compressing IP/UDP/RTP Headers for Low-Speed Serial	X	X	X	

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	Links.				
3.3.10	***Network Management***				***Compliance with this section is required for network management interfaces between CaLV and MS, GS (test), CEV, and LSAM.***
C3I-100	Constellation SYSTEMS shall implement RFC-4293 Management Information Base for the Internet Protocol (IP).	X	X	X	
C3I-294	Constellation SYSTEMS shall implement RFC-4292, IP Forwarding Table MIB.	X	X	X	
C3I-298	Constellation SYSTEMS shall implement RFC-3747, Differentiated Services Configuration MIB.	X	X	X	
C3I-299	Constellation SYSTEMS shall implement RFC-3289, MIB for the Differentiated Services Architecture.	X	X	X	
C3I-300	Constellation SYSTEMS shall implement RFC-2213, Integrated Services Management Information Base using SMIv2.	X	X	X	
C3I-301	Constellation SYSTEMS shall implement RFC-4022, Management Information Base for TRANSMISSION CONTROL PROTOCOL (TCP).	X	X	X	
C3I-302	Constellation SYSTEMS shall implement RFC-4113, Management Information Base for USER DATAGRAM PROTOCOL (UDP).	X	X	X	
C3I-303	Constellation SYSTEMS shall implement RFC-2959, Real Time Protocol MIB.	X	X	X	
3.4	**Security**				***Compliance with this section is required for secure, interoperable communications between CaLV and MS, GS (test), CEV, LSAM, and C&T Networks.***
3.4.1	***Network Layer Security***				

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C3I-199	Constellation SYSTEMS shall implement RFC 4301, Security architecture for the Internet Protocol, at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-200	Constellation SYSTEMS shall implement RFC-4302, IP AUTHENTICATION HEADER (AH), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-201	Constellation SYSTEMS shall implement RFC-4303, IP ENCAPSULATING SECURITY PAYLOAD (ESP), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-204	Constellation SYSTEMS shall implement RFC 4305, Cryptographic Algorithm Implementation Requirements for Encapsulating Security Payload (ESP) and Authentication Header (AH), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-565	Constellation SYSTEMS shall implement RFC 4309, Using Advanced Encryption Standard (AES) CCM Mode with IPsec Encapsulating Security Payload (ESP), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
3.4.2	***Internet Key Exchange***				
C3I-209	Constellation SYSTEMS shall implement RFC-4306, The INTERNET KEY EXCHANGE (IKEv2), for all inter-SYSTEM management of security	X	X	X	

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	associations and keys used by IPSec.				
C3I-568	Constellation SYSTEMS shall implement RFC-4307, Cryptographic Algorithms for use in the Internet Key Exchange Version 2 (IKEv2).	X	X	X	
3.4.3	***Application Layer Security***				
C3I-210	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for inter-SYSTEM updates of security processing logic.	X	X	X	
C3I-566	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for all inter-system exchanges of the security policy information used by application layer security functions.	X	X	X	
C3I-567	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification and described in the for all inter-SYSTEM exchanges of the	X	X	X	

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	identity data used by application layer security functions.				
C3I-569	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for all inter-SYSTEM exchanges of the authentication keys and encryption keys used by application layer security functions.	X	X	X	
3.4.4	***FIPS Compliant Algorithms***				
C3I-203	Constellation SYSTEMS shall implement FIPS PUB 197, ADVANCED ENCRYPTION STANDARD (AES), for all ENCRYPTION of inter-SYSTEM data exchanges.	X	X	X	
C3I-206	Constellation SYSTEMS shall implement SHA-1 per FIPS PUB 180-2, Secure Hash Standard, for hash generation performed for inter-SYSTEM data exchanges.	X	X	X	
C3I-207	Constellation SYSTEMS shall implement FIPS PUB 186-2, DIGITAL SIGNATURE STANDARD (DSS) using the DIGITAL SIGNATURE ALGORITHM (DSA) for all digital signatures exchanged between SYSTEMS.	X	X	X	
C3I-208	Constellation SYSTEMS shall implement FIPS PUB 198, Keyed-HASH MESSAGE AUTHENTICATION CODE (HMAC), for all MESSAGE AUTHENTICATION CODES	X	X	X	

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	(MACs) exchanged between SYSTEMS.				
C3I-665	Constellation SYSTEMS shall implement SHA-256 per FIPS PUB 180-2, Secure Hash Standard, for hash generation performed for inter-SYSTEM data exchanges.	X	X	X	
C3I-666	Constellation SYSTEMS shall implement truncation of SHA-1 based 160-bit Hash Based Messaged Authentication Codes (HMACs) to 96 bits.	X	X	X	
C3I-667	Constellation SYSTEMS shall implement truncation of SHA-256 based 256-bit Hash Based Messaged Authentication Codes (HMACs) to 128 bits.	X	X	X	
3.5	**Data Exchange**				
3.5.1	***Voice Exchange***				***Voice communications are not required for CaLV.***
C3I-173	Constellation SYSTEMS shall assign a delivery priority to voice data sent to another SYSTEM.				
C3I-175	Constellation SYSTEMS shall transfer voice data over a one way link.				
C3I-176	Constellation SYSTEMS shall use ITU G.729, "Coding of speech at 8 kbit/s using conjugate-structure algebraic-code-excited linear prediction (CS-ACELP)".				
C3I-555	Constellation SYSTEMS shall transfer voice in accordance with IETF RFC 3550, Real-Time Transport Protocol (RTP).				
C3I-557	Constellation SYSTEMS shall provide a mechanism to add voice codecs.				
C3I-558	Constellation SYSTEMS shall				

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	provide a mechanism to remove voice codecs.				
3.5.2	***Motion Imagery Transfer***				***Compliance with this section is required for interoperable motion imagery transfer between CaLV and MS, GS (test), LSAM, and CEV.***
C3I-184	Constellation SYSTEMS shall assign a delivery priority for motion imagery data sent to another SYSTEM.	X	X	X	
C3I-185	Constellation SYSTEMS shall transfer motion imagery over a one way link.	X	X	X	
C3I-186	Constellation SYSTEMS shall use ITU H.264, "Advanced Video Coding for Generic Audiovisual Services".	X	X	X	
C3I-283	Constellation SYSTEMS shall transfer motion imagery in accordance with RFC 3550, Real-Time Transport Protocol (RTP).	X	X	X	
C3I-559	Constellation SYSTEMS shall use <TBR 3-13> ISO/IEC 15444-3, "Motion JPEG 2000 (Part 3)".	X	X	X	
C3I-560	Constellation SYSTEMS shall provide a mechanism to add MOTION IMAGERY codecs.	X	X	X	
C3I-561	Constellation SYSTEMS shall provide a mechanism to remove MOTION IMAGERY codecs.	X	X	X	
3.5.3	***Data Exchange Message Formatting and Transmission***				***Compliance with this section is required for interoperable message exchange between CaLV and GS (test), LSAM, and CEV.***
C3I-130	Constellation SYSTEMS shall transfer data exchange messages over a one way link.	X	X	X	
C3I-135	Constellation SYSTEMS shall use a common data exchange message format as defined in	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Appendix C of CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5:				
C3I-659	Constellation SYSTEMS shall assign to each data exchange message that is sent to another SYSTEM the priority that was assigned to the Data of that data exchange message.	X	X	X	
3.5.4	***File Transfer***				***Compliance with this section is required for interoperable file transfer between CaLV and MS, GS (test), LSAM, and CEV.***
C3I-161	Constellation SYSTEMS shall assign a delivery priority to each file sent to another SYSTEM.	X	X	X	
C3I-165	Constellation SYSTEMS shall transfer files in accordance with CCSDS 727.0-B-3, "CCSDS File Delivery Protocol (CFDP) – Recommended Standard".	X	X	X	
3.5.5	***Time Exchange***				***Compliance with this section is required for time exchange/sync interfaces between CaLV and MS, GS (test), CEV, LSAM, and C&T Networks.***
C3I-111	Constellation SYSTEMS shall exchange time in accordance with IETF RFC 1305, NETWORK TIME PROTOCOL (NTP) Version 3.	X	X	X	
3.5.6	***Traffic Prioritization***				
C3I-660	Constellation SYSTEMS shall effect observance of the delivery priorities assigned to voice data, motion imagery data, data exchange messages, and files by invoking traffic prioritization mechanisms provided by the underlying network.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
3.6	**Information**				
3.6.1	***Basic Information Definition***				***Compliance with this section is required for interoperable information definition for information exchanged between CaLV and MS, GS (test), LSAM, and CEV***
C3I-119	Constellation SYSTEMS shall use common COMMAND METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-140	Constellation SYSTEMS shall use common telemetry METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-157	Constellation SYSTEMS shall use a common convention for file formats as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3.	X	X	X	
C3I-169	Constellation SYSTEMS shall use common voice METADATA as defined by the CxP 70022, Constellation	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.				
C3I-180	Constellation SYSTEMS shall use common motion imagery METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-228	Constellation SYSTEMS shall use data types as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3.	X	X	X	
C3I-229	Constellation SYSTEMS shall exchange METADATA that complies with the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-231	Constellation SYSTEMS shall use Universal Resource Indicators (URIs) and namespace constructs using conventions described in RFC3986.	X	X	X	
C3I-355	Constellation SYSTEMS shall	X	X	X	

Phasing					
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	use a hierarchical addressing structure as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.				
C3I-357	Constellation SYSTEMS shall use a common file naming convention as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Sec 3.3.	X	X	X	
C3I-366	Constellation SYSTEMS shall issue inter-SYSTEM COMMANDS in the format defined by the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Sec 3.8.	X	X	X	
C3I-544	Constellation SYSTEMS shall exchange application layer security policies between SYSTEMS in a representation that complies with CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-545	Constellation SYSTEMS shall exchange application layer	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	cryptographic keys between SYSTEMS in a representation that complies with the CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume				
C3I-546	Constellation SYSTEMS shall exchange application layer identity information between SYSTEMS in a representation that complies with CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-652	Constellation SYSTEMS shall exchange application layer security audit data between SYSTEMS in a representation that complies with the CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-661	Constellation Systems shall define METADATA that complies with the CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
3.6.2	***Adaptive Information Definition***				***Compliance with this section is required for more adaptive (ad-hoc) interoperable information definition for information exchanged between CaLV and MS, GS (test), LSAM, and CEV. Note that this functionality is not phased in until lunar***

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
					sortie.
C3I-215	Constellation SYSTEMS shall define TELEMETRY processing algorithms in accordance with CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-222	Constellation SYSTEMS shall use a hierarchical naming scheme in accordance with the CXP-70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-547	Constellation SYSTEMS shall request data using data identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-548	Constellation SYSTEMS shall request files using file identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27>of the CxP 70022 Constellation		X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.				
C3I-549	Constellation SYSTEMS shall construct requests for data using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR) Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-550	Constellation SYSTEMS shall construct requests for file submissions and retrievals using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR) Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	

Table Appendix E-5 - C3I Interoperability Requirements Applicability to Ground Systems

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
3.1	**RF Communication**				
3.1.1	***Common RF Communication***				***Compliance with this section is required for interoperable communications between GS and CEV (for checkout testing), CLV, and CaLV.***
C3I-3	Constellation SYSTEMS shall comply with spectrum selection/allocation, certification and usage restriction policies set forth in NASA Policy Directive (NPD) 2570.5D, NASA Electromagnetic (EM) Spectrum Management.	X	X	X	
C3I-5	Constellation SYSTEMS shall use transmit/receive frequency assignments and spectrum characteristics as defined in CxP 70022 Constellation Command, Control, Communications and Information (C3I) Interoperability Standards Book, Volume 2: Constellation Spectrum and Channel Plan.	X	X	X	
C3I-584	Constellation SYSTEMS shall comply with radio frequency allocation and conditions of assignment for frequency spectrum usage approved by the National Telecommunications & Information Administration (NTIA).	X	X	X	
3.1.2	**Operational Pt-to-Pt RF Communication**				***Compliance with this section is required for interoperable communications between GS and CEV (for checkout testing), LSAM (for checkout testing) , CLV, and CaLV.***
3.1.2.1	***Common Operational Pt-to-Pt RF Communication***				***Compliance with this section is required to support the Operational Point-to-Point Communication link class.***
C3I-6	Constellation SYSTEMS shall	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	transmit using LEFT-HAND CIRCULAR POLARIZATION for operational point-to-point links.				
C3I-7	Constellation SYSTEMS shall receive using LEFT-HAND CIRCULAR POLARIZATION for operational point-to-point links.	X	X	X	
C3I-11	Constellation SYSTEMS shall communicate using at least two independent transmit/receive frequency pairs within the near Earth S-band spectrum allocation for multi-SYSTEM, simultaneous operational point-to-point communications.	X	X	X	
C3I-22	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1.O-1, Section 3 to transmit data streams for operational point-to-point links.	X	X	X	
C3I-23	Constellation SYSTEMS shall use bit randomization techniques in accordance with CCSDS 131.0-B-1 for randomization of transmitted data streams for operational point-to-point links.	X	X	X	
C3I-590	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3 for decoding received data streams using FORWARD ERROR CORRECTION for operational point-to-point links.	X	X	X	
C3I-592	Constellation SYSTEMS shall	X	X	X	

Section/ Req #	Section/Requirement	Phasing: ISS	Phasing: Sortie	Phasing: Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
	use bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-randomization of received data streams for operational point-to-point links.				
C3I-594	Constellation SYSTEMS shall apply the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 as specified in CCSDS 131.1-O-1, Section 3.5 transmitted FEC code block frames for operational point-to-point links.	X	X	X	
C3I-596	Constellation SYSTEMS shall comply with the specifications for service access points as defined in section 3 of the AOS Space Data Link Protocol 732.0.B-2 for reception of Multiprotocol Interconnect over Frame Relay using the CCSDS AOS Virtual Channel Access (VCA) service over operational point-to-point links.	X	X	X	
C3I-612	Constellation SYSTEMS shall transmit Multiprotocol Interconnect over Frame Relay (MPoFR) as serial octet-aligned streams per CCSDS recommendation “IP over CCSDS Space Links”, CCSDS 702.1-R-1, using the Virtual Channel Access (VCA) service of CCSDS Advanced Orbiting Systems (AOS) Space Link Protocol as specified in CCSDS 732.0-B-2 for operational point-to-point links.	X	X	X	
C3I-653	Constellation SYSTEMS shall enable and disable communication link forward error correction (FEC) upon	X	X	X	

Section/ Req #	Section/Requirement	Phasing ISS	Phasing Sortie	Phasing Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
	receipt of COMMAND for operational point-to-point links.				
C3I-668	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for transmission of IP packets for operational point-to-point links.	X	X	X	
C3I-669	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for reception of IP packets for operational point-to-point links.	X	X	X	
C3I-670	Constellation SYSTEMS shall use the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 for synchronization of received FEC code block frames as specified in CCSDS 131.1-O-1 for operational point-to-point links.	X	X	X	
C3I-671	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for transmission of non-FEC coded data streams for operational point-to-point links.	X	X	X	
C3I-672	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for resolution of symbol phase ambiguity of non-FEC coded data streams for operational point-to-point links.	X	X	X	
3.1.2.2	***Point A Operational Pt-to-Pt RF Communication***				***Compliance with this section is required to support the Point A Role in communication while using the Operational Point-to-Point Communication link. GS must support the Point A role to support test and checkout of flight vehicle Point B role operation.***
C3I-308	Constellation point A SYSTEMS shall coherently re-	X	X	X	

Section/ Req #	Section/Requirement	Phasing ISS	Phasing Sortie	Phasing Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
	transmit the received carrier with a turn-around ratio of 240/221(transmit/receive) for coherent point-to-point link operation.				
C3I-314	Constellation point A SYSTEMS shall coherently re-transmit the received range channel data to point B SYSTEM.	X	X	X	
C3I-350	Constellation point A SYSTEMS shall provide a non-coherent mode of operation for operational point-to-point links.	X	X	X	
C3I-573	Constellation point A SYSTEMS shall use transmit signals with modulation schemes in accordance with Table 3.1-2 for operational point-to-point links.	X	X	X	
C3I-574	Constellation point A SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-3 for operational point-to-point links.	X	X	X	
C3I-633	Constellation point A SYSTEMS shall transmit independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 (DG1).	X	X	X	
3.1.2.3	***Point B Operational Pt-to-Pt RF Communication***				***Compliance with this section is required to support the Point B Role in communication while using the Operational Point-to-Point Communication link. GS must support the Point B role to support test and checkout of flight vehicle Point A role operation.***
C3I-315	Constellation point B SYSTEMS shall process the coherent turn-around carrier to make radiometric measurements of	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	range rate data (two-way Doppler data) for operational point-to-point links.				
C3I-572	Constellation point B SYSTEMS shall process coherent turn-around ranging channel data to provide radiometric measurements of range data for operational point-to-point links.	X	X	X	
C3I-575	Constellation point B SYSTEMS shall transmit signals with modulation schemes in accordance with Table 3.1-3 for operational point-to-point links.	X	X	X	
C3I-576	Constellation point B SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-2 for operational point-to-point links.	X	X	X	
C3I-591	Constellation Point B SYSTEMS shall generate and modulate the range channel (Q channel) with the Forward Link Range Channel PN code as defined in the Space Network Interoperable PN Code Libraries, Rev. 1 (451-PN CODE-SNIP).	X	X	X	
C3I-634	Constellation point B SYSTEMS shall receive independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 (DG1).	X	X	X	
3.1.3	**High-Rate Pt-to-Pt RF Communication**				***Compliance with this section is required for GS communications to support checkout testing of CEV high rate RF communications.***
3.1.3.1	***Common High Rate RF Communication***				***Compliance with this section is required to support the frequencies and modulation to enable GS to perform test and checkout of flight vehicle high rate communication systems.***

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-30	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3, to transmit data streams for high rate point-to-point links.	X	X	X	
C3I-31	Constellation SYSTEMS shall use bit randomization techniques in accordance with CCSDS 131.0-B-1 for randomization of transmitted data streams for high rate point-to-point links.	X	X	X	
C3I-581	Constellation SYSTEMS shall transmit using Right-hand Circular polarization for high rate point-to-point links.	X	X	X	
C3I-583	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3, for decoding of received data streams using FEC for high rate point-to-point links.	X	X	X	
C3I-589	Constellation SYSTEMS shall receive using Right-hand Circular polarization for high-rate point-to-point links.	X	X	X	
C3I-598	Constellation SYSTEMS shall use bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-randomization of received data streams for high rate point-to-point links.	X	X	X	
C3I-600	Constellation SYSTEMS shall apply the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 as specified	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	in CCSDS 131.1-O-1, Section 3.5, to transmit FEC code blocks for high rate point-to-point links.				
C3I-601	Constellation SYSTEMS shall comply with the specifications for service access points as defined in section 3 of AOS Space Data Link Protocol 732.0.B-2 for reception of Multiprotocol Interconnect over Frame Relay using the CCSDS AOS Virtual Channel Access service over high rate point-to-point links.	X	X	X	
C3I-603	Constellation SYSTEMS shall transmit Multiprotocol Interconnect over Frame Relay (MPoFR) as serial octet-aligned streams per CCSDS recommendation “IP over CCSDS Space Links”, CCSDS 702.1-R-1, using the Virtual Channel Access (VCA) service of CCSDS Advanced Orbiting Systems (AOS) Space Link Protocol as specified in CCSDS 732.0-B-2 for High Rate point-to-point links.	X	X	X	
C3I-632	Constellation SYSTEMS shall enable and disable communication link forward error correction (FEC) upon receipt of COMMAND for high rate point-to-point links.	X	X	X	
C3I-673	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for transmission of IP packets for high rate point-to-point links.	X	X	X	
C3I-674	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as	X	X	X	

Section/ Req #	Section/Requirement	Phasing ISS	Sortie	Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
	specified by RFC 2427 for reception of IP packets for high rate point-to-point links.				
C3I-675	Constellation SYSTEMS shall use the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 for synchronization of received FEC code block frames as specified in CCSDS 131.1-O-1 for high rate point-to-point links.	X	X	X	
C3I-676	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for transmission of non-FEC coded data streams for high rate point-to-point links.	X	X	X	
C3I-677	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for resolution of symbol phase ambiguity of non-FEC coded data streams for high rate point-to-point links.	X	X	X	
3.1.3.2	***Point A High-rate Pt-to-Pt RF Communication***				***Compliance with this section is required for GS to emulate Point A role systems during flight vehicle test and checkout. This necessary to test flight systems that can assume the Point B role.***
C3I-577	Constellation point A SYSTEMS shall use transmit signals with modulation schemes in accordance with Table 3.1-4 for high rate point-to-point links.	X	X	X	
C3I-578	Constellation point A SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-5 for high rate point-to-point links.	X	X	X	
3.1.3.3	***Point B High-rate Pt-to-Pt RF Communication***				***Compliance with this section is required for GS to emulate space communications infrastructure (eg. GN, SN, DSN) during flight vehicle high rate communication system test and checkout. This is necessary to test flight systems assuming the Point***

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
					A role.
C3I-579	Constellation point B SYSTEMS shall transmit signals with modulation schemes in accordance with Table 3.1-5 for high rate point-to-point links.	X	X	X	
C3I-580	Constellation point B SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-4 for high rate point-to-point links.	X	X	X	
3.1.4	***Multipoint Proximity RF Communication***				***Compliance with this section is required for GS communications to support checkout testing of LSAM proximity RF communications interfaces.***
	RESERVED	TBD	TBD	TBD	
3.1.5	**Recovery RF Communication**				***Compliance with this section is required for interoperable recovery communications interfaces between GS recovery forces and CEV (and possibly EVA).***
3.1.5.1	***Common Recovery RF Communication***				
C3I-347	Constellation SYSTEMS shall transmit to the COSPAS/SARSAT system using the spectrum guidelines provided by ITU-R Recommendation M.633.	X	X	X	
C3I-362	Constellation SYSTEMS shall use amplitude modulation (AM) for analog voice communication with US and international search and rescue forces.	X	X	X	
C3I-363	Constellation SYSTEMS shall transmit to the COSPAS/SARSAT system per COSPAS/SARSAT document C/S T.001 Sections 2 and 3.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-678	Constellation SYSTEMS shall use narrowband frequency modulation (FM) for analog voice communication with US and international maritime search and rescue forces.	X	X	X	
C3I-679	Constellation SYSTEMS shall communicate using the US UHF SATCOM system per MIL-STD-188-181.	X	X	X	
3.1.6	**RF Contingency Voice Communication**				***Compliance with this section is required for interoperable RF Contingency Voice communications interfaces between GS and CEV and to support pre-launch checkout testing of CEV, LSAM and other crew-capable systems.***
3.1.6.1	***Common RF Contingency Voice Communication***				
C3I-385	Constellation SYSTEMS shall modulate the transmitted carrier using amplitude modulation for analog, half-duplex Contingency Voice links.	X	X	X	
C3I-680	Constellation SYSTEMS shall receive an amplitude modulated carrier for Contingency Voice links.	X	X	X	
3.1.7	**Future High Rate Link Class**				
	RESERVED	TBD	TBD	TBD	
3.1.8	**Vehicle Internal Wireless Link Class**				
C3I-681	Constellation SYSTEMS shall use IEEE 802.11g on non-critical internal local area wireless data networks.	X	X	X	
3.2	**Hard-Line Communication**				
3.2.1	***High-Rate, Hard-Line Communication***				***Compliance with this section is required for interoperable hard-line communications between GS and CEV, LSAM, CLV, and CaLV.***

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-58	Constellation SYSTEMS shall use IEEE Std 1394b™-2002 and SAE-AS5643/1 with RFC-2734 for high data volume, hard-line connections between Constellation SYSTEMS.	X	X	X	
3.2.2	***High-Rate, Ground Hard-Line Communication***				
C3I-336	Constellation SYSTEMS shall use ground institutional IP routed networks.	X	X	X	
3.2.3	***Deterministic Hard-Line Communication***				***Compliance with this section is pending determination of any need for GSE interfaces requiring deterministic closed-loop control with CEV <TBD E-14> , CLV <TBD E-15> , and CaLV <TBD E-16>.***
C3I-682	Constellation SYSTEMS shall use SAE-AS5643 and AS5643/1 standards for deterministic rate based hard-line connections between Constellation SYSTEMS.	X	X	X	
3.3	**Network**				
3.3.1	***Connectivity***				***Compliance with this section is required for interoperable IP network communications between GS and MS, CEV, LSAM, CLV, and CaLV.***
C3I-61	Constellation SYSTEMS shall implement version 4 of the Internet Protocol (IPv4) as specified in STD-0005.	X			IPv4 is for ISS Missions only.
C3I-62	Constellation SYSTEMS shall use unicast addresses as defined in RFC-1918, Address Allocation for Private Internets.	X			IPv4 is for ISS Missions only.
C3I-63	Constellation SYSTEMS shall use multicast addresses as defined in RFC-3171, IANA Guidelines for IPv4 Multicast	X			IPv4 is for ISS Missions only.

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Address Assignments.				
C3I-64	Constellation SYSTEMS shall provide a mechanism to manually configure the addresses of all IP-addressable interfaces.	X	X	X	
C3I-72	Constellation SYSTEMS shall provide IP network address to data link layer address mappings for IP addresses external to the SYSTEM.	X	X	X	
C3I-73	Constellation SYSTEMS shall use managed associations to map IP addresses to data link layer addresses for IP addresses external to the SYSTEM.	X	X	X	
C3I-74	Constellation SYSTEMS shall accept modifications to the IP address to data-link layer address mapping information via the network for IP addresses external to the SYSTEM.	X	X	X	
C3I-75	Constellation SYSTEMS shall perform multi-hop routing as specified in RFC-1812, Requirements for IP Version 4 Routers as updated by RFC-2644.	X			IPv4 is for ISS Missions only.
C3I-76	Constellation SYSTEMS shall comply with RFC-1122 (STD-0003), Requirements for Internet Hosts – Communications Layers.	X			IPv4 is for ISS Missions only.
C3I-78	Constellation SYSTEMS shall use manually configured routes instead of dynamically learned ones when there is an exact match in the prefix length for a given destination external to the SYSTEM.	X	X	X	
C3I-79	Constellation SYSTEMS shall use static routing table entries.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-80	Constellation SYSTEMS shall accept changes to the routing tables via the network.	X	X	X	
C3I-87	Constellation SYSTEMS shall advertise only non-default routes via the routing protocols.	X	X	X	
C3I-89	Constellation SYSTEMS shall have a default route specified in the routing tables.	X	X	X	
C3I-90	Constellation SYSTEMS shall fail over to default routes when there is a loss of all routing information or a loss of communication to all SYSTEM network neighbors participating in the dynamic routing protocol for more than 20 seconds.	X	X	X	
C3I-93	Constellation SYSTEMS shall resolve symbolic names to IP addresses using static host table.	X	X	X	
C3I-95	Constellation SYSTEMS shall accept changes to the static host table via the network.	X	X	X	
C3I-96	Constellation SYSTEMS shall implement RFC-2474, Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers.	X	X	X	
C3I-97	Constellation SYSTEMS shall implement RFC-2211, Specification of the Controlled-Load Network System Service.	X	X	X	
C3I-98	Constellation SYSTEMS shall implement <TBR 3-25> RFC-2205, Resource ReSerVation Protocol (RSVP) Version 1 Functional Specification.	X	X	X	
C3I-99	Constellation SYSTEMS shall implement the Simple Network Management Protocol version 3	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	as defined in STD0062.				
C3I-103	Constellation SYSTEMS shall implement Internet STD-0007: TRANSMISSION CONTROL PROTOCOL (TCP).	X	X	X	
C3I-104	Constellation SYSTEMS shall implement RFC-1323 - TCP Extensions for High Performance.	X	X	X	
C3I-105	Constellation SYSTEMS shall implement STD-0006 - UDP, USER DATAGRAM PROTOCOL, for communication with all IP-addressable endpoints.	X	X	X	
C3I-106	Constellation SYSTEMS shall implement RFC-3550 (STD-0064), RTP: A Transport Protocol for Real-Time Applications.	X	X	X	
C3I-281	Constellation SYSTEMS shall implement RFC-3140, Per Hop Behavior Identification Codes.	X	X	X	
C3I-282	Constellation SYSTEMS shall implement RFC-3246, An Expedited Forwarding PHB (PER HOP BEHAVIOR).	X	X	X	
C3I-619	Constellation SYSTEMS shall implement a split-connection TCP Performance Enhancing Proxy (PEP) that implements the SCPS-TP transport layer per CCSDS 714.0.B-1, Space Communications Protocol Specification (SCPS) - Transport Protocol (SCPS-TP), Blue Book, Issue 1, May 1999, on links where the maximum bandwidth*delay product of the link exceeds 1e6 bits and/or whose design bit error rate is equal to or greater than 1e-6.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-620	Constellation SYSTEMS shall implement Internet Protocol version 6 (IPv6) per RFC 2460 Internet Protocol, Version 6 (IPv6) Specification.		X	X	IPv6 Lunar Missions
C3I-621	Constellation SYSTEMS shall implement the Internet Control Messaging Protocol (ICMP) per RFC 792, Internet Control Message Protocol.	X			IPv4 Lunar Missions
C3I-622	Constellation SYSTEMS shall implement the Internet Control Messaging Protocol version 6 (ICMPv6) per RFC 4443 Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification.		X	X	IPv6 Lunar Missions
C3I-654	Constellation SYSTEMS shall implement the Multiprotocol Border Gateway Protocol (MBGP) as specified in RFC-2858.	X	X	X	
C3I-655	Constellation SYSTEMS shall implement the Multicast Listener Discovery protocol, version 2, as specified in RFC-3810 <TBR 3-24>.		X	X	This protocol is required to join end systems to multicast groups in IPv6.
C3I-656	Constellation SYSTEMS shall implement Multicast Extension to OSPF as specified in RFC-1584.	X			MOSPF is IPv4 specific.
C3I-657	Constellation SYSTEMS shall implement the Internet Group Management Protocol (IGMP) as specified in RFC-3376.	X			This protocol is required to join end systems to multicast groups in IPv4.
3.3.2	***Dynamic Routing Between Systems***				***Compliance with this section is required for interoperable IP network dynamic routing between GS and MS, CEV, LSAM, CLV <TBD E-17> , and CaLV.***
C3I-82	Constellation SYSTEMS shall implement RFC-2453, STD-	X			

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	0056 - RIP Version 2.				
C3I-83	Constellation SYSTEMS shall implement RFC-2328 (STD-0054), OPEN SHORTEST PATH FIRST (OSPF) Version 2.	X			
C3I-295	Constellation SYSTEMS shall implement RFC-3626 Optimized Link State Routing Protocol (OLSR).		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
C3I-662	Constellation SYSTEMS shall implement RFC-2080, RIPng for IPv6 .		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
C3I-663	Constellation SYSTEMS shall implement RFC-2740 , OSPF for IPv6.		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
3.3.3	***External Connectivity***				***The GS does not interface with external networks. (NOTE: need to revisit this due to GS interfaces with AF, existing remote user base, etc.)***
C3I-81	Constellation SYSTEMS shall implement RFC-4271-A BORDER GATEWAY PROTOCOL (BGP) Version 4, as specified in RFC4271 "A BORDER GATEWAY PROTOCOL 4 (BGP-4)				
C3I-280	Constellation SYSTEMS shall use external routes learned by Border Gateway Protocol Version 4, as specified in RFC4271 “A Border Gateway Protocol 4 (BGP-4), before those learned via other dynamic routing protocols.				
3.3.4	***Name Service***				***Compliance with this section is required for IP network name services used for network communications between GS and MS, CEV, LSAM, and CaLV. This is required to reduce systems management overhead associated with IP address management.***
C3I-296	Constellation SYSTEMS shall	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	implement IETF STD-0013, Domain Name SYSTEM.				
3.3.5	***Disruption Tolerance***				***GS does not interface with systems under conditions where disruption or delay are issues.***
C3I-107	Constellation SYSTEMS shall implement <TBR 3-12> DTN, DELAY/DISRUPTION TOLERANT NETWORKING Specifications, http://www.ietf.org/internet-drafts/draft-irtf-dtnrg-bundle-spec-05.txt.				
3.3.6	***Dynamic Address Assignment***				***Compliance with this section is pending determination of any need for GSE interfaces with CLV <TBD E-19> and/or CaLV <TBD E-20> that would require dynamic address assignment.***
C3I-67	Constellation SYSTEMS shall implement the DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP) Server functions as specified in RFC-2131 and updated by RFC-4361.	X	X	X	Support for mobile IP end-points such as suits, laptops, and hand-helds.
3.3.7	***Dynamic Address Retrieval***				***Compliance with this section is pending determination of any need for GSE interfaces with LSAM <TBD E-22> and/or CLV <TBD E-23> (NOTE: Need to consider CaLV) that would require dynamic address retrieval functions.***
C3I-69	Constellation SYSTEMS shall obtain network addresses via the DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP) as specified in RFC-2131 and updated by RFC-4361.	X	X	X	
C3I-70	Constellation SYSTEMS shall 'self-assign' an IP address from the 169.254.0.0/16 private	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	address block as specified in RFC-3927, Dynamic Configuration of IPv4 Link-Local Addresses of IPv4 interfaces when unable to obtain an IP address from pre-configuration information and/or DHCP.				
3.3.8	***Tunneling***				***Compliance with this section is required for network tunneling on interfaces between GS and CEV, LSAM, CLV, CaLV. Tunneling is necessary to support Mobile IP and allows controllers to perform traffic engineering and to force traffic to follow particular paths in the network that are different from the routes that might be 'default' or learned via dynamic routing protocols.***
C3I-92	Constellation SYSTEMS shall implement RFC-2784, GENERIC ROUTING ENCAPSULATION (GRE).	X			
C3I-664	Constellation SYSTEMS shall implement RFC-2473, Generic Packet Tunneling in IPv6 Specification.		X	X	IPv6 version for Lunar Missions
3.3.9	***Header Compression***				***Compliance with this section is required for test and checkout of compressed network communications between GS and CEV (test), LSAM <TBD E-24> , and CaLV (EDS).***
C3I-307	Constellation SYSTEMS shall implement RFC-2507 IP Header Compression.	X	X	X	
C3I-588	Constellation SYSTEMS shall implement RFC 2508 Compressing IP/UDP/RTP Headers for Low-Speed Serial Links.	X	X	X	
3.3.10	***Network Management***				***Compliance with this section is required for network management interfaces between GS and MS, CEV, CLV, and CaLV.***

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-100	Constellation SYSTEMS shall implement RFC-4293 Management Information Base for the Internet Protocol (IP).	X	X	X	
C3I-294	Constellation SYSTEMS shall implement RFC-4292, IP Forwarding Table MIB.	X	X	X	
C3I-298	Constellation SYSTEMS shall implement RFC-3747, Differentiated Services Configuration MIB.	X	X	X	
C3I-299	Constellation SYSTEMS shall implement RFC-3289, MIB for the Differentiated Services Architecture.	X	X	X	
C3I-300	Constellation SYSTEMS shall implement RFC-2213, Integrated Services Management Information Base using SMIv2.	X	X	X	
C3I-301	Constellation SYSTEMS shall implement RFC-4022, Management Information Base for TRANSMISSION CONTROL PROTOCOL (TCP).	X	X	X	
C3I-302	Constellation SYSTEMS shall implement RFC-4113, Management Information Base for USER DATAGRAM PROTOCOL (UDP).	X	X	X	
C3I-303	Constellation SYSTEMS shall implement RFC-2959, Real Time Protocol MIB.	X	X	X	
3.4	**Security**				***Compliance with this section is required for secure, interoperable communications between GS and MS, CEV, LSAM, CLV, and CaLV.***
3.4.1	***Network Layer Security***				
C3I-199	Constellation SYSTEMS shall implement RFC 4301, Security architecture for the Internet Protocol, at all Internet Protocol (IP) based inter-SYSTEM data	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	exchange interfaces.				
C3I-200	Constellation SYSTEMS shall implement RFC-4302, IP AUTHENTICATION HEADER (AH), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-201	Constellation SYSTEMS shall implement RFC-4303, IP ENCAPSULATING SECURITY PAYLOAD (ESP), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-204	Constellation SYSTEMS shall implement RFC 4305, Cryptographic Algorithm Implementation Requirements for Encapsulating Security Payload (ESP) and Authentication Header (AH), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-565	Constellation SYSTEMS shall implement RFC 4309, Using Advanced Encryption Standard (AES) CCM Mode with IPsec Encapsulating Security Payload (ESP), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
3.4.2	***Internet Key Exchange***				
C3I-209	Constellation SYSTEMS shall implement RFC-4306, The INTERNET KEY EXCHANGE (IKEv2), for all inter-SYSTEM management of security associations and keys used by IPSec.	X	X	X	
C3I-568	Constellation SYSTEMS shall implement RFC-4307, Cryptographic Algorithms for	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	use in the Internet Key Exchange Version 2 (IKEv2).				
3.4.3	***Application Layer Security***				
C3I-210	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for inter-SYSTEM updates of security processing logic.	X	X	X	
C3I-566	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for all inter-system exchanges of the security policy information used by application layer security functions.	X	X	X	
C3I-567	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification and described in the for all inter-SYSTEM exchanges of the identity data used by application layer security functions.	X	X	X	
C3I-569	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for all inter-SYSTEM exchanges of the authentication keys and encryption keys used by application layer security functions.				
3.4.4	***FIPS Compliant Algorithms***				
C3I-203	Constellation SYSTEMS shall implement FIPS PUB 197, ADVANCED ENCRYPTION STANDARD (AES), for all ENCRYPTION of inter-SYSTEM data exchanges.	X	X	X	
C3I-206	Constellation SYSTEMS shall implement SHA-1 per FIPS PUB 180-2, Secure Hash Standard, for hash generation performed for inter-SYSTEM data exchanges.	X	X	X	
C3I-207	Constellation SYSTEMS shall implement FIPS PUB 186-2, DIGITAL SIGNATURE STANDARD (DSS) using the DIGITAL SIGNATURE ALGORITHM (DSA) for all digital signatures exchanged between SYSTEMS.	X	X	X	
C3I-208	Constellation SYSTEMS shall implement FIPS PUB 198, Keyed-HASH MESSAGE AUTHENTICATION CODE (HMAC), for all MESSAGE AUTHENTICATION CODES (MACs) exchanged between SYSTEMS.	X	X	X	
C3I-665	Constellation SYSTEMS shall implement SHA-256 per FIPS PUB 180-2, Secure Hash	X	X	X	

Section/ Req #	Section/Requirement	Phasing ISS	Phasing Sortie	Phasing Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
	Standard, for hash generation performed for inter-SYSTEM data exchanges.				
C3I-666	Constellation SYSTEMS shall implement truncation of SHA-1 based 160-bit Hash Based Messaged Authentication Codes (HMACs) to 96 bits.	X	X	X	
C3I-667	Constellation SYSTEMS shall implement truncation of SHA-256 based 256-bit Hash Based Messaged Authentication Codes (HMACs) to 128 bits.	X	X	X	
3.5	**Data Exchange**				
3.5.1	***Voice Exchange***				***Compliance with this section is required for interoperable voice communications between GS and MS, CEV, and LSAM (for checkout testing).***
C3I-173	Constellation SYSTEMS shall assign a delivery priority to voice data sent to another SYSTEM.	X	X	X	
C3I-175	Constellation SYSTEMS shall transfer voice data over a one way link.	X	X	X	
C3I-176	Constellation SYSTEMS shall use ITU G.729, "Coding of speech at 8 kbit/s using conjugate-structure algebraic-code-excited linear prediction (CS-ACELP)".	X	X	X	
C3I-555	Constellation SYSTEMS shall transfer voice in accordance with IETF RFC 3550, Real-Time Transport Protocol (RTP).	X	X	X	
C3I-557	Constellation SYSTEMS shall provide a mechanism to add voice codecs.	X	X	X	
C3I-558	Constellation SYSTEMS shall provide a mechanism to remove voice codecs.	X	X	X	
3.5.2	***Motion Imagery Transfer***				***Compliance with this section is required for***

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
					interoperable motion imagery transfer between GS and MS, CEV, LSAM, CLV, and CaLV.
C3I-184	Constellation SYSTEMS shall assign a delivery priority for motion imagery data sent to another SYSTEM.	X	X	X	
C3I-185	Constellation SYSTEMS shall transfer motion imagery over a one way link.	X	X	X	
C3I-186	Constellation SYSTEMS shall use ITU H.264, "Advanced Video Coding for Generic Audiovisual Services".	X	X	X	
C3I-283	Constellation SYSTEMS shall transfer motion imagery in accordance with RFC 3550, Real-Time Transport Protocol (RTP).	X	X	X	
C3I-559	Constellation SYSTEMS shall use <TBR 3-13> ISO/IEC 15444-3, "Motion JPEG 2000 (Part 3)".	X	X	X	
C3I-560	Constellation SYSTEMS shall provide a mechanism to add MOTION IMAGERY codecs.	X	X	X	
C3I-561	Constellation SYSTEMS shall provide a mechanism to remove MOTION IMAGERY codecs.	X	X	X	
3.5.3	***Data Exchange Message Formatting and Transmission***				***Compliance with this section is required for interoperable message exchange between GS and CEV, LSAM, CLV, and CaLV.***
C3I-130	Constellation SYSTEMS shall transfer data exchange messages over a one way link.	X	X	X	
C3I-135	Constellation SYSTEMS shall use a common data exchange message format as defined in Appendix C of CxP 70022 Constellation COMMAND, Control, Communication, and	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Information (C3I) Interoperability Standards Book, Volume 5:				
C3I-659	Constellation SYSTEMS shall assign to each data exchange message that is sent to another SYSTEM the priority that was assigned to the Data of that data exchange message.	X	X	X	
3.5.4	***File Transfer***				***Compliance with this section is required for interoperable file transfer between GS and MS, CEV, LSAM, CLV, and CaLV.***
C3I-161	Constellation SYSTEMS shall assign a delivery priority to each file sent to another SYSTEM.	X	X	X	
C3I-165	Constellation SYSTEMS shall transfer files in accordance with CCSDS 727.0-B-3, "CCSDS File Delivery Protocol (CFDP) – Recommended Standard".	X	X	X	
3.5.5	***Time Exchange***				***Compliance with this section is required for time exchange/sync interfaces between GS and MS, CEV, LSAM (for checkout testing) , CLV, and CaLV.***
C3I-111	Constellation SYSTEMS shall exchange time in accordance with IETF RFC 1305, NETWORK TIME PROTOCOL (NTP) Version 3.	X	X	X	
3.5.6	***Traffic Prioritization***				
C3I-660	Constellation SYSTEMS shall effect observance of the delivery priorities assigned to voice data, motion imagery data, data exchange messages, and files by invoking traffic prioritization mechanisms provided by the underlying network.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
3.6	**Information**				
3.6.1	***Basic Information Definition***				***Compliance with this section is required for interoperable information definition for information exchanged between GS and MS, CEV, LSAM, CLV, and CaLV.***
C3I-119	Constellation SYSTEMS shall use common COMMAND METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-140	Constellation SYSTEMS shall use common telemetry METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-157	Constellation SYSTEMS shall use a common convention for file formats as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3.	X	X	X	
C3I-169	Constellation SYSTEMS shall use common voice METADATA as defined by the CxP 70022, Constellation Command, Control,	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.				
C3I-180	Constellation SYSTEMS shall use common motion imagery METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-228	Constellation SYSTEMS shall use data types as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3.	X	X	X	
C3I-229	Constellation SYSTEMS shall exchange METADATA that complies with the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-231	Constellation SYSTEMS shall use Universal Resource Indicators (URIs) and namespace constructs using conventions described in RFC3986.	X	X	X	
C3I-355	Constellation SYSTEMS shall use a hierarchical addressing	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	structure as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.				
C3I-357	Constellation SYSTEMS shall use a common file naming convention as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Sec 3.3.	X	X	X	
C3I-366	Constellation SYSTEMS shall issue inter-SYSTEM COMMANDS in the format defined by the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Sec 3.8.	X	X	X	
C3I-544	Constellation SYSTEMS shall exchange application layer security policies between SYSTEMS in a representation that complies with CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-545	Constellation SYSTEMS shall exchange application layer cryptographic keys between	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	SYSTEMS in a representation that complies with the CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume				
C3I-546	Constellation SYSTEMS shall exchange application layer identity information between SYSTEMS in a representation that complies with CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-652	Constellation SYSTEMS shall exchange application layer security audit data between SYSTEMS in a representation that complies with the CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-661	Constellation Systems shall define METADATA that complies with the CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
3.6.2	***Adaptive Information Definition***				***Compliance with this section is required for more adaptive (ad-hoc) interoperable information definition for information exchanged between GS and MS, CEV, LSAM, CLV, CaLV. Note that this functionality is not phased in until lunar sortie.***

Phasing					
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-215	Constellation SYSTEMS shall define TELEMETRY processing algorithms in accordance with CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-222	Constellation SYSTEMS shall use a hierarchical naming scheme in accordance with the CXP-70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-547	Constellation SYSTEMS shall request data using data identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-548	Constellation SYSTEMS shall request files using file identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27>of the CxP 70022 Constellation Command, Control, Communication, and		X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.				
C3I-549	Constellation SYSTEMS shall construct requests for data using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR) Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-550	Constellation SYSTEMS shall construct requests for file submissions and retrievals using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR) Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	

Table Appendix E-6 - C3I Interoperability Requirements Applicability to MS

Phasing

Section/ Req #	Section/Requirement	ISS	Sortie	Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
3.1	**RF Communication**				
3.1.1	***Common RF Communication***				***MS does not use RF communication links to exchange information but instead uses institutional ground network connections.***
C3I-3	Constellation SYSTEMS shall comply with spectrum selection/allocation, certification and usage restriction policies set forth in NASA Policy Directive (NPD) 2570.5D, NASA Electromagnetic (EM) Spectrum Management.				
C3I-5	Constellation SYSTEMS shall use transmit/receive frequency assignments and spectrum characteristics as defined in CxP 70022 Constellation Command, Control, Communications and Information (C3I) Interoperability Standards Book, Volume 2: Constellation Spectrum and Channel Plan.				
C3I-584	Constellation SYSTEMS shall comply with radio frequency allocation and conditions of assignment for frequency spectrum usage approved by the National Telecommunications & Information Administration (NTIA).				
3.1.2	**Operational Pt-to-Pt RF Communication**				***MS does not use RF communication links to exchange information but instead uses institutional ground network connections.***
3.1.2.1	***Common Operational Pt-to-Pt RF Communication***				***No current requirement for this class of communications on MS.***
C3I-6	Constellation SYSTEMS shall transmit using LEFT-HAND CIRCULAR POLARIZATION for operational point-to-point links.				
C3I-7	Constellation SYSTEMS shall receive using LEFT-HAND CIRCULAR POLARIZATION				

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	for operational point-to-point links.				
C3I-11	Constellation SYSTEMS shall communicate using at least two independent transmit/receive frequency pairs within the near Earth S-band spectrum allocation for multi-SYSTEM, simultaneous operational point-to-point communications.				
C3I-22	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1.O-1, Section 3 to transmit data streams for operational point-to-point links.				
C3I-23	Constellation SYSTEMS shall use bit randomization techniques in accordance with CCSDS 131.0-B-1 for randomization of transmitted data streams for operational point-to-point links.				
C3I-590	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3 for decoding received data streams using FORWARD ERROR CORRECTION for operational point-to-point links.				
C3I-592	Constellation SYSTEMS shall use bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-randomization of received data streams for operational point-to-point links.				
C3I-594	Constellation SYSTEMS shall				

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	apply the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 as specified in CCSDS 131.1-O-1, Section 3.5 transmitted FEC code block frames for operational point-to-point links.				
C3I-596	Constellation SYSTEMS shall comply with the specifications for service access points as defined in section 3 of the AOS Space Data Link Protocol 732.0.B-2 for reception of Multiprotocol Interconnect over Frame Relay using the CCSDS AOS Virtual Channel Access (VCA) service over operational point-to-point links.				
C3I-612	Constellation SYSTEMS shall transmit Multiprotocol Interconnect over Frame Relay (MPoFR) as serial octet-aligned streams per CCSDS recommendation “IP over CCSDS Space Links”, CCSDS 702.1-R-1, using the Virtual Channel Access (VCA) service of CCSDS Advanced Orbiting Systems (AOS) Space Link Protocol as specified in CCSDS 732.0-B-2 for operational point-to-point links.				
C3I-653	Constellation SYSTEMS shall enable and disable communication link forward error correction (FEC) upon receipt of COMMAND for operational point-to-point links.				
C3I-668	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for transmission of IP packets for				

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	operational point-to-point links.				
C3I-669	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for reception of IP packets for operational point-to-point links.				
C3I-670	Constellation SYSTEMS shall use the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 for synchronization of received FEC code block frames as specified in CCSDS 131.1-O-1 for operational point-to-point links.				
C3I-671	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for transmission of non-FEC coded data streams for operational point-to-point links.				
C3I-672	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for resolution of symbol phase ambiguity of non-FEC coded data streams for operational point-to-point links.				
3.1.2.2	***Point A Operational Pt-to-Pt RF Communication***				***No current requirement for this class of communications on MS.***
C3I-308	Constellation point A SYSTEMS shall coherently re-transmit the received carrier with a turn-around ratio of 240/221(transmit/receive) for coherent point-to-point link operation.				
C3I-314	Constellation point A SYSTEMS shall coherently re-transmit the received range channel data to point B SYSTEM.				
C3I-350	Constellation point A				

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	SYSTEMS shall provide a non-coherent mode of operation for operational point-to-point links.				
C3I-573	Constellation point A SYSTEMS shall use transmit signals with modulation schemes in accordance with Table 3.1-2 for operational point-to-point links.				
C3I-574	Constellation point A SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-3 for operational point-to-point links.				
C3I-633	Constellation point A SYSTEMS shall transmit independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 (DG1).				
3.1.2.3	***Point B Operational Pt-to-Pt RF Communication***				***No current requirement for this class of communications on MS.***
C3I-315	Constellation point B SYSTEMS shall process the coherent turn-around carrier to make radiometric measurements of range rate data (two-way Doppler data) for operational point-to-point links.				
C3I-572	Constellation point B SYSTEMS shall process coherent turn-around ranging channel data to provide radiometric measurements of range data for operational point-to-point links.				
C3I-575	Constellation point B SYSTEMS shall transmit signals with modulation schemes in accordance with Table 3.1-3 for operational point-to-point links.				
C3I-576	Constellation point B SYSTEMS				

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	shall receive signals with modulation schemes in accordance with Table 3.1-2 for operational point-to-point links.				
C3I-591	Constellation Point B SYSTEMS shall generate and modulate the range channel (Q channel) with the Forward Link Range Channel PN code as defined in the Space Network Interoperable PN Code Libraries, Rev. 1 (451-PN CODE-SNIP).				
C3I-634	Constellation point B SYSTEMS shall receive independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 (DG1).				
3.1.3	**High-Rate Pt-to-Pt RF Communication**				***MS does not use RF communication links to exchange information but instead uses institutional ground network connections.***
3.1.3.1	***Common High Rate RF Communication***				***No current requirement for this class of communications on MS.***
C3I-30	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3, to transmit data streams for high rate point-to-point links.				
C3I-31	Constellation SYSTEMS shall use bit randomization techniques in accordance with CCSDS 131.0-B-1 for randomization of transmitted data streams for high rate point-to-point links.				
C3I-581	Constellation SYSTEMS shall transmit using Right-hand				

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	Circular polarization for high rate point-to-point links.				
C3I-583	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3, for decoding of received data streams using FEC for high rate point-to-point links.				
C3I-589	Constellation SYSTEMS shall receive using Right-hand Circular polarization for high-rate point-to-point links.				
C3I-598	Constellation SYSTEMS shall use bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-randomization of received data streams for high rate point-to-point links.				
C3I-600	Constellation SYSTEMS shall apply the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 as specified in CCSDS 131.1-O-1, Section 3.5, to transmit FEC code blocks for high rate point-to-point links.				
C3I-601	Constellation SYSTEMS shall comply with the specifications for service access points as defined in section 3 of AOS Space Data Link Protocol 732.0.B-2 for reception of Multiprotocol Interconnect over Frame Relay using the CCSDS AOS Virtual Channel Access service over high rate point-to-point links.				
C3I-603	Constellation SYSTEMS shall transmit Multiprotocol Interconnect over Frame Relay				

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	(MPoFR) as serial octet-aligned streams per CCSDS recommendation "IP over CCSDS Space Links", CCSDS 702.1-R-1, using the Virtual Channel Access (VCA) service of CCSDS Advanced Orbiting Systems (AOS) Space Link Protocol as specified in CCSDS 732.0-B-2 for High Rate point-to-point links.				
C3I-632	Constellation SYSTEMS shall enable and disable communication link forward error correction (FEC) upon receipt of COMMAND for high rate point-to-point links.				
C3I-673	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for transmission of IP packets for high rate point-to-point links.				
C3I-674	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for reception of IP packets for high rate point-to-point links.				
C3I-675	Constellation SYSTEMS shall use the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 for synchronization of received FEC code block frames as specified in CCSDS 131.1-O-1 for high rate point-to-point links.				
C3I-676	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for transmission of non-FEC coded data streams for high rate point-to-point links.				

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C3I-677	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for resolution of symbol phase ambiguity of non-FEC coded data streams for high rate point-to-point links.				
3.1.3.2	***Point A High-rate Pt-to-Pt RF Communication***				***No current requirement for this class of communications on MS.***
C3I-577	Constellation point A SYSTEMS shall use transmit signals with modulation schemes in accordance with Table 3.1-4 for high rate point-to-point links.				
C3I-578	Constellation point A SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-5 for high rate point-to-point links.				
3.1.3.3	***Point B High-rate Pt-to-Pt RF Communication***				***No current requirement for this class of communications on MS.***
C3I-579	Constellation point B SYSTEMS shall transmit signals with modulation schemes in accordance with Table 3.1-5 for high rate point-to-point links.				
C3I-580	Constellation point B SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-4 for high rate point-to-point links.				
3.1.4	***Multipoint Proximity RF Communication***				***MS does not use RF communication links to exchange information but instead uses institutional ground network connections.***
	RESERVED				
3.1.5	**Recovery RF Communication**				***MS does not use RF communication links to exchange information but instead uses institutional ground network connections. Note that recovery communication interfaces with MS will be implemented through the ground IP networks.***

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3.1.5.1	***Common Recovery RF Communication***				
C3I-347	Constellation SYSTEMS shall transmit to the COSPAS/SARSAT system using the spectrum guidelines provided by ITU-R Recommendation M.633.				
C3I-362	Constellation SYSTEMS shall use amplitude modulation (AM) for analog voice communication with US and international search and rescue forces.				
C3I-363	Constellation SYSTEMS shall transmit to the COSPAS/SARSAT system per COSPAS/SARSAT document C/S T.001 Sections 2 and 3.				
C3I-678	Constellation SYSTEMS shall use narrowband frequency modulation (FM) for analog voice communication with US and international maritime search and rescue forces.				
C3I-679	Constellation SYSTEMS shall communicate using the US UHF SATCOM system per MIL-STD-188-181.				
3.1.6	**RF Contingency Voice Communication**				***MS does not use RF communication links to exchange information but instead uses institutional ground network connections. Note that recovery communication interfaces with MS will be implemented through the ground IP networks.***
3.1.6.1	***Common RF Contingency Voice Communication***				
C3I-385	Constellation SYSTEMS shall modulate the transmitted carrier using amplitude modulation for analog, half-duplex Contingency Voice links.				

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C3I-680	Constellation SYSTEMS shall receive an amplitude modulated carrier for Contingency Voice links.				
3.1.7	**Future High Rate Link Class**				
	RESERVED				
3.1.8	**Vehicle Internal Wireless Link Class**				
C3I-681	Constellation SYSTEMS shall use IEEE 802.11g on non-critical internal local area wireless data networks.				
3.2	**Hard-Line Communication**				
3.2.1	***High-Rate, Hard-Line Communication***				***MS does not have direct interfaces with flight systems requiring a common physical communications interface. All communications between MS and other systems will occur using institutional ground IP networks that utilize existing standard physical interfaces.***
C3I-58	Constellation SYSTEMS shall use IEEE Std 1394b™-2002 and SAE-AS5643/1 with RFC-2734 for high data volume, hard-line connections between Constellation SYSTEMS.				
3.2.2	***High-Rate, Ground Hard-Line Communication***				
C3I-336	Constellation SYSTEMS shall use ground institutional IP routed networks.	X	X	X	
3.2.3	***Deterministic Hard-Line Communication***				***MS does not have any deterministic hard-line communications interfaces with any systems.***
C3I-682	Constellation SYSTEMS shall use SAE-AS5643 and AS5643/1 standards for deterministic rate based hard-line connections between Constellation SYSTEMS.				

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3.3	**Network**				
3.3.1	***Connectivity***				***Compliance with this section is required for interoperable IP network communications between MS and GS, CEV, LSAM, CLV, and CaLV.***
C3I-61	Constellation SYSTEMS shall implement version 4 of the Internet Protocol (IPv4) as specified in STD-0005.	X			IPv4 is for ISS Missions only.
C3I-62	Constellation SYSTEMS shall use unicast addresses as defined in RFC-1918, Address Allocation for Private Internets.	X			IPv4 is for ISS Missions only.
C3I-63	Constellation SYSTEMS shall use multicast addresses as defined in RFC-3171, IANA Guidelines for IPv4 Multicast Address Assignments.	X			IPv4 is for ISS Missions only.
C3I-64	Constellation SYSTEMS shall provide a mechanism to manually configure the addresses of all IP-addressable interfaces.	X	X	X	
C3I-72	Constellation SYSTEMS shall provide IP network address to data link layer address mappings for IP addresses external to the SYSTEM.	X	X	X	
C3I-73	Constellation SYSTEMS shall use managed associations to map IP addresses to data link layer addresses for IP addresses external to the SYSTEM.	X	X	X	
C3I-74	Constellation SYSTEMS shall accept modifications to the IP address to data-link layer address mapping information via the network for IP addresses external to the SYSTEM.	X	X	X	
C3I-75	Constellation SYSTEMS shall perform multi-hop routing as specified in RFC-1812,	X			IPv4 is for ISS Missions only.

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	Requirements for IP Version 4 Routers as updated by RFC-2644.				
C3I-76	Constellation SYSTEMS shall comply with RFC-1122 (STD-0003), Requirements for Internet Hosts – Communications Layers.	X			IPv4 is for ISS Missions only.
C3I-78	Constellation SYSTEMS shall use manually configured routes instead of dynamically learned ones when there is an exact match in the prefix length for a given destination external to the SYSTEM.	X	X	X	
C3I-79	Constellation SYSTEMS shall use static routing table entries.	X	X	X	
C3I-80	Constellation SYSTEMS shall accept changes to the routing tables via the network.	X	X	X	
C3I-87	Constellation SYSTEMS shall advertise only non-default routes via the routing protocols.	X	X	X	
C3I-89	Constellation SYSTEMS shall have a default route specified in the routing tables.	X	X	X	
C3I-90	Constellation SYSTEMS shall fail over to default routes when there is a loss of all routing information or a loss of communication to all SYSTEM network neighbors participating in the dynamic routing protocol for more than 20 seconds.	X	X	X	
C3I-93	Constellation SYSTEMS shall resolve symbolic names to IP addresses using static host table.	X	X	X	
C3I-95	Constellation SYSTEMS shall accept changes to the static host table via the network.	X	X	X	
C3I-96	Constellation SYSTEMS shall implement RFC-2474,	X	X	X	

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	Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers.				
C3I-97	Constellation SYSTEMS shall implement RFC-2211, Specification of the Controlled-Load Network System Service.	X	X	X	
C3I-98	Constellation SYSTEMS shall implement <TBR 3-25> RFC-2205, Resource ReSerVation Protocol (RSVP) Version 1 Functional Specification.	X	X	X	
C3I-99	Constellation SYSTEMS shall implement the Simple Network Management Protocol version 3 as defined in STD0062.	X	X	X	
C3I-103	Constellation SYSTEMS shall implement Internet STD-0007: TRANSMISSION CONTROL PROTOCOL (TCP).	X	X	X	
C3I-104	Constellation SYSTEMS shall implement RFC-1323 - TCP Extensions for High Performance.	X	X	X	
C3I-105	Constellation SYSTEMS shall implement STD-0006 - UDP, USER DATAGRAM PROTOCOL, for communication with all IP-addressable endpoints.	X	X	X	
C3I-106	Constellation SYSTEMS shall implement RFC-3550 (STD-0064), RTP: A Transport Protocol for Real-Time Applications.	X	X	X	
C3I-281	Constellation SYSTEMS shall implement RFC-3140, Per Hop Behavior Identification Codes.	X	X	X	
C3I-282	Constellation SYSTEMS shall	X	X	X	

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	implement RFC-3246, An Expedited Forwarding PHB (PER HOP BEHAVIOR).				
C3I-619	Constellation SYSTEMS shall implement a split-connection TCP Performance Enhancing Proxy (PEP) that implements the SCPS-TP transport layer per CCSDS 714.0.B-1, Space Communications Protocol Specification (SCPS) - Transport Protocol (SCPS-TP), Blue Book, Issue 1, May 1999, on links where the maximum bandwidth*delay product of the link exceeds 1e6 bits and/or whose design bit error rate is equal to or greater than 1e-6.	X	X	X	
C3I-620	Constellation SYSTEMS shall implement Internet Protocol version 6 (IPv6) per RFC 2460 Internet Protocol, Version 6 (IPv6) Specification.		X	X	IPv6 Lunar Missions
C3I-621	Constellation SYSTEMS shall implement the Internet Control Messaging Protocol (ICMP) per RFC 792, Internet Control Message Protocol.	X			IPv4 Lunar Missions
C3I-622	Constellation SYSTEMS shall implement the Internet Control Messaging Protocol version 6 (ICMPv6) per RFC 4443 Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification.		X	X	IPv6 Lunar Missions
C3I-654	Constellation SYSTEMS shall implement the Multiprotocol Border Gateway Protocol (MBGP) as specified in RFC-2858.	X	X	X	
C3I-655	Constellation SYSTEMS shall implement the Multicast Listener		X	X	This protocol is required to join end systems to multicast groups in IPv6.

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	Discovery protocol, version 2, as specified in RFC-3810 <TBR 3-24>.				
C3I-656	Constellation SYSTEMS shall implement Multicast Extension to OSPF as specified in RFC-1584.	X			MOSPF is IPv4 specific.
C3I-657	Constellation SYSTEMS shall implement the Internet Group Management Protocol (IGMP) as specified in RFC-3376.	X			This protocol is required to join end systems to multicast groups in IPv4.
3.3.2	***Dynamic Routing Between Systems***				***Compliance with this section is required for interoperable IP network dynamic routing between MS and GS, CEV, LSAM, CLV , and CaLV.***
C3I-82	Constellation SYSTEMS shall implement RFC-2453, STD-0056 - RIP Version 2.	X			
C3I-83	Constellation SYSTEMS shall implement RFC-2328 (STD-0054), OPEN SHORTEST PATH FIRST (OSPF) Version 2.	X			
C3I-295	Constellation SYSTEMS shall implement RFC-3626 Optimized Link State Routing Protocol (OLSR).		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
C3I-662	Constellation SYSTEMS shall implement RFC-2080, RIPng for IPv6 .		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
C3I-663	Constellation SYSTEMS shall implement RFC-2740 , OSPF for IPv6.		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
3.3.3	***External Connectivity***				***The MS interfaces with network users external to the Constellation IP network to provide remote user capabilities and public access to information. Note that the requirements called out in this section of the specification provide a the standards and protocols that enable secure external connectivity (and are not specific to any given external interface).***
C3I-81	Constellation SYSTEMS shall	X	X	X	

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	implement RFC-4271-A BORDER GATEWAY PROTOCOL (BGP) Version 4, as specified in RFC4271 "A BORDER GATEWAY PROTOCOL 4 (BGP-4)				
C3I-280	Constellation SYSTEMS shall use external routes learned by Border Gateway Protocol Version 4, as specified in RFC4271 "A Border Gateway Protocol 4 (BGP-4), before those learned via other dynamic routing protocols.	X	X	X	
3.3.4	***Name Service***				***Compliance with this section is required for IP network name services used for network communications between MS and GS, CEV, LSAM, EVA, CLV, and CaLV. This is required to reduce systems management overhead associated with IP address management.***
C3I-296	Constellation SYSTEMS shall implement IETF STD-0013, Domain Name SYSTEM.	X	X	X	
3.3.5	***Disruption Tolerance***				***Compliance with this section is required to enable efficient communications during delayed or intermittent communications. This is required for interoperable DTN communications between MS and CEV and LSAM. Note that this section is phased in at Lunar Sortie.***
C3I-107	Constellation SYSTEMS shall implement <TBR 3-12> DTN, DELAY/DISRUPTION TOLERANT NETWORKING Specifications, http://www.ietf.org/internet-drafts/draft-irtf-dtnrg-bundle-spec-05.txt.		X	X	
3.3.6	***Dynamic Address Assignment***				***Compliance at the system interface is not required***

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					since the MS does not interface with other systems in ad-hoc network configurations. (Note that this capability would be expected on internal MS networks not covered in the interface.)
C3I-67	Constellation SYSTEMS shall implement the DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP) Server functions as specified in RFC-2131 and updated by RFC-4361.				Support for mobile IP end-points such as suits, laptops, and hand-helds.
3.3.7	***Dynamic Address Retrieval***				***Compliance at the system interface is not required since the MS does not interface with other systems in ad-hoc network configurations. (Note that this capability would be expected on internal MS networks not covered in the interface.)***
C3I-69	Constellation SYSTEMS shall obtain network addresses via the DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP) as specified in RFC-2131 and updated by RFC-4361.				
C3I-70	Constellation SYSTEMS shall 'self-assign' an IP address from the 169.254.0.0/16 private address block as specified in RFC-3927, Dynamic Configuration of IPv4 Link-Local Addresses of IPv4 interfaces when unable to obtain an IP address from pre-configuration information and/or DHCP.				
3.3.8	***Tunneling***				***Compliance with this section is required for network tunneling on interfaces between MS and CEV, LSAM, CLV, or CaLV. Tunneling is necessary to support Mobile IP and allows controllers to perform traffic engineering and to force traffic to follow particular paths in the network that are different from the routes that***

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					might be 'default' or learned via dynamic routing protocols.
C3I-92	Constellation SYSTEMS shall implement RFC-2784, GENERIC ROUTING ENCAPSULATION (GRE).	X			
C3I-664	Constellation SYSTEMS shall implement RFC-2473, Generic Packet Tunneling in IPv6 Specification.		X	X	IPv6 version for Lunar Missions
3.3.9	***Header Compression***				***Compliance is not required since MS does not use constrained bandwidth communications links to communicate with other systems***
C3I-307	Constellation SYSTEMS shall implement RFC-2507 IP Header Compression.				
C3I-588	Constellation SYSTEMS shall implement RFC 2508 Compressing IP/UDP/RTP Headers for Low-Speed Serial Links.				
3.3.10	***Network Management***				***Compliance with this section is required for network management interfaces between MS and GS, CEV, LSAM, CLV, or CaLV.***
C3I-100	Constellation SYSTEMS shall implement RFC-4293 Management Information Base for the Internet Protocol (IP).	X	X	X	
C3I-294	Constellation SYSTEMS shall implement RFC-4292, IP Forwarding Table MIB.	X	X	X	
C3I-298	Constellation SYSTEMS shall implement RFC-3747, Differentiated Services Configuration MIB.	X	X	X	
C3I-299	Constellation SYSTEMS shall implement RFC-3289, MIB for the Differentiated Services	X	X	X	

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	Architecture.				
C3I-300	Constellation SYSTEMS shall implement RFC-2213, Integrated Services Management Information Base using SMIv2.	X	X	X	
C3I-301	Constellation SYSTEMS shall implement RFC-4022, Management Information Base for TRANSMISSION CONTROL PROTOCOL (TCP).	X	X	X	
C3I-302	Constellation SYSTEMS shall implement RFC-4113, Management Information Base for USER DATAGRAM PROTOCOL (UDP).	X	X	X	
C3I-303	Constellation SYSTEMS shall implement RFC-2959, Real Time Protocol MIB.	X	X	X	
3.4	**Security**				***Compliance with this section is required for secure, interoperable communications between MS and GS, CEV, LSAM, CLV, or CaLV.***
3.4.1	***Network Layer Security***				
C3I-199	Constellation SYSTEMS shall implement RFC 4301, Security architecture for the Internet Protocol, at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-200	Constellation SYSTEMS shall implement RFC-4302, IP AUTHENTICATION HEADER (AH), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-201	Constellation SYSTEMS shall implement RFC-4303, IP ENCAPSULATING SECURITY PAYLOAD (ESP), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-204	Constellation SYSTEMS shall implement RFC 4305, Cryptographic Algorithm Implementation Requirements for Encapsulating Security Payload (ESP) and Authentication Header (AH), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-565	Constellation SYSTEMS shall implement RFC 4309, Using Advanced Encryption Standard (AES) CCM Mode with IPsec Encapsulating Security Payload (ESP), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
3.4.2	***Internet Key Exchange***				
C3I-209	Constellation SYSTEMS shall implement RFC-4306, The INTERNET KEY EXCHANGE (IKEv2), for all inter-SYSTEM management of security associations and keys used by IPSec.	X	X	X	
C3I-568	Constellation SYSTEMS shall implement RFC-4307, Cryptographic Algorithms for use in the Internet Key Exchange Version 2 (IKEv2).	X	X	X	
3.4.3	***Application Layer Security***				
C3I-210	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for inter-SYSTEM updates of security processing logic.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-566	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for all inter-system exchanges of the security policy information used by application layer security functions.	X	X	X	
C3I-567	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification and described in the for all inter-SYSTEM exchanges of the identity data used by application layer security functions.	X	X	X	
C3I-569	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for all inter-SYSTEM exchanges of the authentication keys and encryption keys used by application layer security functions.	X	X	X	
3.4.4	***FIPS Compliant Algorithms***				
C3I-203	Constellation SYSTEMS shall implement FIPS PUB 197,	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	ADVANCED ENCRYPTION STANDARD (AES), for all ENCRYPTION of inter-SYSTEM data exchanges.				
C3I-206	Constellation SYSTEMS shall implement SHA-1 per FIPS PUB 180-2, Secure Hash Standard, for hash generation performed for inter-SYSTEM data exchanges.	X	X	X	
C3I-207	Constellation SYSTEMS shall implement FIPS PUB 186-2, DIGITAL SIGNATURE STANDARD (DSS) using the DIGITAL SIGNATURE ALGORITHM (DSA) for all digital signatures exchanged between SYSTEMS.	X	X	X	
C3I-208	Constellation SYSTEMS shall implement FIPS PUB 198, Keyed-HASH MESSAGE AUTHENTICATION CODE (HMAC), for all MESSAGE AUTHENTICATION CODES (MACs) exchanged between SYSTEMS.	X	X	X	
C3I-665	Constellation SYSTEMS shall implement SHA-256 per FIPS PUB 180-2, Secure Hash Standard, for hash generation performed for inter-SYSTEM data exchanges.	X	X	X	
C3I-666	Constellation SYSTEMS shall implement truncation of SHA-1 based 160-bit Hash Based Messaged Authentication Codes (HMACs) to 96 bits.	X	X	X	
C3I-667	Constellation SYSTEMS shall implement truncation of SHA-256 based 256-bit Hash Based Messaged Authentication Codes (HMACs) to 128 bits.	X	X	X	
3.5	**Data Exchange**				

Section/ Req #	Section/Requirement	Phasing ISS	Phasing Sortie	Phasing Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
3.5.1	***Voice Exchange***				***Compliance with this section is required for interoperable voice communications between MS and GS, CEV, or LSAM.***
C3I-173	Constellation SYSTEMS shall assign a delivery priority to voice data sent to another SYSTEM.	X	X	X	
C3I-175	Constellation SYSTEMS shall transfer voice data over a one way link.	X	X	X	
C3I-176	Constellation SYSTEMS shall use ITU G.729, "Coding of speech at 8 kbit/s using conjugate-structure algebraic-code-excited linear prediction (CS-ACELP)".	X	X	X	
C3I-555	Constellation SYSTEMS shall transfer voice in accordance with IETF RFC 3550, Real-Time Transport Protocol (RTP).	X	X	X	
C3I-557	Constellation SYSTEMS shall provide a mechanism to add voice codecs.	X	X	X	
C3I-558	Constellation SYSTEMS shall provide a mechanism to remove voice codecs.	X	X	X	
3.5.2	***Motion Imagery Transfer***				***Compliance with this section is required for interoperable motion imagery transfer between MS and GS, CEV, LSAM, CLV, or CaLV.***
C3I-184	Constellation SYSTEMS shall assign a delivery priority for motion imagery data sent to another SYSTEM.	X	X	X	
C3I-185	Constellation SYSTEMS shall transfer motion imagery over a one way link.	X	X	X	
C3I-186	Constellation SYSTEMS shall use ITU H.264, "Advanced Video Coding for Generic Audiovisual Services".	X	X	X	

Section/ Req #	Section/Requirement	Phasing ISS	Phasing Sortie	Phasing Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
C3I-283	Constellation SYSTEMS shall transfer motion imagery in accordance with RFC 3550, Real-Time Transport Protocol (RTP).	X	X	X	
C3I-559	Constellation SYSTEMS shall use <TBR 3-13> ISO/IEC 15444-3, "Motion JPEG 2000 (Part 3)".	X	X	X	
C3I-560	Constellation SYSTEMS shall provide a mechanism to add MOTION IMAGERY codecs.	X	X	X	
C3I-561	Constellation SYSTEMS shall provide a mechanism to remove MOTION IMAGERY codecs.	X	X	X	
3.5.3	***Data Exchange Message Formatting and Transmission***				***Compliance with this section is required for interoperable message exchange between MS and CEV, LSAM, CLV, or CaLV.***
C3I-130	Constellation SYSTEMS shall transfer data exchange messages over a one way link.	X	X	X	
C3I-135	Constellation SYSTEMS shall use a common data exchange message format as defined in Appendix C of CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5:	X	X	X	
C3I-659	Constellation SYSTEMS shall assign to each data exchange message that is sent to another SYSTEM the priority that was assigned to the Data of that data exchange message.	X	X	X	
3.5.4	***File Transfer***				***Compliance with this section is required for interoperable file transfer between MS and GS, CEV, LSAM, CLV, or CaLV.***
C3I-161	Constellation SYSTEMS shall	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	assign a delivery priority to each file sent to another SYSTEM.				
C3I-165	Constellation SYSTEMS shall transfer files in accordance with CCSDS 727.0-B-3, "CCSDS File Delivery Protocol (CFDP) – Recommended Standard".	X	X	X	
3.5.5	***Time Exchange***				***Compliance with this section is required for time exchange/sync interfaces between MS and C&T Networks.***
C3I-111	Constellation SYSTEMS shall exchange time in accordance with IETF RFC 1305, NETWORK TIME PROTOCOL (NTP) Version 3.	X	X	X	
3.5.6	***Traffic Prioritization***				
C3I-660	Constellation SYSTEMS shall effect observance of the delivery priorities assigned to voice data, motion imagery data, data exchange messages, and files by invoking traffic prioritization mechanisms provided by the underlying network.	X	X	X	
3.6	**Information**				
3.6.1	***Basic Information Definition***				***Compliance with this section is required for interoperable information definition for information exchanged between MS and GS, CEV, LSAM, CLV, and CaLV.***
C3I-119	Constellation SYSTEMS shall use common COMMAND METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	

Phasing					
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-140	Constellation SYSTEMS shall use common telemetry METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-157	Constellation SYSTEMS shall use a common convention for file formats as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3.	X	X	X	
C3I-169	Constellation SYSTEMS shall use common voice METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-180	Constellation SYSTEMS shall use common motion imagery METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-228	Constellation SYSTEMS shall use data types as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3.	X	X	X	
C3I-229	Constellation SYSTEMS shall exchange METADATA that complies with the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-231	Constellation SYSTEMS shall use Universal Resource Indicators (URIs) and namespace constructs using conventions described in RFC3986.	X	X	X	
C3I-355	Constellation SYSTEMS shall use a hierarchical addressing structure as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-357	Constellation SYSTEMS shall use a common file naming convention as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book,	X	X	X	

Section/ Req #	Section/Requirement	Phasing ISS	Sortie	Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
	Volume 4: Information Representation Specification, Sec 3.3.				
C3I-366	Constellation SYSTEMS shall issue inter-SYSTEM COMMANDS in the format defined by the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Sec 3.8.	X	X	X	
C3I-544	Constellation SYSTEMS shall exchange application layer security policies between SYSTEMS in a representation that complies with CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-545	Constellation SYSTEMS shall exchange application layer cryptographic keys between SYSTEMS in a representation that complies with the CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-546	Constellation SYSTEMS shall exchange application layer identity information between SYSTEMS in a representation that complies with CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book,	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Volume				
C3I-652	Constellation SYSTEMS shall exchange application layer security audit data between SYSTEMS in a representation that complies with the CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-661	Constellation Systems shall define METADATA that complies with the CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
3.6.2	***Adaptive Information Definition***				***Compliance with this section is required for more adaptive (ad-hoc) interoperable information definition for information exchanged between MS and GS, CEV, LSAM, CLV, CaLV. Note that this functionality is not phased in until lunar sortie.***
C3I-215	Constellation SYSTEMS shall define TELEMETRY processing algorithms in accordance with CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-222	Constellation SYSTEMS shall use a hierarchical naming scheme in accordance with the CXP-70022, Constellation Command, Control,		X	X	

Section/ Req #	Section/Requirement	Phasing ISS	Phasing Sortie	Phasing Outpost	Phasing Rationale / Assumptions for Intra-System Requirements
	Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.				
C3I-547	Constellation SYSTEMS shall request data using data identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-548	Constellation SYSTEMS shall request files using file identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27>of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-549	Constellation SYSTEMS shall construct requests for data using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR) Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 4: Information		X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Representation Specification.				
C3I-550	Constellation SYSTEMS shall construct requests for file submissions and retrievals using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR) Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	

Table Appendix E-7 - C3I Interoperability Requirements Applicability to EVA

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
3.1	**RF Communication**				
3.1.1	***Common RF Communication***				***Compliance with this section is required for interoperable communications between EVA and LSAM or surface systems. Note that these requirements dictate spectrum, channel, interference compatibility.***
C3I-3	Constellation SYSTEMS shall comply with spectrum selection/allocation, certification and usage restriction policies set forth in NASA Policy Directive (NPD) 2570.5D, NASA Electromagnetic (EM) Spectrum Management.	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-5	Constellation SYSTEMS shall use transmit/receive frequency assignments and spectrum characteristics as defined in CxP 70022 Constellation Command, Control, Communications and Information (C3I) Interoperability Standards Book, Volume 2: Constellation Spectrum and Channel Plan.	X	X	X	
C3I-584	Constellation SYSTEMS shall comply with radio frequency allocation and conditions of assignment for frequency spectrum usage approved by the National Telecommunications & Information Administration (NTIA).	X	X	X	
3.1.2	**Operational Pt-to-Pt RF Communication**				***No current requirement for this class of communications on EVA.***
3.1.2.1	***Common Operational Pt-to-Pt RF Communication***				***No current requirement for this class of communications on EVA.***
C3I-6	Constellation SYSTEMS shall transmit using LEFT-HAND CIRCULAR POLARIZATION for operational point-to-point links.				
C3I-7	Constellation SYSTEMS shall receive using LEFT-HAND CIRCULAR POLARIZATION for operational point-to-point links.				
C3I-11	Constellation SYSTEMS shall communicate using at least two independent transmit/receive frequency pairs within the near Earth S-band spectrum allocation for multi-SYSTEM, simultaneous operational point-to-point communications.				
C3I-22	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK				

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	(LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1.O-1, Section 3 to transmit data streams for operational point-to-point links.				
C3I-23	Constellation SYSTEMS shall use bit randomization techniques in accordance with CCSDS 131.0-B-1 for randomization of transmitted data streams for operational point-to-point links.				
C3I-590	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3 for decoding received data streams using FORWARD ERROR CORRECTION for operational point-to-point links.				
C3I-592	Constellation SYSTEMS shall use bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-randomization of received data streams for operational point-to-point links.				
C3I-594	Constellation SYSTEMS shall apply the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 as specified in CCSDS 131.1-O-1, Section 3.5 transmitted FEC code block frames for operational point-to-point links.				
C3I-596	Constellation SYSTEMS shall comply with the specifications for service access points as defined in section 3 of the AOS Space Data Link Protocol 732.0.B-2 for reception of				

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Multiprotocol Interconnect over Frame Relay using the CCSDS AOS Virtual Channel Access (VCA) service over operational point-to-point links.				
C3I-612	Constellation SYSTEMS shall transmit Multiprotocol Interconnect over Frame Relay (MPoFR) as serial octet-aligned streams per CCSDS recommendation "IP over CCSDS Space Links", CCSDS 702.1-R-1, using the Virtual Channel Access (VCA) service of CCSDS Advanced Orbiting Systems (AOS) Space Link Protocol as specified in CCSDS 732.0-B-2 for operational point-to-point links.				
C3I-653	Constellation SYSTEMS shall enable and disable communication link forward error correction (FEC) upon receipt of COMMAND for operational point-to-point links.				
C3I-668	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for transmission of IP packets for operational point-to-point links.				
C3I-669	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for reception of IP packets for operational point-to-point links.				
C3I-670	Constellation SYSTEMS shall use the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 for synchronization of received FEC code block frames as specified in				

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	CCSDS 131.1-O-1 for operational point-to-point links.				
C3I-671	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for transmission of non-FEC coded data streams for operational point-to-point links.				
C3I-672	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for resolution of symbol phase ambiguity of non-FEC coded data streams for operational point-to-point links.				
3.1.2.2	***Point A Operational Pt-to-Pt RF Communication***				***No current requirement for this class of communications on EVA.***
C3I-308	Constellation point A SYSTEMS shall coherently re-transmit the received carrier with a turn-around ratio of 240/221(transmit/receive) for coherent point-to-point link operation.				
C3I-314	Constellation point A SYSTEMS shall coherently re-transmit the received range channel data to point B SYSTEM.				
C3I-350	Constellation point A SYSTEMS shall provide a non-coherent mode of operation for operational point-to-point links.				
C3I-573	Constellation point A SYSTEMS shall use transmit signals with modulation schemes in accordance with Table 3.1-2 for operational point-to-point links.				
C3I-574	Constellation point A SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-3 for				

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	operational point-to-point links.				
C3I-633	Constellation point A SYSTEMS shall transmit independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 (DG1).				
3.1.2.3	***Point B Operational Pt-to-Pt RF Communication***				***No current requirement for this class of communications on EVA.***
C3I-315	Constellation point B SYSTEMS shall process the coherent turn-around carrier to make radiometric measurements of range rate data (two-way Doppler data) for operational point-to-point links.				
C3I-572	Constellation point B SYSTEMS shall process coherent turn-around ranging channel data to provide radiometric measurements of range data for operational point-to-point links.				
C3I-575	Constellation point B SYSTEMS shall transmit signals with modulation schemes in accordance with Table 3.1-3 for operational point-to-point links.				
C3I-576	Constellation point B SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-2 for operational point-to-point links.				
C3I-591	Constellation Point B SYSTEMS shall generate and modulate the range channel (Q channel) with the Forward Link Range Channel PN code as defined in the Space Network Interoperable PN Code Libraries, Rev. 1 (451-PN CODE-SNIP).				

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-634	Constellation point B SYSTEMS shall receive independent, non-bit interleaved data streams on the inphase and quadrature modulation channels when using Data Group 1 (DG1).				
3.1.3	**High-Rate Pt-to-Pt RF Communication**				***No current requirement for this class of communications on EVA.***
3.1.3.1	***Common High Rate RF Communication***				***No current requirement for this class of communications on EVA.***
C3I-30	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3, to transmit data streams for high rate point-to-point links.				
C3I-31	Constellation SYSTEMS shall use bit randomization techniques in accordance with CCSDS 131.0-B-1 for randomization of transmitted data streams for high rate point-to-point links.				
C3I-581	Constellation SYSTEMS shall transmit using Right-hand Circular polarization for high rate point-to-point links.				
C3I-583	Constellation SYSTEMS shall use CCSDS Rate ½ LOW DENSITY PARITY CHECK (LDPC) FORWARD ERROR CORRECTION (FEC) as specified by CCSDS 131.1-O-1, Section 3, for decoding of received data streams using FEC for high rate point-to-point links.				
C3I-589	Constellation SYSTEMS shall receive using Right-hand Circular polarization for high-rate point-to-point links.				
C3I-598	Constellation SYSTEMS shall				

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	use bit de-randomization techniques in accordance with CCSDS 131.0-B-1 for de-randomization of received data streams for high rate point-to-point links.				
C3I-600	Constellation SYSTEMS shall apply the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 as specified in CCSDS 131.1-O-1, Section 3.5, to transmit FEC code blocks for high rate point-to-point links.				
C3I-601	Constellation SYSTEMS shall comply with the specifications for service access points as defined in section 3 of AOS Space Data Link Protocol 732.0.B-2 for reception of Multiprotocol Interconnect over Frame Relay using the CCSDS AOS Virtual Channel Access service over high rate point-to-point links.				
C3I-603	Constellation SYSTEMS shall transmit Multiprotocol Interconnect over Frame Relay (MPoFR) as serial octet-aligned streams per CCSDS recommendation “IP over CCSDS Space Links”, CCSDS 702.1-R-1, using the Virtual Channel Access (VCA) service of CCSDS Advanced Orbiting Systems (AOS) Space Link Protocol as specified in CCSDS 732.0-B-2 for High Rate point-to-point links.				
C3I-632	Constellation SYSTEMS shall enable and disable communication link forward error correction (FEC) upon receipt of COMMAND for high				

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	rate point-to-point links.				
C3I-673	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for transmission of IP packets for high rate point-to-point links.				
C3I-674	Constellation SYSTEMS shall use Multiprotocol Interconnect over Frame Relay (MPoFR) as specified by RFC 2427 for reception of IP packets for high rate point-to-point links.				
C3I-675	Constellation SYSTEMS shall use the 64-bit Attached Sync Marker (ASM) as defined in CCSDS 131.0-B-1 for synchronization of received FEC code block frames as specified in CCSDS 131.1-O-1 for high rate point-to-point links.				
C3I-676	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for transmission of non-FEC coded data streams for high rate point-to-point links.				
C3I-677	Constellation SYSTEMS shall use Non-Return-to-Zero-Mark (NRZ-M) coding for resolution of symbol phase ambiguity of non-FEC coded data streams for high rate point-to-point links.				
3.1.3.2	***Point A High-rate Pt-to-Pt RF Communication***				***No current requirement for this class of communications on EVA.***
C3I-577	Constellation point A SYSTEMS shall use transmit signals with modulation schemes in accordance with Table 3.1-4 for high rate point-to-point links.				
C3I-578	Constellation point A SYSTEMS shall receive signals				

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	with modulation schemes in accordance with Table 3.1-5 for high rate point-to-point links.				
3.1.3.3	***Point B High-rate Pt-to-Pt RF Communication***				***No current requirement for this class of communications on EVA.***
C3I-579	Constellation point B SYSTEMS shall transmit signals with modulation schemes in accordance with Table 3.1-5 for high rate point-to-point links.				
C3I-580	Constellation point B SYSTEMS shall receive signals with modulation schemes in accordance with Table 3.1-4 for high rate point-to-point links.				
3.1.4	***Multipoint Proximity RF Communication***				***Compliance with this section is required for interoperable communications between EVA and LSAM or surface systems.***
	RESERVED	TBD	TBD	TBD	
3.1.5	**Recovery RF Communication**				***Recovery communications are not required for EVA (would use CEV's system).*** ***Compliance with this section is required for interoperable RF contingency voice communications interfaces between EVA and LSAM or CEV as a backup voice link.***
3.1.5.1	***Common Recovery RF Communication***				
C3I-347	Constellation SYSTEMS shall transmit to the COSPAS/SARSAT system using the spectrum guidelines provided by ITU-R Recommendation M.633.				
C3I-362	Constellation SYSTEMS shall use amplitude modulation (AM) for analog voice communication with US and international search				

		Phasing			
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	and rescue forces.				
C3I-363	Constellation SYSTEMS shall transmit to the COSPAS/SARSAT system per COSPAS/SARSAT document C/S T.001 Sections 2 and 3.				
C3I-678	Constellation SYSTEMS shall use narrowband frequency modulation (FM) for analog voice communication with US and international maritime search and rescue forces.				
C3I-679	Constellation SYSTEMS shall communicate using the US UHF SATCOM system per MIL-STD-188-181.				
3.1.6	**RF Contingency Voice Communication**				***Compliance with this section is required <TBR E-1> for interoperable RF contingency voice communications interfaces between EVA and LSAM or CEV as a backup voice link.***
3.1.6.1	***Common RF Contingency Voice Communication***				
C3I-385	Constellation SYSTEMS shall modulate the transmitted carrier using amplitude modulation for analog, half-duplex Contingency Voice links.	X	X	X	
C3I-680	Constellation SYSTEMS shall receive an amplitude modulated carrier for Contingency Voice links.	X	X	X	
3.1.7	**Future High Rate Link Class**				
	RESERVED	TBD	TBD	TBD	
3.1.8	**Vehicle Internal Wireless Link Class**				
C3I-681	Constellation SYSTEMS shall use IEEE 802.11g on non-critical internal local area	X	X	X	

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	wireless data networks.				
3.2	**Hard-Line Communication**				
3.2.1	***High-Rate, Hard-Line Communication***				***Compliance with this section is required for interoperable hard-line (IP) communications between EVA and LSAM.*** ***Note that this may not apply to the EVA umbilical interface to EVA suits that do not include a PLS.***
C3I-58	Constellation SYSTEMS shall use IEEE Std 1394b™-2002 and SAE-AS5643/1 with RFC-2734 for high data volume, hard-line connections between Constellation SYSTEMS.	X	X	X	
3.2.2	***High-Rate, Ground Hard-Line Communication***				
C3I-336	Constellation SYSTEMS shall use ground institutional IP routed networks.				
3.2.3	***Deterministic Hard-Line Communication***				***There are no EVA interfaces requiring deterministic closed-loop control.***
C3I-682	Constellation SYSTEMS shall use SAE-AS5643 and AS5643/1 standards for deterministic rate based hard-line connections between Constellation SYSTEMS.				
3.3	**Network**				
3.3.1	***Connectivity***				***Compliance with this section is required for interoperable IP network communications between EVA and LSAM or surface systems (in addition to networked communications with MS or CEV).***
C3I-61	Constellation SYSTEMS shall implement version 4 of the Internet Protocol (IPv4) as specified in STD-0005.	X			IPv4 is for ISS Missions only.
C3I-62	Constellation SYSTEMS shall use unicast addresses as defined in RFC-1918, Address	X			IPv4 is for ISS Missions only.

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	Allocation for Private Internets.				
C3I-63	Constellation SYSTEMS shall use multicast addresses as defined in RFC-3171, IANA Guidelines for IPv4 Multicast Address Assignments.	X			IPv4 is for ISS Missions only.
C3I-64	Constellation SYSTEMS shall provide a mechanism to manually configure the addresses of all IP-addressable interfaces.	X	X	X	
C3I-72	Constellation SYSTEMS shall provide IP network address to data link layer address mappings for IP addresses external to the SYSTEM.	X	X	X	
C3I-73	Constellation SYSTEMS shall use managed associations to map IP addresses to data link layer addresses for IP addresses external to the SYSTEM.	X	X	X	
C3I-74	Constellation SYSTEMS shall accept modifications to the IP address to data-link layer address mapping information via the network for IP addresses external to the SYSTEM.	X	X	X	
C3I-75	Constellation SYSTEMS shall perform multi-hop routing as specified in RFC-1812, Requirements for IP Version 4 Routers as updated by RFC-2644.	X			IPv4 is for ISS Missions only.
C3I-76	Constellation SYSTEMS shall comply with RFC-1122 (STD-0003), Requirements for Internet Hosts – Communications Layers.	X			IPv4 is for ISS Missions only.
C3I-78	Constellation SYSTEMS shall use manually configured routes instead of dynamically learned ones when there is an exact match in the prefix length for a	X	X	X	

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	given destination external to the SYSTEM.				
C3I-79	Constellation SYSTEMS shall use static routing table entries.	X	X	X	
C3I-80	Constellation SYSTEMS shall accept changes to the routing tables via the network.	X	X	X	
C3I-87	Constellation SYSTEMS shall advertise only non-default routes via the routing protocols.	X	X	X	
C3I-89	Constellation SYSTEMS shall have a default route specified in the routing tables.	X	X	X	
C3I-90	Constellation SYSTEMS shall fail over to default routes when there is a loss of all routing information or a loss of communication to all SYSTEM network neighbors participating in the dynamic routing protocol for more than 20 seconds.	X	X	X	
C3I-93	Constellation SYSTEMS shall resolve symbolic names to IP addresses using static host table.	X	X	X	
C3I-95	Constellation SYSTEMS shall accept changes to the static host table via the network.	X	X	X	
C3I-96	Constellation SYSTEMS shall implement RFC-2474, Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers.	X	X	X	
C3I-97	Constellation SYSTEMS shall implement RFC-2211, Specification of the Controlled-Load Network System Service.	X	X	X	
C3I-98	Constellation SYSTEMS shall implement <TBR 3-25> RFC-2205, Resource ReSerVation Protocol (RSVP) Version 1 Functional Specification.	X	X	X	

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C3I-99	Constellation SYSTEMS shall implement the Simple Network Management Protocol version 3 as defined in STD0062.	X	X	X	
C3I-103	Constellation SYSTEMS shall implement Internet STD-0007: TRANSMISSION CONTROL PROTOCOL (TCP).	X	X	X	
C3I-104	Constellation SYSTEMS shall implement RFC-1323 - TCP Extensions for High Performance.	X	X	X	
C3I-105	Constellation SYSTEMS shall implement STD-0006 - UDP, USER DATAGRAM PROTOCOL, for communication with all IP-addressable endpoints.	X	X	X	
C3I-106	Constellation SYSTEMS shall implement RFC-3550 (STD-0064), RTP: A Transport Protocol for Real-Time Applications.	X	X	X	
C3I-281	Constellation SYSTEMS shall implement RFC-3140, Per Hop Behavior Identification Codes.	X	X	X	
C3I-282	Constellation SYSTEMS shall implement RFC-3246, An Expedited Forwarding PHB (PER HOP BEHAVIOR).	X	X	X	
C3I-619	Constellation SYSTEMS shall implement a split-connection TCP Performance Enhancing Proxy (PEP) that implements the SCPS-TP transport layer per CCSDS 714.0.B-1, Space Communications Protocol Specification (SCPS) - Transport Protocol (SCPS-TP), Blue Book, Issue 1, May 1999, on links where the maximum	X	X	X	

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	bandwidth*delay product of the link exceeds 1e6 bits and/or whose design bit error rate is equal to or greater than 1e-6.				
C3I-620	Constellation SYSTEMS shall implement Internet Protocol version 6 (IPv6) per RFC 2460 Internet Protocol, Version 6 (IPv6) Specification.		X	X	IPv6 Lunar Missions
C3I-621	Constellation SYSTEMS shall implement the Internet Control Messaging Protocol (ICMP) per RFC 792, Internet Control Message Protocol.	X			IPv4 Lunar Missions
C3I-622	Constellation SYSTEMS shall implement the Internet Control Messaging Protocol version 6 (ICMPv6) per RFC 4443 Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification.		X	X	IPv6 Lunar Missions
C3I-654	Constellation SYSTEMS shall implement the Multiprotocol Border Gateway Protocol (MBGP) as specified in RFC-2858.	X	X	X	
C3I-655	Constellation SYSTEMS shall implement the Multicast Listener Discovery protocol, version 2, as specified in RFC-3810 <TBR 3-24>.		X	X	This protocol is required to join end systems to multicast groups in IPv6.
C3I-656	Constellation SYSTEMS shall implement Multicast Extension to OSPF as specified in RFC-1584.	X			MOSPF is IPv4 specific.
C3I-657	Constellation SYSTEMS shall implement the Internet Group Management Protocol (IGMP) as specified in RFC-3376.	X			This protocol is required to join end systems to multicast groups in IPv4.
3.3.2	***Dynamic Routing Between Systems***				***Compliance with this section is required for interoperable IP network dynamic routing between EVA and MS, LSAM, and surface systems***

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					(particularly in a mesh configuration).
C3I-82	Constellation SYSTEMS shall implement RFC-2453, STD-0056 - RIP Version 2.	X			
C3I-83	Constellation SYSTEMS shall implement RFC-2328 (STD-0054), OPEN SHORTEST PATH FIRST (OSPF) Version 2.	X			
C3I-295	Constellation SYSTEMS shall implement RFC-3626 Optimized Link State Routing Protocol (OLSR).		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
C3I-662	Constellation SYSTEMS shall implement RFC-2080, RIPng for IPv6 .		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
C3I-663	Constellation SYSTEMS shall implement RFC-2740 , OSPF for IPv6.		X	X	Dynamic routing phasing for Lunar Missions under IPv6.
3.3.3	***External Connectivity***				***The EVA system does not interface with external networks.***
C3I-81	Constellation SYSTEMS shall implement RFC-4271-A BORDER GATEWAY PROTOCOL (BGP) Version 4, as specified in RFC4271 "A BORDER GATEWAY PROTOCOL 4 (BGP-4)				
C3I-280	Constellation SYSTEMS shall use external routes learned by Border Gateway Protocol Version 4, as specified in RFC4271 “A Border Gateway Protocol 4 (BGP-4), before those learned via other dynamic routing protocols.				
3.3.4	***Name Service***				***Compliance with this section is required for IP network name services used for network communications between EVA and LSAM or surface systems. This is required to reduce systems***

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					management overhead associated with IP address management. ***NOTE: May need to discuss. Depends on assumed operations concept for surface systems and the ad-hoc network topologies that may be required. However, assume that suits would be designated by name rather than IP to allow for suits to be used on different network segments.***
C3I-296	Constellation SYSTEMS shall implement IETF STD-0013, Domain Name SYSTEM.				
3.3.5	***Disruption Tolerance***				***EVA would require this capability to allow interoperable end-to-end communication with delayed communications links (from lunar surface to earth) or in disruption prone areas due to surface blockage.***
C3I-107	Constellation SYSTEMS shall implement <TBR 3-12> DTN, DELAY/DISRUPTION TOLERANT NETWORKING Specifications, http://www.ietf.org/internet-drafts/draft-irtf-dtnrg-bundle-spec-05.txt.		X	X	
3.3.6	***Dynamic Address Assignment***				***EVA systems would not be required <TBD E-27> to dynamicallyassign IP addresses.*** ***NOTE: Need to discuss. Depends on assumed operations concept for surface systems and the ad-hoc network topologies that may be required. However, suits may need to provide this function to allow for surface systems to be used on different network segments.***
C3I-67	Constellation SYSTEMS shall implement the DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP) Server functions as specified in RFC-2131 and updated by RFC-4361.	X	X	X	Support for mobile IP end-points such as suits, laptops, and hand-helds. This is subject to removal without someone championing this requirement for ISS.

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3.3.7	***Dynamic Address Retrieval***				***EVA systems will need the ability to dynamically retrieve their addresses in order to work with different network segments (internal LSAM, surface WAN, ad-hoc remote network, etc.)***
C3I-69	Constellation SYSTEMS shall obtain network addresses via the DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP) as specified in RFC-2131 and updated by RFC-4361.	X	X	X	
C3I-70	Constellation SYSTEMS shall 'self-assign' an IP address from the 169.254.0.0/16 private address block as specified in RFC-3927, Dynamic Configuration of IPv4 Link-Local Addresses of IPv4 interfaces when unable to obtain an IP address from pre-configuration information and/or DHCP.	X	X	X	
3.3.8	***Tunneling***				***Compliance with this section is required for network tunneling on interfaces between EVA and LSAM or surface systems. Tunneling is necessary to support Mobile IP and allows controllers to perform traffic engineering and to force traffic to follow particular paths in the network that are different from the routes that might be 'default' or learned via dynamic routing protocols.***
C3I-92	Constellation SYSTEMS shall implement RFC-2784, GENERIC ROUTING ENCAPSULATION (GRE).	X			
C3I-664	Constellation SYSTEMS shall implement RFC-2473, Generic Packet Tunneling in IPv6 Specification.		X	X	IPv6 version for Lunar Missions
3.3.9	***Header Compression***				***Compliance with this section is required for***

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					network tunneling on interfaces between EVA and LSAM or surface systems. Tunneling is necessary to support Mobile IP and allows controllers to perform traffic engineering and to force traffic to follow particular paths in the network that are different from the routes that might be 'default' or learned via dynamic routing protocols.
C3I-307	Constellation SYSTEMS shall implement RFC-2507 IP Header Compression.	X	X	X	
C3I-588	Constellation SYSTEMS shall implement RFC 2508 Compressing IP/UDP/RTP Headers for Low-Speed Serial Links.	X	X	X	
3.3.10	***Network Management***				***Compliance with this section is required for network management interfaces between EVA and MS (via LSAM or surface systems).***
C3I-100	Constellation SYSTEMS shall implement RFC-4293 Management Information Base for the Internet Protocol (IP).	X	X	X	
C3I-294	Constellation SYSTEMS shall implement RFC-4292, IP Forwarding Table MIB.	X	X	X	
C3I-298	Constellation SYSTEMS shall implement RFC-3747, Differentiated Services Configuration MIB.	X	X	X	
C3I-299	Constellation SYSTEMS shall implement RFC-3289, MIB for the Differentiated Services Architecture.	X	X	X	
C3I-300	Constellation SYSTEMS shall implement RFC-2213, Integrated Services Management Information Base using SMIv2.	X	X	X	
C3I-301	Constellation SYSTEMS shall implement RFC-4022, Management Information Base	X	X	X	

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	for TRANSMISSION CONTROL PROTOCOL (TCP).				
C3I-302	Constellation SYSTEMS shall implement RFC-4113, Management Information Base for USER DATAGRAM PROTOCOL (UDP).	X	X	X	
C3I-303	Constellation SYSTEMS shall implement RFC-2959, Real Time Protocol MIB.	X	X	X	
3.4	**Security**				***Compliance with this section is required for secure, interoperable communications between EVA and MS, LSAM, or surface systems. Note that this may particularly be required to secure medical communications between crew and ground.***
3.4.1	***Network Layer Security***				
C3I-199	Constellation SYSTEMS shall implement RFC 4301, Security architecture for the Internet Protocol, at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-200	Constellation SYSTEMS shall implement RFC-4302, IP AUTHENTICATION HEADER (AH), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-201	Constellation SYSTEMS shall implement RFC-4303, IP ENCAPSULATING SECURITY PAYLOAD (ESP), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
C3I-204	Constellation SYSTEMS shall implement RFC 4305, Cryptographic Algorithm Implementation Requirements for Encapsulating Security Payload (ESP) and Authentication Header (AH), at	X	X	X	

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	all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.				
C3I-565	Constellation SYSTEMS shall implement RFC 4309, Using Advanced Encryption Standard (AES) CCM Mode with IPsec Encapsulating Security Payload (ESP), at all Internet Protocol (IP) based inter-SYSTEM data exchange interfaces.	X	X	X	
3.4.2	***Internet Key Exchange***				
C3I-209	Constellation SYSTEMS shall implement RFC-4306, The INTERNET KEY EXCHANGE (IKEv2), for all inter-SYSTEM management of security associations and keys used by IPSec.	X	X	X	
C3I-568	Constellation SYSTEMS shall implement RFC-4307, Cryptographic Algorithms for use in the Internet Key Exchange Version 2 (IKEv2).	X	X	X	
3.4.3	***Application Layer Security***				
C3I-210	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for inter-SYSTEM updates of security processing logic.	X	X	X	
C3I-566	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book,	X	X	X	

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	Volume 5: Data Exchange Protocol Specification for all inter-system exchanges of the security policy information used by application layer security functions.				
C3I-567	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification and described in the for all inter-SYSTEM exchanges of the identity data used by application layer security functions.	X	X	X	
C3I-569	Constellation SYSTEMS shall comply with the security mechanisms specified in CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5: Data Exchange Protocol Specification for all inter-SYSTEM exchanges of the authentication keys and encryption keys used by application layer security functions.	X	X	X	
3.4.4	***FIPS Compliant Algorithms***				
C3I-203	Constellation SYSTEMS shall implement FIPS PUB 197, ADVANCED ENCRYPTION STANDARD (AES), for all ENCRYPTION of inter-SYSTEM data exchanges.	X	X	X	
C3I-206	Constellation SYSTEMS shall implement SHA-1 per FIPS PUB 180-2, Secure Hash	X	X	X	

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	Standard, for hash generation performed for inter-SYSTEM data exchanges.				
C3I-207	Constellation SYSTEMS shall implement FIPS PUB 186-2, DIGITAL SIGNATURE STANDARD (DSS) using the DIGITAL SIGNATURE ALGORITHM (DSA) for all digital signatures exchanged between SYSTEMS.	X	X	X	
C3I-208	Constellation SYSTEMS shall implement FIPS PUB 198, Keyed-HASH MESSAGE AUTHENTICATION CODE (HMAC), for all MESSAGE AUTHENTICATION CODES (MACs) exchanged between SYSTEMS.	X	X	X	
C3I-665	Constellation SYSTEMS shall implement SHA-256 per FIPS PUB 180-2, Secure Hash Standard, for hash generation performed for inter-SYSTEM data exchanges.	X	X	X	
C3I-666	Constellation SYSTEMS shall implement truncation of SHA-1 based 160-bit Hash Based Messaged Authentication Codes (HMACs) to 96 bits.	X	X	X	
C3I-667	Constellation SYSTEMS shall implement truncation of SHA-256 based 256-bit Hash Based Messaged Authentication Codes (HMACs) to 128 bits.	X	X	X	
3.5	**Data Exchange**				
3.5.1	***Voice Exchange***				***Compliance with this section is required for interoperable voice communications between EVA and LSAM (or MS via LSAM).***
C3I-173	Constellation SYSTEMS shall assign a delivery priority to voice data sent to another	X	X	X	

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	SYSTEM.				
C3I-175	Constellation SYSTEMS shall transfer voice data over a one way link.	X	X	X	
C3I-176	Constellation SYSTEMS shall use ITU G.729, "Coding of speech at 8 kbit/s using conjugate-structure algebraic-code-excited linear prediction (CS-ACELP)".	X	X	X	
C3I-555	Constellation SYSTEMS shall transfer voice in accordance with IETF RFC 3550, Real-Time Transport Protocol (RTP).	X	X	X	
C3I-557	Constellation SYSTEMS shall provide a mechanism to add voice codecs.	X	X	X	
C3I-558	Constellation SYSTEMS shall provide a mechanism to remove voice codecs.	X	X	X	
3.5.2	***Motion Imagery Transfer***				***Compliance with this section is required for interoperable motion imagery transfer between EVA and LSAM (or MS via LSAM).***
C3I-184	Constellation SYSTEMS shall assign a delivery priority for motion imagery data sent to another SYSTEM.	X	X	X	
C3I-185	Constellation SYSTEMS shall transfer motion imagery over a one way link.	X	X	X	
C3I-186	Constellation SYSTEMS shall use ITU H.264, "Advanced Video Coding for Generic Audiovisual Services".	X	X	X	
C3I-283	Constellation SYSTEMS shall transfer motion imagery in accordance with RFC 3550, Real-Time Transport Protocol (RTP).	X	X	X	
C3I-559	Constellation SYSTEMS shall use <TBR 3-13> ISO/IEC	X	X	X	

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	15444-3, "Motion JPEG 2000 (Part 3)".				
C3I-560	Constellation SYSTEMS shall provide a mechanism to add MOTION IMAGERY codecs.	X	X	X	
C3I-561	Constellation SYSTEMS shall provide a mechanism to remove MOTION IMAGERY codecs.	X	X	X	
3.5.3	***Data Exchange Message Formatting and Transmission***				***Compliance with this section is required for interoperable commanding between EVA and LSAM or surface systems.*** ***Note: This assumes that the surface systems will require some level of control from the EVA system.***
C3I-130	Constellation SYSTEMS shall transfer data exchange messages over a one way link.	X	X	X	
C3I-135	Constellation SYSTEMS shall use a common data exchange message format as defined in Appendix C of CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 5:	X	X	X	
C3I-659	Constellation SYSTEMS shall assign to each data exchange message that is sent to another SYSTEM the priority that was assigned to the Data of that data exchange message.	X	X	X	
3.5.4	***File Transfer***				***Compliance with this section is required for interoperable telemetry between EVA and LSAM (or MS via LSAM).***
C3I-161	Constellation SYSTEMS shall assign a delivery priority to each file sent to another SYSTEM.	X	X	X	
C3I-165	Constellation SYSTEMS shall transfer files in accordance with CCSDS 727.0-B-3, "CCSDS	X	X	X	

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	File Delivery Protocol (CFDP) – Recommended Standard".				
3.5.5	***Time Exchange***				***Compliance with this section is required for interoperable file transfer between EVA and LSAM (or MS via LSAM).***
C3I-111	Constellation SYSTEMS shall exchange time in accordance with IETF RFC 1305, NETWORK TIME PROTOCOL (NTP) Version 3.	X	X	X	
3.5.6	***Traffic Prioritization***				***Compliance with this section is required for time exchange/sync interfaces between EVA LSAM (or MS via LSAM).***
C3I-660	Constellation SYSTEMS shall effect observance of the delivery priorities assigned to voice data, motion imagery data, data exchange messages, and files by invoking traffic prioritization mechanisms provided by the underlying network.	X	X	X	
3.6	**Information**				
3.6.1	***Basic Information Definition***				***Compliance with this section is required for interoperable information definition for information exchanged between EVA and LSAM (or MS via LSAM) or surface systems.***
C3I-119	Constellation SYSTEMS shall use common COMMAND METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-140	Constellation SYSTEMS shall use common telemetry	X	X	X	

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	METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.				
C3I-157	Constellation SYSTEMS shall use a common convention for file formats as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3.	X	X	X	
C3I-169	Constellation SYSTEMS shall use common voice METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-180	Constellation SYSTEMS shall use common motion imagery METADATA as defined by the CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-228	Constellation SYSTEMS shall use data types as defined by the	X	X	X	

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	CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Section 3.3.				
C3I-229	Constellation SYSTEMS shall exchange METADATA that complies with the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-231	Constellation SYSTEMS shall use Universal Resource Indicators (URIs) and namespace constructs using conventions described in RFC3986.	X	X	X	
C3I-355	Constellation SYSTEMS shall use a hierarchical addressing structure as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
C3I-357	Constellation SYSTEMS shall use a common file naming convention as defined by the CxP 70022, Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification,	X	X	X	

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	Sec 3.3.				
C3I-366	Constellation SYSTEMS shall issue inter-SYSTEM COMMANDS in the format defined by the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification, Sec 3.8.	X	X	X	
C3I-544	Constellation SYSTEMS shall exchange application layer security policies between SYSTEMS in a representation that complies with CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-545	Constellation SYSTEMS shall exchange application layer cryptographic keys between SYSTEMS in a representation that complies with the CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-546	Constellation SYSTEMS shall exchange application layer identity information between SYSTEMS in a representation that complies with CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume	X	X	X	
C3I-652	Constellation SYSTEMS shall	X	X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	exchange application layer security audit data between SYSTEMS in a representation that complies with the CxP 70022, Constellation Command, Control, Communications, and Information (C3I) Interoperability Standards Book, Volume				
C3I-661	Constellation Systems shall define METADATA that complies with the CxP 70022 Constellation COMMAND, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.	X	X	X	
3.6.2	***Adaptive Information Definition***				***Compliance with this section is required for more adaptive (ad-hoc) interoperable information definition for information exchanged between EVA and LSAM (or MS via LSAM) or surface systems.*** ***Note that this functionality is not phased in until lunar sortie.***
C3I-215	Constellation SYSTEMS shall define TELEMETRY processing algorithms in accordance with CxP 70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-222	Constellation SYSTEMS shall use a hierarchical naming scheme in accordance with the CXP-70022, Constellation Command, Control, Communication, and		X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
	Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.				
C3I-547	Constellation SYSTEMS shall request data using data identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-548	Constellation SYSTEMS shall request files using file identifiers defined in the NExIOM & C3I System Of Registries (NCSOR), Section 3.13 <TBR 3-27>of the CxP 70022 Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	
C3I-549	Constellation SYSTEMS shall construct requests for data using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR) Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	

		Phasing			
Section/ Req #	**Section/Requirement**	**ISS**	**Sortie**	**Outpost**	**Phasing Rationale / Assumptions for Intra-System Requirements**
C3I-550	Constellation SYSTEMS shall construct requests for file submissions and retrievals using a protocol defined in the NExIOM & C3I System Of Registries (NCSOR) Section 3.13 <TBR 3-27> of the CxP 70022 Constellation Command, Control, Communication and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification.		X	X	

Appendix F Verification Cross Reference Matrix

Requirement Number	Section Number	Section Title	Method (***for reference only***)				Verification Requirement
			I	A	D	T	
C3I-3	C3I_3.1.1	Common RF Communication		X		X	C3I-3V
C3I-5	C3I_3.1.1	Common RF Communication		X		X	C3I-5V
C3I-6	C3I_3.1.2.1	Common Operational Point-to-Point RF Communication				X	C3I-6V
C3I-7	C3I_3.1.2.1	Common Operational Point-to-Point RF Communication				X	C3I-7V
C3I-11	C3I_3.1.2.1	Common Operational Point-to-Point RF Communication		X		X	C3I-11V
C3I-22	C3I_3.1.2.1	Common Operational Point-to-Point RF Communication	X			X	C3I-22V
C3I-23	C3I_3.1.2.1	Common Operational Point-to-Point RF Communication				X	C3I-23V
C3I-30	C3I_3.1.3.1	Common High Rate RF Communication	X		X	X	C3I-30V
C3I-31	C3I_3.1.3.1	Common High Rate RF Communication				X	C3I-31V
C3I-58	C3I_3.2.1	High-Rate, Hard-Line Communication					C3I-58V
C3I-61	C3I_3.3.1	Connectivity				X	C3I-61V
C3I-62	C3I_3.3.1	Connectivity				X	C3I-62V
C3I-63	C3I_3.3.1	Connectivity				X	C3I-63V
C3I-64	C3I_3.3.1	Connectivity				X	C3I-64V
C3I-67	C3I_3.3.6	Dynamic Address Assignment				X	C3I-67V
C3I-69	C3I_3.3.7	Dynamic Address Retrieval				X	C3I-69V
C3I-70	C3I_3.3.7	Dynamic Address Retrieval				X	C3I-70V
C3I-72	C3I_3.3.1	Connectivity				X	C3I-72V

Requirement Number	Section Number	Section Title	Method (*for reference only*)				Verification Requirement
			I	A	D	T	
C3I-73	C3I_3.3.1	Connectivity				X	C3I-73V
C3I-74	C3I_3.3.1	Connectivity				X	C3I-74V
C3I-75	C3I_3.3.1	Connectivity				X	C3I-75V
C3I-76	C3I_3.3.1	Connectivity				X	C3I-76V
C3I-78	C3I_3.3.1	Connectivity				X	C3I-78V
C3I-79	C3I_3.3.1	Connectivity				X	C3I-79V
C3I-80	C3I_3.3.1	Connectivity				X	C3I-80V
C3I-81	C3I_3.3.3	External Connectivity				X	C3I-81V
C3I-82	C3I_3.3.2	Dynamic Routing Between Systems				X	C3I-82V
C3I-83	C3I_3.3.2	Dynamic Routing Between Systems				X	C3I-83V
C3I-87	C3I_3.3.1	Connectivity				X	C3I-87V
C3I-89	C3I_3.3.1	Connectivity				X	C3I-89V
C3I-90	C3I_3.3.1	Connectivity				X	C3I-90V
C3I-92	C3I_3.3.8	Tunneling (GRE)				X	C3I-92V
C3I-93	C3I_3.3.1	Connectivity				X	C3I-93V
C3I-95	C3I_3.3.1	Connectivity				X	C3I-95V
C3I-96	C3I_3.3.1	Connectivity				X	C3I-96V
C3I-97	C3I_3.3.1	Connectivity				X	C3I-97V
C3I-98	C3I_3.3.1	Connectivity				X	C3I-98V
C3I-99	C3I_3.3.1	Connectivity				X	C3I-99V
C3I-100	C3I_3.3.10	Network Management				X	C3I-100V
C3I-103	C3I_3.3.1	Connectivity				X	C3I-103V
C3I-104	C3I_3.3.1	Connectivity				X	C3I-104V
C3I-105	C3I_3.3.1	Connectivity				X	C3I-105V
C3I-106	C3I_3.3.1	Connectivity				X	C3I-106V
C3I-107	C3I_3.3.5	Disruption Tolerance				X	C3I-107V
C3I-111	C3I_3.5.5	Time Exchange	X			X	C3I-111V
C3I-119	C3I_3.6.1	Basic Information Definition				X	C3I-119V
C3I-130	C3I_3.5.3	Data Exchange Message				X	C3I-130V

Requirement Number	Section Number	Section Title	Method (*for reference only*)				Verification Requirement
			I	A	D	T	
		Formatting and Transmission					
C3I-135	C3I_3.5.3	Data Exchange Message Formatting and Transmission	X				C3I-135V
C3I-140	C3I_3.6.1	Basic Information Definition				X	C3I-140V
C3I-157	C3I_3.6.1	Basic Information Definition	X		X		C3I-157V
C3I-161	C3I_3.5.4	File Transfer	X			X	C3I-161V
C3I-165	C3I_3.5.4	File Transfer				X	C3I-165V
C3I-169	C3I_3.6.1	Basic Information Definition				X	C3I-169V
C3I-173	C3I_3.5.1	Voice Exchange	X			X	C3I-173V
C3I-175	C3I_3.5.1	Voice Exchange				X	C3I-175V
C3I-176	C3I_3.5.1	Voice Exchange	X				C3I-176V
C3I-180	C3I_3.6.1	Basic Information Definition				X	C3I-180V
C3I-184	C3I_3.5.2	Motion Imagery Transfer	X			X	C3I-184V
C3I-185	C3I_3.5.2	Motion Imagery Transfer				X	C3I-185V
C3I-186	C3I_3.5.2	Motion Imagery Transfer	X				C3I-186V
C3I-199	C3I_3.4.1	Network Layer Security	X			X	C3I-199V
C3I-200	C3I_3.4.1	Network Layer Security	X			X	C3I-200V
C3I-201	C3I_3.4.1	Network Layer Security	X			X	C3I-201V
C3I-203	C3I_3.4.4	FIPS Compliant Algorithms	X			X	C3I-203V
C3I-204	C3I_3.4.1	Network Layer Security	X			X	C3I-204V
C3I-206	C3I_3.4.4	FIPS Compliant Algorithms	X			X	C3I-206V
C3I-207	C3I_3.4.4	FIPS Compliant Algorithms	X			X	C3I-207V
C3I-208	C3I_3.4.4	FIPS Compliant Algorithms	X			X	C3I-208V
C3I-209	C3I_3.4.2	Internet Key Exchange (IKE)	X			X	C3I-209V

Requirement Number	Section Number	Section Title	Method (*for reference only*)				Verification Requirement
			I	A	D	T	
C3I-210	C3I_3.4.3	Application Layer Security	X			X	C3I-210V
C3I-215	C3I_3.6.2	Adaptive Information Definition	X				C3I-215V
C3I-222	C3I_3.6.2	Adaptive Information Definition	X				C3I-222V
C3I-228	C3I_3.6.1	Basic Information Definition	X				C3I-228V
C3I-229	C3I_3.6.1	Basic Information Definition	X			X	C3I-229V
C3I-231	C3I_3.6.1	Basic Information Definition	X				C3I-231V
C3I-280	C3I_3.3.3	External Connectivity				X	C3I-280V
C3I-281	C3I_3.3.1	Connectivity				X	C3I-281V
C3I-282	C3I_3.3.1	Connectivity				X	C3I-282V
C3I-283	C3I_3.5.2	Motion Imagery Transfer	X			X	C3I-283V
C3I-294	C3I_3.3.10	Network Management				X	C3I-294V
C3I-295	C3I_3.3.2	Dynamic Routing Between Systems				X	C3I-295V
C3I-296	C3I_3.3.4	Name Service				X	C3I-296V
C3I-298	C3I_3.3.10	Network Management				X	C3I-298V
C3I-299	C3I_3.3.10	Network Management				X	C3I-299V
C3I-300	C3I_3.3.10	Network Management				X	C3I-300V
C3I-301	C3I_3.3.10	Network Management				X	C3I-301V
C3I-302	C3I_3.3.10	Network Management				X	C3I-302V
C3I-303	C3I_3.3.10	Network Management				X	C3I-303V
C3I-307	C3I_3.3.9	Header Compression				X	C3I-307V
C3I-308	C3I_3.1.2.2	Point A Operational Point-to-Point RF Communication				X	C3I-308V
C3I-314	C3I_3.1.2.2	Point A Operational Point-to-Point RF Communication		X		X	C3I-314V
C3I-315	C3I_3.1.2.3	Point B Operational Point-to-Point RF Communication		X		X	C3I-315V

Requirement Number	Section Number	Section Title	Method (*for reference only*)				Verification Requirement
			I	A	D	T	
C3I-336	C3I_3.2.2	High-Rate, Ground Hard-line Communication				X	C3I-336V
C3I-347	C3I_3.1.5.1	Common Recovery RF Communication		X		X	C3I-347V
C3I-350	C3I_3.1.2.2	Point A Operational Point-to-Point RF Communication				X	C3I-350V
C3I-355	C3I_3.6.1	Basic Information Definition	X				C3I-355V
C3I-357	C3I_3.6.1	Basic Information Definition	X				C3I-357V
C3I-362	C3I_3.1.5.1	Common Recovery RF Communication		X		X	C3I-362V
C3I-363	C3I_3.1.5.1	Common Recovery RF Communication		X		X	C3I-363V
C3I-366	C3I_3.6.1	Basic Information Definition	X			X	C3I-366V
C3I-385	C3I_3.1.6.1	Common RF Contingency Voice Communication				X	C3I-385V
C3I-544	C3I_3.6.1	Basic Information Definition	X			X	C3I-544V
C3I-545	C3I_3.6.1	Basic Information Definition	X			X	C3I-545V
C3I-546	C3I_3.6.1	Basic Information Definition	X			X	C3I-546V
C3I-547	C3I_3.6.2	Adaptive Information Definition	X			X	C3I-547V
C3I-548	C3I_3.6.2	Adaptive Information Definition	X			X	C3I-548V
C3I-549	C3I_3.6.2	Adaptive Information Definition	X			X	C3I-549V
C3I-550	C3I_3.6.2	Adaptive Information Definition	X			X	C3I-550V
C3I-555	C3I_3.5.1	Voice Exchange	X			X	C3I-555V
C3I-557	C3I_3.5.1	Voice Exchange	X			X	C3I-557V
C3I-558	C3I_3.5.1	Voice Exchange	X			X	C3I-558V
C3I-559	C3I_3.5.2	Motion Imagery Transfer	X				C3I-559V

Requirement Number	Section Number	Section Title	Method (*for reference only*)				Verification Requirement
			I	A	D	T	
C3I-560	C3I_3.5.2	Motion Imagery Transfer	X			X	C3I-560V
C3I-561	C3I_3.5.2	Motion Imagery Transfer	X			X	C3I-561V
C3I-565	C3I_3.4.1	Network Layer Security	X			X	C3I-565V
C3I-566	C3I_3.4.3	Application Layer Security	X			X	C3I-566V
C3I-567	C3I_3.4.3	Application Layer Security	X			X	C3I-567V
C3I-568	C3I_3.4.2	Internet Key Exchange (IKE)	X			X	C3I-568V
C3I-569	C3I_3.4.3	Application Layer Security	X			X	C3I-569V
C3I-572	C3I_3.1.2.3	Point B Operational Point-to-Point RF Communication				X	C3I-572V
C3I-573	C3I_3.1.2.2	Point A Operational Point-to-Point RF Communication				X	C3I-573V
C3I-574	C3I_3.1.2.2	Point A Operational Point-to-Point RF Communication				X	C3I-574V
C3I-575	C3I_3.1.2.3	Point B Operational Point-to-Point RF Communication				X	C3I-575V
C3I-576	C3I_3.1.2.3	Point B Operational Point-to-Point RF Communication				X	C3I-576V
C3I-577	C3I_3.1.3.2	Point A High-Rate Point-to-Point RF Communication				X	C3I-577V
C3I-578	C3I_3.1.3.2	Point A High-Rate Point-to-Point RF Communication				X	C3I-578V
C3I-579	C3I_3.1.3.3	Point B High-Rate Point-to-Point RF Communication				X	C3I-579V
C3I-580	C3I_3.1.3.3	Point B High-Rate Point-to-Point RF Communication				X	C3I-580V
C3I-581	C3I_3.1.3.1	Common High Rate RF Communication				X	C3I-581V
C3I-583	C3I_3.1.3.1	Common High Rate RF	X		X	X	C3I-583V

Requirement Number	Section Number	Section Title	Method (*for reference only*)				Verification Requirement
			I	A	D	T	
		Communication					
C3I-584	C3I_3.1.1	Common RF Communication	X				C3I-584V
C3I-588	C3I_3.3.9	Header Compression				X	C3I-588V
C3I-589	C3I_3.1.3.1	Common High Rate RF Communication				X	C3I-589V
C3I-590	C3I_3.1.2.1	Common Operational Point-to-Point RF Communication	X			X	C3I-590V
C3I-591	C3I_3.1.2.3	Point B Operational Point-to-Point RF Communication		X		X	C3I-591V
C3I-592	C3I_3.1.2.1	Common Operational Point-to-Point RF Communication			X		C3I-592V
C3I-594	C3I_3.1.2.1	Common Operational Point-to-Point RF Communication			X		C3I-594V
C3I-596	C3I_3.1.2.1	Common Operational Point-to-Point RF Communication			X		C3I-596V
C3I-598	C3I_3.1.3.1	Common High Rate RF Communication			X		C3I-598V
C3I-600	C3I_3.1.3.1	Common High Rate RF Communication			X		C3I-600V
C3I-601	C3I_3.1.3.1	Common High Rate RF Communication			X		C3I-601V
C3I-603	C3I_3.1.3.1	Common High Rate RF Communication			X		C3I-603V
C3I-612	C3I_3.1.2.1	Common Operational Point-to-Point RF Communication			X		C3I-612V
C3I-619	C3I_3.3.1	Connectivity				X	C3I-619V
C3I-620	C3I_3.3.1	Connectivity				X	C3I-620V
C3I-621	C3I_3.3.1	Connectivity				X	C3I-621V
C3I-622	C3I_3.3.1	Connectivity				X	C3I-622V
C3I-632	C3I_3.1.3.1	Common High Rate RF Communication				X	C3I-632V

Requirement Number	Section Number	Section Title	Method (***for reference only***)				Verification Requirement
			I	A	D	T	
C3I-633	C3I_3.1.2.2	Point A Operational Point-to-Point RF Communication		X		X	C3I-633V
C3I-634	C3I_3.1.2.3	Point B Operational Point-to-Point RF Communication		X		X	C3I-634V
C3I-652	C3I_3.6.1	Basic Information Definition	X			X	C3I-652V
C3I-653	C3I_3.1.2.1	Common Operational Point-to-Point RF Communication				X	C3I-653V
C3I-654	C3I_3.3.1	Connectivity				X	C3I-654V
C3I-655	C3I_3.3.1	Connectivity				X	C3I-655V
C3I-656	C3I_3.3.1	Connectivity				X	C3I-656V
C3I-657	C3I_3.3.1	Connectivity				X	C3I-657V
C3I-659	C3I_3.5.3	Data Exchange Message Formatting and Transmission				X	C3I-659V
C3I-660	C3I_3.5.6	Traffic Prioritization				X	C3I-660V
C3I-661	C3I_3.6.1	Basic Information Definition	X				C3I-661V
C3I-662	C3I_3.3.2	Dynamic Routing Between Systems					CLV_GOE
C3I-663	C3I_3.3.2	Dynamic Routing Between Systems				X	C3I-663V
C3I-664	C3I_3.3.8	Tunneling (GRE)					C3I-664V
C3I-665	C3I_3.4.4	FIPS Compliant Algorithms	X			X	C3I-665V
C3I-666	C3I_3.4.4	FIPS Compliant Algorithms	X			X	C3I-666V
C3I-667	C3I_3.4.4	FIPS Compliant Algorithms	X			X	C3I-667V
C3I-668	C3I_3.1.2.1	Common Operational Point-to-Point RF Communication					
C3I-669	C3I_3.1.2.1	Common Operational Point-to-Point RF					

Requirement Number	Section Number	Section Title	Method (*for reference only*)				Verification Requirement
			I	A	D	T	
		Communication					
C3I-670	C3I_3.1.2.1	Common Operational Point-to-Point RF Communication					
C3I-671	C3I_3.1.2.1	Common Operational Point-to-Point RF Communication					
C3I-672	C3I_3.1.2.1	Common Operational Point-to-Point RF Communication					
C3I-673	C3I_3.1.3.1	Common High Rate RF Communication					
C3I-674	C3I_3.1.3.1	Common High Rate RF Communication					
C3I-675	C3I_3.1.3.1	Common High Rate RF Communication					
C3I-676	C3I_3.1.3.1	Common High Rate RF Communication					
C3I-677	C3I_3.1.3.1	Common High Rate RF Communication					
C3I-678	C3I_3.1.5.1	Common Recovery RF Communication					
C3I-679	C3I_3.1.5.1	Common Recovery RF Communication					
C3I-680	C3I_3.1.6.1	Common RF Contingency Voice Communication					
C3I-681	C3I_3.1.8	Vehicle Internal Wireless Link Class					
C3I-682	C3I_3.2.3	Deterministic Hard-line Communication					
C3I-701	C3I_3.8	Interoperability Requirements Applicability	X				C3I-701V
C3I-702	C3I_3.8	Interoperability Requirements Applicability	X				C3I-702V
C3I-703	C3I_3.8	Interoperability Requirements Applicability	X				C3I-703V
C3I-704	C3I_3.8	Interoperability Requirements Applicability	X				C3I-704V

Requirement Number	Section Number	Section Title	Method (***for reference only***)				Verification Requirement
			I	A	D	T	
C3I-705	C3I_3.8	Interoperability Requirements Applicability	X				C3I-705V
C3I-707	C3I_3.8	Interoperability Requirements Applicability	X				C3I-707V