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Communications, Navigation, and Networking reConfigurable Testbed (CoNNeCT) Project

National Aeronautics and Space Administration
John H. Glenn Research Center at Lewis Field, OH 44135

CoNNeCT PROJECT

GROUND SOFTWARE REQUIREMENTS SPECIFICATION

AUTHORIZED by CM when under FORMAL Configuration Control	
Date	**Signature**
04/15/2010	*/s/ James A. Drury*

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PREFACE

National Aeronautics and Space Administration (NASA) is developing an on-orbit, adaptable, Software Defined Radios (SDR)/Space Telecommunications Radio System (STRS)-based testbed facility to conduct a suite of experiments to advance technologies, reduce risk, and enable future mission capabilities on the International Space Station (ISS). The Communications, Navigation, and Networking reConfigurable Testbed (CoNNeCT) Project will provide NASA, industry, other Government agencies, and academic partners the opportunity to develop and field communications, navigation, and networking technologies in the laboratory and space environment based on reconfigurable, software defined radio platforms and the STRS Architecture. The CoNNeCT Payload Operations Nomenclature is "SCAN Testbed" and this nomenclature will be used in all ISS integration, safety, verification, and operations documentation. Also included are the required support efforts for Mission Integration and Operations, consisting of a ground system and the Glenn Telescience Support Center (GRC TSC). This document has been prepared in accordance with NASA Glenn's Configuration Management Procedural Requirements GLPR 8040.1 and applies to the CoNNeCT configuration management activities performed at NASA's Glenn Research Center (GRC). This document is consistent with the requirements of SSP 41170, Configuration Management Requirements, International Space Station, and Space Assurance and Requirements Guideline (SARG).

This document contains software requirements derived from the Level IV CoNNeCT Project Software Requirements Specification as they pertain to the ground software. The Mission Operations Plan activities provide the flight and ground operations support efforts for the CoNNeCT Project flight and ground system. The Glenn Telescience Support Center (GRC TSC) Facility provides the command and communication support efforts for the CoNNeCT Project flight and ground systems.

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SIGNATURE PAGE

Prepared By:

/s/ Lindsey M. Flash — *04/15/2010*

Lindsey M. Flash — Date
CoNNeCT Ground Software Lead
NASA Glenn Research Center

Concurred By:

/s/ Denise Varga — *04/15/2010*

Denise M. Varga — Date
CoNNeCT Software Lead
NASA Glenn Research Center

/s/ Michael J. Barrett — *15APR2010*

Michael Barrett — Date
CoNNeCT Chief Engineer
NASA Glenn Research Center

/s/ Todd A. Tofil — *04-15-2010*

Todd A. Tofil — Date
CoNNeCT Lead Systems Engineer
NASA Glenn Research Center

/s/ Mark Luboski — *04/15/2010*

Mark Luboski — Date
CoNNeCT Software Product Assurance
ARES Corporation

/s/ J. Freeh — *04/15/2010*

Joshua E. Freeh — Date
CoNNeCT Mission Operations Lead
NASA Glenn Research Center

Approved By:

/s/ Ann P. Over — *04/15/2010*

Ann P. Over — Date
CoNNeCT Project Manager
NASA Glenn Research Center

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1.0 INTRODUCTION

This document establishes the second level software requirements as they pertain to the ground software for the Communications, Navigation, and Networking reConfigurable Testbed (CoNNeCT) Project. These requirements are flowed down from higher level specifications and derived from the first level software requirements documented in the "CoNNeCT Software Requirements Specification", GRC-CONN-REQ-0084.

All of the requirements specified in this document will be verified and validated as part of the formal Verification and Validation effort at GRC. A requirements traceability matrix will show the flow-down of requirements from higher-level project documents through software requirements, architecture, design, code, test, and final verification and validation.

1.1 Purpose

The purpose of this specification is to document the requirements levied on the CoNNeCT ground software developed under WBS 6.0 to command and control the CoNNeCT Ground Integration Unit (GIU) and CoNNeCT payload from the CoNNeCT Control Center (CCC).

1.2 Scope

The scope of this document covers the ground software requirements for the CoNNeCT project. It includes all ground software that is developed under WBS 6.0, Software, at Glenn Research Center (GRC). This includes software used on the ground at the CCC to operate both the GIU and the payload. It does not cover any Commercial Off The Shelf (COTS) software that may be operated within the CCC. This document does not include any ground software developed at partner locations or software developed outside of WBS 6.0 at GRC. Requirements in this document trace to higher level project documents. Specifically, the parent document to this document is the CoNNeCT Software Requirements Specification.

This document covers requirements for Phase I of CoNNeCT, which includes development of the payload and ground systems up through launch and on-orbit checkout. Phase II of CoNNeCT will cover experiment development, mission operations, and development of additional communications technologies in software. Phase II software requirements are covered in this document to the extent that the initial design does not preclude adding the intended software capabilities once on orbit. These requirements are designated by "[Phase II]" under the requirement number. Detailed Phase II requirements will be covered in a separate specification. Phase II capabilities specified in this document will be verified by analysis showing that the current design allows the capabilities to be implemented as part of Mission Operations.

1.3 Computer Software Configuration Items

The Ground Software is comprised of several Computer Software Configuration Items (CSCIs). The purpose of these CSCI definitions is to allocate requirements to lower-level software decomposition, and to document which requirements will be met by which configuration items. Corresponding designs and further documentation will be made available for each CSCI listed. The ground software CSCIs are defined below in Table 1-1.

Table 1-1—CoNNeCT Ground Software CSCI Definition

ID	CSCI Name	Purpose
CTADS	CoNNeCT Telemetry Acquisition and Display System	Ground Software used to communicate with the payload via the primary path through the Huntsville Operations Support Center (HOSC) and the International Space Station (ISS). Includes commanding the payload and receiving telemetry from the payload.
DDS	Data Distribution Services	Ground Software used to organize and distribute payload data to authorized external users via a web interface.
EXP	Experimental Path Software	Ground Software used to communicate with the payload via the experimental paths through the Space Network (SN) or Near Earth Network (NEN). Includes commanding the payload and receiving telemetry and experimental data from the payload.

2.0 APPLICABLE DOCUMENTS

This section lists the NASA/Government and non-NASA/Government specifications, standards, guidelines, handbooks, or other special publications applicable to this document.

2.1 Applicable Documents

Applicable documents are those documents that form a part of this document. These documents carry the same weight as if they were stated within the body of this document.

Document Number	Applicable Document Title
GRC-CONN-DBK-0128	CoNNeCT Command and Telemetry Databook
GRC-CONN-LIST-0064	Avionics Instrumentation List
GRC-CONN-REQ-0084	CoNNeCT Software Requirements Specification
GRC-CONN-RPT-0227	Fault Detection, Isolation, and Recovery (FDIR) Report

2.2 Reference Documents

Reference documents are those documents that, though not a part of this document, serve to clarify the intent and contents of this document.

Document Number	Reference Document Title
GLPR 8739.1	GRC Procedural Requirements for Software Assurance
GRC-CONN-DOC-0152	CoNNeCT System Modes and States Document
GRC-CONN-OPS-0176	Mission Operations Handbook
NPR 7150.2	NASA Software Engineering Requirements
POIF-1005 Rev F	Payload Operations Handbook
TSC-DOC-002D	GRC TSC Requirements Document

2.3 Order of Precedence for Documents

In the event of a conflict between this document and other documents specified herein, the requirements of this document shall apply. In the event of a conflict between this document and higher level documents, the higher level documents shall take precedence over this document.

All documents used, applicable or reference, are to be the approved versions released as of the contract start date. All document changes issued after contract baseline establishment shall be reviewed for impact on the scope of work. Nothing in this document supersedes applicable laws and regulations unless a specific exemption has been obtained.

3.0 REQUIREMENTS

The following section contains a full set of requirements for the CoNNeCT ground software. Each requirement definition contains (a) the identification of a parent requirement, (b) a requirement identifier, (c) requirement text, (d) requirement rationale, and (e) allocation to one or more CSCIs. Traceability from the parent requirement all the way down to the verification test, including verification methods that will be used for each requirement will be detailed in Section 4 of this document.

The entire set of requirements has been prioritized by the Software Team. A column indicating the priority occurs in each requirement table, and is determined based on the priority designated to the parent requirement. The priorities that have been defined are:

- **P1** – must have at launch; supports incompressible test list
- **P2** – should have at launch; supports mission success criteria
- **P3** – can defer; including all Phase II requirements, but not the underlying capability to support implementation of these requirements.

Each requirement will be given a unique ID containing the letters “GSRS-”, followed by the section number and a sequential number starting with 1 appended to the section number. For instance, the first requirement in Section 4.2 will be “GSRS-4.2.1”. The tenth requirement from Section 4.3 will be “GSRS-4.3.10”. Each parent requirement listed will identify the unique requirement ID from the Software Requirements Specification from which that requirement is derived.

3.1 Software Quality Requirements

This paragraph specifies requirements concerned with software quality factors such as, reliability (the ability to perform with correct, consistent results), maintainability (the ability to be easily corrected), availability (the ability to be accessed and operated when needed), flexibility (the ability to be easily adapted to changing requirements), portability (the ability to be easily modified for a new environment), reusability (the ability to be used in multiple applications), testability (the ability to be easily and thoroughly tested), usability (the ability to be easily learned and used), and other attributes.

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.11.1	GSRS-3.1.1	The Ground Software **shall** be developed according to NPR 7150.2A Software Engineering Requirements for Class C software. *Rationale: All software for the CoNNeCT project is classified as Class C software. Some of the CSCIs are delivered code and will fall under the requirements for Software Acquisition or Software Reuse in NPR 7150.2. Cooperative Agreements and existing contracts may prohibit enforcement of this requirement on radio and Waveform software.*	P1	CTADS, DDS, EXP

3.2 Software Safety Requirements

The Flight Software has been identified as a hazard control for inadvertent Ka-band radiation on the payload. However, the Ground Software is not designated as safety critical since hazardous commands will be sent to the payload from the ground via the HOSC, and will not be sent from the CCC. Therefore, the ground software is not responsible for transmitting hazardous commands to the payload, and therefore, is not considered safety critical.

The following ground software requirements capture safety-related requirements.

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.2.1.6	GSRS-3.2.1	The Ground Software **shall** implement a two stage process for sending any command to the payload. *Rationale: A "prepare" then "send" sequence will be used on the ground to issue any command to the payload. This ensures commands are not sent from the ground accidentally.*	P1	CTADS, EXP

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.7.1	GSRS-3.2.2	The Ground Software development and procurement **shall** comply with requirements of NASA-STD-8719.13 Rev. B, Software Safety Standard for any portions of the ground software that are considered safety critical. *Rationale: NASA-STD-8719.13 Rev B identifies the activities necessary to ensure that safety is designed into the safety critical portions of CoNNeCT software. The standard specifies the software safety activities, data, and documentation necessary for the acquisition or development of software in a safety critical system. Note that currently no portions of the ground software are considered safety critical.*	P1	CTADS, EXP

3.3 Command and Control

Command and Control is the mechanism by which the CoNNeCT payload is operated from the ground. All commands originate at the CoNNeCT Control Center located in Building 333 at the NASA Glenn Research Center and are transmitted to the payload for processing. Commands will be transmitted to the payload into the avionics subsystem via the "primary path", which is through the ISS ELC. However, commands will also be transmitted to the payload into the RF subsystem via the "experimental path", which is through the Space Network or the Near Earth Network. Commands, determined to be critical or hazardous, according to the definitions in POIF-1005 Rev F SOP 6.6 and SOP 6.7, will not be sent via the experimental path. Coordination with the HOSC is required in order to send hazardous or critical commands to the payload. Critical commands can be initiated at the CCC and coordinated with the HOSC. Hazardous commands cannot be initiated from the CCC; all hazardous commands must be sent to the payload by the HOSC.

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.2.1.1 SRS-3.2.3.2 SRS-3.2.6.3 SRS-3.5.1	GSRS-3.3.1	The Ground Software **shall** send all commands defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128, and designated for the primary path to the payload via the primary path. *Rationale: The CoNNeCT payload will be operated from the CoNNeCT Control Center, which will transmit commands to the payload. The primary mode of commanding the payload will be via the primary path.*	P1	CTADS

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.2.1.2	GSRS-3.3.2	The Ground Software **shall** send all non-safety critical commands defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128, and designated for the experimental path to the payload via the experimental path. *Rationale: The SDRs must accept commands from the ground via the experimental path. However, commands determined to be safety critical must only be sent via the primary path.*	P3	EXP
SRS-3.2.1.6	GSRS-3.3.3	The Ground Software **shall** provide a command interface to generate and send all commands from the CoNNeCT Control Center to the CoNNeCT payload as defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128. *Rationale: All commanding of CoNNeCT will be initiated from the ground at the CoNNeCT Control Center by a human user.*	P1	CTADS, EXP
SRS-3.2.1.1	GSRS-3.3.4	The Ground Software **shall** display a command status received from the flight system to indicate if each initiated command is accepted by the flight system or rejected by the flight system. *Rationale: The flight system will indicate if the command is accepted or rejected, and the ground system will receive that information via telemetry and display it to an operator. Operators must be notified when a command is not accepted by the flight system so that he or she can troubleshoot the problem.*	P1	CTADS, EXP
SRD3253 MISSING SRS <**TBR-01**>	GSRS-3.3.5	The Ground Software **shall** send commands to the payload during an on-board command sequence execution. *Rationale: The ground software must not prohibit an operator from sending a command when the flight system is already executing scripts or commands. A stop command is needed to allow for termination of an in-progress command execution in flight. Only specific emergency stop commands can interrupt a flight process, and such commands are detailed in the Command and Telemetry Databook, GRC-CONN-DBK-0128.*	P1	CTADS, EXP

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.2.1.1	GSRS-3.3.6	The Ground Software **shall** reject sending invalid commands. *Rationale: The software must check all commands and all command parameters and only send valid commands to the payload. Invalid commands, including invalid command parameters, will not be sent to the payload and must be reported back to the operator so that he or she can issue the correct command or troubleshoot the problem.*	P1	CTADS, EXP
MISSING SRD MISSING SRS <**TBR-02**>	GSRS-3.3.7	The Ground Software **shall** encrypt all commands sent via the experimental paths using <**TBD-13**> type of encryption. *Note: This may or may not be a real requirement; still pending decision. No corresponding SRD, GSRD, or SRS requirement exists.*	P3	EXP

3.4 Health and Status, Telemetry, and Experiment Data

Health and Status is defined by the CoNNeCT project and consists of the payload parameters that both CoNNeCT and ISS should monitor to assess the health of the payload. Telemetry consists of all engineering data collected on the payload, including Health and Status, and sent down to the ground. Experiment data consists of data produced and collected while a CoNNeCT experiment is running. Telemetry will typically be transmitted to the ground via the primary path through ISS; however, as part of an experiment, experiment data and telemetry may also be downlinked via the experimental path.

A complete list of Health and Status and Telemetry is defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128.

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.2.2.2 SRS-3.2.6.3	GSRS-3.4.1	The Ground Software **shall** receive and display all payload health and status telemetry received from the Flight System as defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128, via the primary path. *Rationale: Telemetry defined in the Command and Telemetry Databook will include payload telemetry transmitted to the ground from the flight software, as well as specific CoNNeCT-required ISS health and status data available in the HOSC database.*	P1	CTADS
SRS-3.2.2.3	GSRS-3.4.2	The Ground Software **shall** receive and display all payload telemetry sent during AOS from the Flight System via the primary path at least once per minute during an experiment period. *Rationale: Telemetry will be downlinked as it is received and will likely exceed this requirement. However, during LOS, this may not be possible.*	P2	CTADS
SRS-3.2.2.4	GSRS-3.4.3	The Ground Software **shall** receive and display all payload telemetry received from the Flight System as defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128, via the SN experimental path. *Rationale: Telemetry defined in the Command and Telemetry Databook must be received on the ground via the experimental path.*	P3	EXP
SRS-3.2.2.4	GSRS-3.4.4	The Ground Software **shall** receive and display all payload telemetry received from the Flight System as defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128, via the NEN experimental path. *Rationale: Telemetry defined in the Command and Telemetry Databook must be received on the ground via the experimental path.*	P3	EXP

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRD3038 MISSING SRS <**TBR-03**>	GSRS-3.4.5	The Ground Software **shall** collect and display metrics and statistics regarding the health of the data links as defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128. *Rationale: Experimenters want to know networking statistics (i.e., packets sent/received) and metrics that can be used to evaluate the health of the data link. This information may come from the payload via the experimental path, but is more likely to come from the Space Network itself.*	P3	EXP
SRS-3.2.3.1	GSRS-3.4.6	The Ground Software **shall** monitor engineering data and provide notification per the Command and Telemetry Data Book, GRC-CONN-DBK-0128 and the Fault Detection, Isolation, and Recovery (FDIR) Report. *Rationale: This requirement implies that there are certain faults or conditions that the software must recognize and report. These conditions are defined in GRC-CONN-DBK-0128. The FDIR Report will describe actions to be taken when faults are detected.*	P1	CTADS, EXP
SRS-3.2.6.16	GSRS-3.4.7	The Ground Software **shall** provide data isolation for each radio (for example, 1 APID per radio). *Rationale: Radio technology is proprietary information; therefore, no radio vendor should be able to see data from a radio other than their own. The software must isolate the data so that each radio vendor user may view only their own radio data and any non-radio-specific data.*	P1	CTADS, EXP
SRS-3.2.6.4	GSRS-3.4.8	The Ground Software **shall** receive and display experiment data sent from the Flight System and defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128, via the primary path. *Rationale: Experiment data defined in the Command and Telemetry Databook must be received on the ground via the primary path.*	P2	CTADS

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.2.6.16	GSRS-3.4.9	The Ground Software **shall** provide web pages from which authorized and authenticated users may retrieve CoNNeCT data via secure Internet Protocol from locations remote to the CCC. *Rationale: Experimenters not located in the CCC will need to view experiment data. Users must be granted access (authorized) and must provide correct credentials such as a username and password (authenticated).*	P3	DDS
SRS-3.2.6.16	GSRS-3.4.10	The Ground Software web pages **shall** provide data isolation for all access to CoNNeCT data web pages so that no radio vendor may view proprietary data owned by another vendor. *Rationale: Experimenters not located in the CCC will need to view experiment data. Radio technology is proprietary information; therefore, no radio vendor should be able to see data from a radio other than their own.*	P3	DDS
SRS-3.2.6.16	GSRS-3.4.11	The Ground Software web pages **shall** be available to authorized users external to GRC. *Rationale: Authorized and authenticated users must be able to view data from a network outside of GRC. Serving web pages from the GRC External Services Network (ESN) allows for web pages to be available externally to GRC, which is outside of the GRC network and the TSC network. This allows appropriate non-GRC badged individuals (i.e., remote PIs) to access the posted data.*	P3	DDS
SRS-3.2.2.2	GSRS-3.4.12	The Ground Software **shall** provide alerts of out of limits telemetry values as defined in the Fault Detection, Isolation, and Recovery (FDIR) Report, GRC-CONN-RPT-0227. *Rationale: Caution and warning limits must be reported to the operator so he or she may take appropriate action, if necessary.*	P1	CTADS, EXP

3.5 File Transfer

Files will be transferred between the ground system and the flight system and may be transferred via the primary path and or the experimental path.

For uploading a file from the ground to the flight system via the primary path, two choices exist: (1) The file may be uploaded via the Payload Multiplexer/Demultiplexer (MDM); (2) The file may be uploaded via a command. If a file is uploaded via the Payload MDM, due to MDM size restrictions, it must be separated into even byte segments no larger than 8MB per segment. The file must be segmented on the ground and then reassembled on the flight system. An Operations Change Request (OCR) must be written to request the desired file to be placed from the ground onto the Payload MDM in order for the flight system to retrieve the file from the MDM. This operational procedure could take days or up to weeks to complete, and requires coordination with the Huntsville Operations Support Center (HOSC). Since this process is an operational procedure, no error checking and retransmission in case of error is necessary by the ground software if this route is chosen. If a file is uploaded via a command, it must be separated into segments no larger than 94 bytes per segment. The file is then uploaded in the needed number of sequential commands containing the file segments and is reassembled by the Payload Avionics Software (PAS). In this case, any errors that occur during transmission may need to be retransmitted from the ground until the entire file is determined to be error free.

For downlinking a file from the flight system to the ground via the primary path, the same two choices outlined above exist. The process is similar, but in reverse.

For uploading or downlinking a file via the experimental path, the file must be segmented into segments no larger than <**TBD-10**> per segment. The Payload MDM option does not exist for the experimental path. Uploaded files are sent via commands. Downlinked files are sent via telemetry packets.

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.2.6.10	GSRS-3.5.1	The Ground Software **shall** upload files of **<TBD-17>** size or less to the flight system transmitted via the primary commanding path. *Rationale: The Ground Software can send files to the flight system by sending portions of the file in commands sent via the primary path. This implies that the Ground Software must segment the file to fit into the available space in a command. Each command has space for 94 bytes of file size, so the approximate number of commands needed to send a given file can be calculated by dividing the file size in bytes by 94. A 100 kilobyte file requires roughly 21 minutes of AOS to transfer via the commanding path. Large files will take potentially hundreds of thousands of commands (and many hours of AOS) via this path; therefore, larger files will be sent to the flight system via the Payload MDM.*	P1	CTADS
SRD3989 MISSING SRS <**TBR-04**>	GSRS-3.5.2	The Ground Software **shall** upload files of 12 MB or less with no errors transmitted via the SN experimental path. *Rationale: Files must be uploaded via the experimental path. The maximum file size is based on the Harris Waveform uploads. If errors are detected in an uploaded file, the portions in error must be re-transmitted until the entire file is determined to be error free.*	P3	EXP
SRD3989 MISSING SRS <**TBR-05**>	GSRS-3.5.3	The Ground Software **shall** upload files of 12 MB or less with no errors transmitted via the NEN experimental path. *Rationale: Files must be uploaded via the experimental path. The maximum file size is based on the Harris Waveform uploads. If errors are detected in an uploaded file, the portions in error must be re-transmitted until the entire file is determined to be error free.*	P3	EXP

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.2.3.2 SRS-3.5.1	GSRS-3.5.4	The Ground Software **shall** receive files from the flight system transmitted via the primary telemetry path. *Rationale: The Ground Software can receive files from the flight system in telemetry packets sent via the primary path. This implies that the Ground Software must reassemble file segments received in each telemetry packet containing the file. Each telemetry packet has space for approximately 1428 bytes of file size, so the approximate number of telemetry packets needed to receive a given file can be calculated by dividing the file size in bytes by 1428. To avoid sending a file down using hundreds of thousands of telemetry packets, large files should be sent from the flight system via the Payload MDM.*	P1	CTADS
SRD3991 MISSING SRS <**TBR-06**>	GSRS-3.5.5	The Ground Software **shall** receive files with no errors from the flight system via the SN experimental path. *Rationale: Files must be downlinked via the experimental path. If errors are detected in a downlinked file, the portions in error must be re-transmitted until the entire file is determined to be error free.*	P3	EXP
SRD3991 MISSING SRS <**TBR-07**>	GSRS-3.5.6	The Ground Software **shall** receive files with no errors from the flight system via the NEN experimental path. *Rationale: Files must be downlinked via the experimental path. If errors are detected in a downlinked file, the portions in error must be re-transmitted until the entire file is determined to be error free.*	P3	EXP
SRS-3.2.6.10	GSRS-3.5.7	The Ground Software **shall** segment files for upload via the Payload MDM into even byte segments of size 8 MB or less. *Rationale: Files will be uploaded from the ground to the payload via the Payload MDM, and the Payload MDM file size limit is 8 MB. Therefore, files larger than 8MB (for example, the 12 MB Harris Waveform) must be broken up for upload in multiple segments. The actual upload to the Payload MDM will be handled by personnel following a Mission Operations procedure.*	P1	CTADS

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.2.3.2 SRS-3.5.1	GSRS-3.5.8	The Ground Software **shall** reassemble segmented files downlinked via the Payload MDM. *Rationale: Files will be downlinked from the payload to the ground via the Payload MDM, and the Payload MDM file size limit is 8 MB. Therefore, files larger than 8 MB must be broken up for downlink in multiple segments. The Payload Avionics Software will segment the file and place it on the Payload MDM, and the file segments will be retrieved from the Payload MDM by personnel following a Mission Operations procedure. The Ground Software will then need to reassemble the file segments into one file.*	P1	CTADS
SRS-3.2.6.10	GSRS-3.5.9	The Ground Software **shall** perform error checking on all received files and request retransmission of any file segments containing errors until a transmitted file is determined to be error free. *Rationale: If errors are detected in a downlinked file, the portions in error must be retransmitted until the entire file is determined to be error free.*	P1	CTADS

3.6 Ground System States and Modes

The following requirements imply system states (i.e., Safe State) or operational modes that could drive system design. The CoNNeCT system states and modes will be defined in the CoNNeCT System Modes and States Document, GRC-CONN-DOC-0152. The states for Mission Operations and how these states affect operations will be detailed in the Mission Operations Handbook, GRC-CONN-OPS-0176.

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.1.3	GSRS-3.6.1	The Ground Software **shall** display a confirmation warning if a command is issued that is not valid for the current state or mode of the payload according to the Modes and States Description Document, GRC-CONN-DOC-0152. *Rationale: For safety or operational purposes, certain commands may only be allowed when the payload is in certain modes or states. The ground software must warn an operator and receive confirmation to send a command to the payload when it is not allowed according to the Modes and States Handbook.*	P2	CTADS, EXP

3.7 Ground Verification Capability

A CoNNeCT Ground Verification Facility (GVF) will be maintained in an environmentally controlled area in Building 333 at the Glenn Research Center. The GVF will replicate the Flight System using high-fidelity flight equivalent units, including a Ground Integration Unit (GIU). All flight software and radio waveforms will be verified and validated in the GVF prior to uploading onto the Flight System during mission operations. The GVF will also serve for Flight System anomaly detection and resolution on the ground. A connection between the CCC and the GVF will be installed and maintained throughout the lifetime of the CoNNeCT project.

3.8 Time Synchronization

Time synchronization among flight and ground elements to a common time source is critical to the correlation of data and calculating data link quality, as well as monitoring the payload and performing operations. Ground elements must synchronize to the same time source as the flight elements.

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.2.7.1	GSRS-3.8.1	The Ground Software **shall** synchronize its clock with the TSC provided time. *Rationale: In order to maintain proper synchronization between flight and ground elements, the ground software will rely on the TSC provided time, which is synchronized to Greenwich Mean Time according to TSC-DOC-002D, Rev D. The CCC must ensure that the TSC provided time is within acceptable ranges to properly synchronize with the payload.*	P2	CTADS, EXP

3.9 Reconfigurable Operations

A key capability of SDR technology is being able to modify the functionality of the radios via software updates. This is a key requirement for CoNNeCT and is critical for launch capability. The ground software will support reconfigurable operations via uploads from the Ground System to the Flight System.

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.2.1.7	GSRS-3.9.1	The Ground Software **shall** be upgradable to support new flight software. *Rationale: The Ground Software will need to allow for new commands and new telemetry to be added after the payload is in orbit and operational and for the lifetime of the project. A key capability of SDR technology is being able to modify the functionality of the radios via software updates.*	P1	CTADS, EXP

3.10 Environmental Requirements

This section contains requirements regarding the environment in which the software must operate.

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.9.1	GSRS-3.10.1	The Ground Software **shall** implement any date sensitive code or timers in a manner that allows operations for a period of at least two years after launch. *Rationale: The payload minimum design life is 2 years and the software must be able to operate for that entire time.*	P2	CTADS, EXP, DDS

3.11 Experiments

This section contains requirements for the experiments that will be run on CoNNeCT. Not all of these capabilities need to be implemented in experiments prior to launch, but the Ground Software must provide a framework that allows these capabilities to be exercised at some point during the project's lifecycle of operations. All new software and new capabilities added post-launch will be tested in the Ground Verification Facility prior to uploading to the flight system during mission operations.

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.2.6.5	GSRS-3.11.1	The Ground Software **shall** generate a pseudorandom bit sequence (PRBS) on command of 2^{23}-1 (for Ka-band) and 2^{11}-1 (for S-band) length for experimental links in real-time at experiment data rates. *Rationale: This data is used for Bit Error Rate calculations. Link characterization experiments are best served with pseudorandom bit sequence data sources.*	P3	EXP

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.2.6.1	GSRS-3.11.2	The CCC **shall** have multiple logical addresses to support Delay-Tolerant Networking (DTN). *Rationale: DTN requires multiple IP address, so the Ground Software must not preclude accepting data from multiple IP addresses.* *Note: This may not be a software requirement, but rather a requirement levied on the CCC hardware. Pending further resolution. <**TBR-08**>*	P3	EXP
SRS-3.2.6.9	GSRS-3.11.3	**<TBD-14>**	P3	EXP
SRS-3.2.6.8	GSRS-3.11.4	**<TBD-15>**	P3	EXP
SRS-3.2.6.7	GSRS-3.11.5	**<TBD-16>**	P3	EXP

3.12 Software External Interface Requirements

The following sections identify the external interfaces to the CoNNeCT Ground Software.

3.12.1 Huntsville Operations Support Center (HOSC) Interface Requirements

The CoNNeCT Ground System must interface with the Huntsville Operations Support Center (HOSC) for communications to the Flight System via the primary path. The HOSC will be the primary method for transmitting commands and data from/to the CCC to the payload. An interface with the HOSC is already established at the GRC Telescience Support Center (TSC) and is operational and in use by multiple payloads. This section details requirements levied on the CoNNeCT Ground Software for interfacing to the HOSC.

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.3.6.1	GSRS-3.12.1.1	The Ground Software **shall** utilize the Telescience Resource Kit (TReK) Software for sending data to and receiving data from the Marshall Space Flight Center (MSFC) Huntsville Operations Support Center (HOSC). *Rationale: TReK provides a well-established interface to the HOSC. TReK's primary functions are to acquire, process, display, and store telemetry data received from the HOSC and to send command uplink requests to the HOSC.*	P1	CTADS

3.12.2 Space Network Interface Requirements

The CoNNeCT Ground System must interface with the Space Network (SN) for communications to the Flight System via the experimental path. The Space Network will be used to transmit non-hazardous commands and non-critical commands from the CCC to the payload and data from the payload to the CCC via direct RF communications through TDRSS, i.e. without going through the HOSC. Implementation will be facilitated by and closely coordinated with the NASA Integrated Services Network (NISN).

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRD3770 SRS-3.3.4.1	GSRS-3.12.2.1	**<TBD-5>**	P3	EXP
SRD3793 GSRD-005 SRS-3.3.4.1	GSRS-3.12.2.2	**<TBD-6>**	P3	EXP

3.12.3 Near Earth Network Interface Requirements

The CoNNeCT Ground System must interface with the Near Earth Network (NEN) for communications to the Flight System via the experimental path. The Near Earth Network will be used to transmit non-hazardous commands and non-critical commands from the CCC to the payload and data from the payload to the CCC via direct RF communications through TDRSS, i.e. without going through the HOSC. Implementation will be facilitated by and closely coordinated with the NASA Integrated Services Network (NISN).

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRD2526 SRS-3.3.5.1	GSRS-3.12.3.1	**<TBD-7>**	P3	EXP

3.13 Software Internal Interface Requirements

The interface between the Payload Avionics Software (PAS) and Ground Software is not a direct or hard-wired interface. This interface can take many forms, i.e., through the Space Network or Near-Earth Network or through the HOSC. These external interfaces are described in Section 3.12. This section is intended to describe the requirements on the Ground Software for interfacing with the PAS so that data and commands can be transmitted and received, and for interfacing with Mission Operations Software so that operations and experiments can be conducted.

3.13.1 Ground Software / Payload Avionics Software Interface

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.4.5.1	GSRS-3.13.1.1	**<TBD-8>**	P1	CTADS, EXP

3.13.2 Ground Software / Mission Operations Software Interface

Parent Req.	Req. ID	Requirement Text and Rationale	Priority	Allocated To
SRS-3.2.4.1	GSRS-3.13.2.1	The Ground Software **shall** generate files containing TDRS tracking information for upload to the flight system. *Rationale: Mission Operations Software will be used to track any assigned TDRS and will provide orbital prediction information. Some mechanism is needed to translate the output from that orbital prediction information into a file that is readable by the PAS for antenna movement on the flight system.*	P2	CTADS, EXP

4.0 REQUIREMENTS TRACEABILITY AND VERIFICATION MATRIX

The tables below identify the traceability and verification methods for each requirement identified in Section 3 of this document. They contain:

1. **Table 4-1**: Traceability from each ground software requirement in this specification to the higher level software requirement it addresses from the Software Requirements Specification (SRS). Any requirement in this specification that is missing a parent requirement in the SRS is tracked in Table C-2. This table also defines a set of verification methods and **shall** specify for each requirement in Section 3 of this document the method(s) to be used to ensure that the requirement has been met. Verification methods may include:

   a. **Inspection**: The visual examination of code, documentation, etc.

   b. **Analysis**: The processing of accumulated data obtained from other verification methods. Examples are reduction, interpretation, or extrapolation of test results.

   c. **Test**: The operation of the software, or a part of the software, using instrumentation or other special test equipment to collect data for later analysis.

   d. **Demonstration**: The operation of the software, or a part of the software, that relies on observable functional operation not requiring the use of instrumentation, special test equipment, or subsequent analysis.

2. **Table 4-2**: Traceability from each higher level software requirement contained in the SRS allocated to ground software to the requirements in this specification that address it. All higher level software requirements allocated to ground software **shall** be accounted for. Any SRS requirements that have not been flown down into this specification are listed in Table D-1.

Table 4-1—CoNNeCT Ground Software Requirements Traceability and Verification Matrix

Requirement Number		Requirement	Verification Type				Remarks
SRS	GSRS		I	A	T	D	
3.11.1	3.1.1	The Ground Software **shall** be developed according to NPR 7150.2 Software Engineering Requirements for Class C software.	X				
3.2.1.6	3.2.1	The Ground Software **shall** implement a two stage process for sending any command to the payload.				X	

Requirement Number		Requirement	Verification Type				Remarks
SRS	GSRS		I	A	T	D	
3.7.1	3.2.2	The Ground Software development and procurement **shall** comply with requirements of NASA-STD-8719.13 Rev. B, Software Safety Standard for any portions of the ground software that are considered safety critical.	X				
3.2.1.1, 3.2.3.2, 3.2.6.3, 3.5.1	3.3.1	The Ground Software **shall** send all commands defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128, and designated for the primary path to the payload via the primary path.			X		Test with ELC Simulator
3.2.1.2	3.3.2	The Ground Software **shall** send all non-safety critical commands defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128, and designated for the experimental path to the payload via the experimental path.			X		Special test equipment needed?
3.2.1.6	3.3.3	The Ground Software **shall** provide a command interface to generate and send all commands from the CoNNeCT Control Center to the CoNNeCT payload as defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128.			X		
3.2.1.1	3.3.4	The Ground Software **shall** display a command status received from the flight system to indicate if each initiated command is accepted by the flight system or rejected by the flight system.			X		
TBR-01	3.3.5	The Ground Software **shall** send commands to the payload during an on-board command sequence execution.			X		
3.2.1.1	3.3.6	The Ground Software **shall** reject invalid commands.				X	
TBR-02	3.3.7	The Ground Software **shall** encrypt all commands sent via the experimental paths using <**TBD-13**> type of encryption.			X		

Requirement Number		Requirement	Verification Type				Remarks
SRS	GSRS		I	A	T	D	
3.2.2.2, 3.2.6.3	3.4.1	The Ground Software **shall** receive and display all payload health and status telemetry received from the Flight System as defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128, via the primary path.			X		
3.2.2.3	3.4.2	The Ground Software **shall** receive and display all payload telemetry sent during AOS from the Flight System via the primary path at least once per minute during an experiment period.			X		
3.2.2.4	3.4.3	The Ground Software **shall** receive and display all payload telemetry received from the Flight System as defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128, via the SN experimental path.			X		
3.2.2.4	3.4.4	The Ground Software **shall** receive and display all payload telemetry received from the Flight System as defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128, via the NEN experimental path.			X		
TBR-03	3.4.5	The Ground Software **shall** collect and display metrics and statistics regarding the health of the data links as defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128.			X		
3.2.3.1	3.4.6	The Ground Software **shall** monitor engineering data and provide notification per the Command and Telemetry Data Book, GRC-CONN-DBK-0128 and the Fault Detection, Isolation, and Recovery (FDIR) Report.			X		
3.2.6.16	3.4.7	The Ground Software **shall** provide data isolation for each radio (for example, 1 APID per radio).			X		
3.2.6.4	3.4.8	The Ground Software **shall** receive and display experiment data sent from the Flight System and defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128, via the primary path.			X		

Requirement Number		Requirement	Verification Type				Remarks
SRS	GSRS		I	A	T	D	
3.2.6.16	3.4.9	The Ground Software **shall** provide web pages from which authorized and authenticated users may retrieve CoNNeCT data via secure Internet Protocol from locations remote to the CCC.				X	
3.2.6.16	3.4.10	The Ground Software web pages **shall** provide data isolation for all access to CoNNeCT data web pages so that no radio vendor may view proprietary data owned by another vendor.				X	
3.2.6.16	3.4.11	The Ground Software web pages **shall** be available to authorized users external to GRC.				X	
3.2.2.2	3.4.12	The Ground Software **shall** provide alerts of out of limits telemetry values as defined in the Fault Detection, Isolation, and Recovery (FDIR) Report, GRC-CONN-RPT-0227.				X	
3.2.6.10	3.5.1	The Ground Software **shall** upload files of **<TBD-17>** size or less to the flight system transmitted via the primary commanding path.			X		
TBR-04	3.5.2	The Ground Software **shall** upload files of 12 MB or less with no errors transmitted via the SN experimental path.			X		
TBR-05	3.5.3	The Ground Software **shall** upload files of 12 MB or less with no errors transmitted via the NEN experimental path.			X		
3.2.3.2, 3.5.1	3.5.4	The Ground Software **shall** receive files from the flight system transmitted via the primary telemetry path.			X		
TBR-06	3.5.5	The Ground Software **shall** receive files with no errors from the flight system via the SN experimental path.			X		
TBR-07	3.5.6	The Ground Software **shall** receive files with no errors from the flight system via the NEN experimental path.			X		
3.2.6.10	3.5.7	The Ground Software **shall** segment files for upload via the Payload MDM into even byte segments of size 8 MB or less.			X		

Requirement Number		Requirement	Verification Type				Remarks
SRS	GSRS		I	A	T	D	
3.2.3.2, 3.5.1	3.5.8	The Ground Software **shall** reassemble segmented files downlinked via the Payload MDM.			X		
3.2.6.10	3.5.9	The Ground Software **shall** perform error checking on all received files and request retransmission of any file segments containing errors until a transmitted file is determined to be error free.			X		
3.1.3	3.6.1	The Ground Software **shall** display a confirmation warning if a command is issued that is not valid for the current state or mode of the payload according to the Modes and States Description Document, GRC-CONN-DOC-0152.			X		
3.2.7.1	3.8.1	The Ground Software **shall** synchronize its clock with the TSC provided time.			X		
3.2.1.7	3.9.1	The Ground Software **shall** be upgradable to support new flight software.		X			
3.9.1	3.10.1	The Ground Software **shall** implement any date sensitive code or timers in a manner that allows operations for a period of at least two years after launch.		X			
3.2.6.5	3.11.1	The Ground Software **shall** generate a pseudorandom bit sequence (PRBS) on command of 2^{23}-1 (for Ka-band) and 2^{11}-1 (for S-band) length for experimental links in real-time at experiment data rates.				X	
3.2.6.1	3.11.2	The CCC **shall** have multiple logical addresses to support Delay-Tolerant Networking (DTN).		X		X	DTN will not be verified prior to flight but will be demonstrated by PIs on EM hardware prior to flight.
3.2.6.9	3.11.3	**<TBD-14>**					
3.2.6.8	3.11.4	**<TBD-15>**					
3.2.6.7	3.11.5	**<TBD-16>**					

Requirement Number		Requirement	Verification Type				Remarks
SRS	GSRS		I	A	T	D	
3.3.6.1	3.12.1.1	The Ground Software **shall** utilize the Telescience Resource Kit (TReK) Software for sending data to and receiving data from the Marshall Space Flight Center (MSFC) Huntsville Operations Support Center (HOSC).	X				
3.3.4.1	3.12.2.1	**<TBD-5>**					
3.3.4.1	3.12.2.2	**<TBD-6>**					
3.3.5.1	3.12.3.1	**<TBD-7>**					
3.4.5.1	3.13.1.1	**<TBD-8>**					
3.2.4.1	3.13.2.1	The Ground Software **shall** generate files containing TDRS tracking information for upload to the flight system.			X		The TDRS tracking information needs to be provided by Mission Operations.

Table 4-2—CoNNeCT Software Requirements Traceability to Ground Software

Requirement Allocation Cross Reference Matrix	
SRS (Parent) Requirement Number	Trace to GSRS Requirement Number
SRS-3.1.2	Shouldn't be allocated to GSW
SRS-3.1.3	GSRS-3.6.1
SRS-3.2.1.1	GSRS-3.3.1, GSRS-3.3.4, GSRS-3.3.6
SRS-3.2.1.2	GSRS-3.3.2
SRS-3.2.1.4	Shouldn't be allocated to GSW
SRS-3.2.1.6	GSRS-3.2.1, GSRS-3.3.3
SRS-3.2.1.7	GSRS-3.9.1
SRS-3.2.2.2	GSRS-3.4.1, GSRS-3.4.12
SRS-3.2.2.3	GSRS-3.4.2
SRS-3.2.2.4	GSRS-3.4.3, GSRS-3.4.4
SRS-3.2.3.1	GSRS-3.4.6
SRS-3.2.3.2	GSRS-3.3.1, GSRS-3.5.4, GSRS-3.5.8
SRS-3.2.4.1	GSRS-3.13.2.1
SRS-3.2.6.1	GSRS-3.11.2
SRS-3.2.6.3	GSRS-3.3.1, GSRS-3.4.1
SRS-3.2.6.4	GSRS-3.4.8
SRS-3.2.6.5	GSRS-3.11.1
SRS-3.2.6.7	GSRS-3.11.5
SRS-3.2.6.8	GSRS-3.11.4
SRS-3.2.6.9	GSRS-3.11.3
SRS-3.2.6.10	GSRS-3.5.1, GSRS-3.5.7, GSRS-3.5.9
SRS-3.2.6.15	This will be a CCC requirement
SRS-3.2.6.16	GSRS-3.4.7, GSRS-3.4.9, GSRS-3.4.10, GSRS-3.4.11
SRS-3.2.7.1	GSRS-3.8.1
SRS-3.3.4.1	GSRS-3.12.2.1, GSRS-3.12.2.2
SRS-3.3.5.1	GSRS-3.12.3.1
SRS-3.3.6.1	GSRS-3.12.1.1
SRS-3.4.5.1	GSRS-3.13.1.1
SRS-3.5.1	GSRS-3.5.4, GSRS-3.3.1, GSRS-3.5.8
SRS-3.7.1	GSRS-3.2.2
SRS-3.9.1	GSRS-3.10.1
SRS-3.11.1	GSRS-3.1.1

APPENDIX A ACRONYMS AND ABBREVIATIONS

A.1 Scope

This appendix lists the acronyms and abbreviations used in this document.

A.2 List of Acronyms and Abbreviations

Table A-1—Acronyms

AOS	Acquisition of Signal
APID	Application Process Identifier
BER	Bit Error Rate
CCC	CoNNeCT Control Center
CoNNeCT	Communications, Navigation, and Networking reConfigurable Testbed
COTS	Commercial Off The Shelf
CSCI	Computer Software Configuration Item
DTN	Delay-Tolerant Networking
FDIR	Fault Detection, Isolation, and Recovery
GIU	Ground Integration Unit
GRC	Glenn Research Center
GSE	Ground Support Equipment
GSRS	Ground Software Requirements Specification
HOSC	Huntsville Operations Support Center
ISS	International Space Station
LOS	Loss of Signal
MB	Megabytes
Mbps	Megabits per Second
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NEN	Near Earth Network
NISN	NASA Integrated Services Network
PAS	Payload Avionics Software
PI	Principal Investigator
PL MDM	Payload Multiplexer/Demultiplexer
PRBS	Pseudo-Random Bit Sequence
RF	Radio Frequency
SDR	Software Defined Radio
SN	Space Network
SRS	Software Requirements Specification
STRS	Space Telecommunications Radio System
TBD	To Be Determined
TBR	To Be Resolved
TDRS(S)	Tracking and Data Relay Satellite (System)
TReK	Telescience Resource Kit
TSC	Telescience Support Center

APPENDIX B DEFINITIONS

B.1 Scope

This appendix lists the definitions used in this document.

B.2 List of Definitions

Table B-1—Definitions

Activity: (1) Any of the project components or research functions that are executed to deliver a product or service or provide support or insight to mature technologies. (2) A set of tasks that describe the technical effort to accomplish a process and help generate expected outcomes.

Advanced Technology Development: ATD is one of four interrelated NASA product lines. ATD programs and projects are investments that produce entirely new capabilities or that help overcome technical limitations of existing systems. ATD is seen as a bridge between BAR and actual application in NASA, such as FS&GS projects or elsewhere. ATD projects typically fall within a Technology Readiness Level (TRL) range of 4 to 6.

Architecture and Design: A description of the mission elements, their interfaces, their logical and physical layout, and the analysis of the design to determine expected performance and margins. Includes System Design Synthesis, System Design Analysis, and System Design Validation products.

Baseline: An agreed-to set of requirements, designs, or documents that will have changes controlled through a formal approval and monitoring process.

Configuration Management: A systematic process for establishing and maintaining control and evaluation of all changes to baseline documentation, products (Configuration Items), and subsequent changes to that documentation which defines the original scope of effort. The systematic control, identification, status accounting, and verification of all Configuration Items throughout their life cycle.

Contractor: Per NPR 7123.1, a "contractor" is an individual, partnership, company, corporation, association, or other service having a contract with the Agency for the design, development, manufacture, maintenance, modification, operation, or supply of items or services under the terms of a contract to a program or project within the scope of this NPR. Research grantees, research contractors, and research subcontractors are excluded from this definition.

Customer: The organization or individual that has requested a product and will receive the product to be delivered. The customer may be an end user of the product, the acquiring agent for the end user, or the requestor of the work products from a technical effort. Each product within the system hierarchy has a customer. A subset of "stakeholders." (Refer to Stakeholder.)

Decision Authority: The Agency's responsible individual who authorizes the transition at a KDP to the next life-cycle phase for a program/project.

Designated Governing Authority: The management entity above the program, project, or activity level with technical oversight responsibility.

Entry Criteria: Minimum accomplishments each project needs to fulfill to enter into the next life-cycle phase or level of technical maturity.

Exit Criteria: Specific accomplishments that should be satisfactorily demonstrated before a project can progress to the next product-line life-cycle phase.

Expectation: Statements of needs, desires, capabilities, and wants that are not expressed as a requirement (not expressed as a "shall" statement) is to be referred to as an "expectation." Once the set of expectations from applicable stakeholders is collected, analyzed, and converted into a "shall" statement, the "expectation" becomes a "requirement." Expectations can be stated in either qualitative (nonmeasurable) or quantitative (measurable) terms. Requirements are always stated in quantitative terms. Expectations can be stated in terms of functions, behaviors, or constraints with respect to the product being engineered or the process used to engineer the product.

Flight Systems and Ground Support: FS&GS is one of four interrelated NASA product lines. FS&GS projects result in the most complex and visible of NASA investments. To manage these systems, the Formulation and Implementation phases for FS&GS projects follow the NASA project life-cycle model consisting of phases A (Concept Development) through F (Closeout). Primary drivers for FS&GS projects are safety and mission success.

Formulation Phase: The first part of the NASA management life cycle defined in NPR 7120.5 where system requirements are baselined, feasible concepts are determined, a system definition is baselined for the selected concept(s), and preparation is made for progressing to the Implementation phase.

I**mplementation Phase**: The part of the NASA management life cycle defined in NPR 7120.5 where the detailed design of system products is completed and the products to be deployed are fabricated, assembled, integrated, and tested; and the products are deployed to their customers or users for their assigned use or mission.

Interface Control Document (ICD): A specification of the mechanical, thermal, electrical, power, command, data, and other interfaces that system elements must meet.

Key Decision Point: The event at which the Decision Authority determines the readiness of a program/project to progress to the next phase of the life cycle (or to the next KDP).

Level 1 Requirement: A Project's fundamental and basic set of requirements levied by the Program or Headquarters on the project.

Logical Decomposition: The decomposition of the defined technical requirements by functions, time, and behaviors to determine the appropriate set of logical models and related derived technical requirements. Models may include functional flow block diagrams, timelines, data control flow, states and modes, behavior diagrams, operator tasks, and functional failure modes.

Measure of Effectiveness: A measure by which a stakeholder's expectations will be judged in assessing satisfaction with products or systems produced and delivered in accordance with the associated technical effort. The MOE is deemed to be critical to not only the acceptability of the product by the stakeholder but also critical to operational/mission usage. An MOE is typically qualitative in nature or not able to be used directly as a "design-to" requirement.

Measure of Performance: A quantitative measure that, when met by the design solution, will help ensure that an MOE for a product or system will be satisfied. These MOPs are given special attention during design to ensure that the MOEs to which they are associated are met. There are generally two or more measures of performance for each MOE.

Other Interested Parties: A subset of "stakeholders," other interested parties are groups or individuals that are not customers of a planned technical effort but may be affected by the resulting product, the manner in which the product is realized or used, or have a responsibility for providing life-cycle support services. A subset of "stakeholders." (Refer to Stakeholder.)

Operations Concept: A concept that defines how the mission will be verified, launched, commissioned, operated, and disposed of. Defines how the design is used to meet the requirements.

Peer Review: Independent evaluation by internal or external subject matter experts who do not have a vested interest in the work product under review. Peer reviews can be planned focused reviews, conducted on selected work products by the producer's peers to identify defects and issues prior to that work product moving into a milestone review or approval cycle.

Product: A part of a system consisting of end products that perform operational functions and enabling products that perform life-cycle services related to the end product or a result of the technical efforts in the form of a work product (e.g., plan, baseline, or test result).

Product-Based WBS Model: Refer to WBS model.

Product Realization: The act of making, buying, or reusing a product, or the assembly and integration of lower level realized products into a new product, as well as the verification and validation that the product satisfies its appropriate set of requirements and the transition of the product to its customer.

Program: A strategic investment by a mission directorate (or mission support office) that has defined goals, objectives, architecture, funding level, and a management structure that supports one or more projects.

Project: (1) A specific investment having defined goals, objectives, requirements, life-cycle cost, a beginning, and an end. A project yields new or revised products or services that directly address NASA's strategic needs. They may be performed wholly in-house; by Government, industry, academia partnerships; or through contracts with private industry. (2) A unit of work performed in programs, projects, and activities.

Realized Product: The desired output from the application of the four Product Realization Processes. The form of this product is dependent on the phase of the product-line life cycle and the phase exit criteria.

Relevant Stakeholder: Refer to Stakeholder.

Requirement: The agreed upon need, desire, want, capability, capacity, or demand for personnel, equipment, facilities, or other resources or services by specified quantities for specific periods of time or at a specified time expressed as a "shall" statement. Acceptable form for a requirement statement is individually clear, correct, feasible to obtain, unambiguous in meaning, and can be validated at the level of the system structure at which stated.

Risk: The combination of the probability that a program or project will experience an undesired event (some examples include a cost overrun, schedule slippage, safety mishap, health problem, malicious activities, environmental impact, failure to achieve a needed scientific or technological breakthrough or mission success criteria) and the consequences, impact, or severity of the undesired event, were it to occur. Both the probability and consequences may have associated uncertainties. (Reference 7120.5.)

Software: As defined in NPD 2820.1, NASA Software Policy.

Specification: A document that prescribes, in a complete, precise, verifiable manner, the requirements, design, behavior, or characteristics of a system or system component.

Stakeholder: A group or individual who is affected by or is in some way accountable for the outcome of an undertaking. The term "relevant stakeholder" is a subset of the term "stakeholder" and describes people or roles that are designated in a plan for stakeholder involvement. Since "stakeholder" may describe a very large number of people, a lot of time and effort would be consumed by attempting to deal with all of them. For this reason, "relevant stakeholder" is used in most practice statements to describe the people identified to contribute to a specific task. There are two main classes of stakeholders. Refer to "customers" and "other interested parties."

Success Criteria: Specific accomplishments that must be satisfactorily demonstrated to meet the objectives of a technical review so that a technical effort can progress further in the life cycle. Success criteria are documented in the corresponding technical review plan.

System: (a) The combination of elements that function together to produce the capability to meet a need. The elements include all hardware, software, equipment, facilities, personnel, processes, and procedures needed for this purpose. (Refer to NPR 7120.5.) (b) The end product (which performs operational functions) and enabling products (which provide life-cycle support services to the operational end products) that make up a system. (Refer to WBS definition.)

Systems Approach: The application of a systematic, disciplined engineering approach that is quantifiable, recursive, iterative, and repeatable for the development, operation, and maintenance of systems integrated into a whole throughout the life cycle of a project or program.

Systems Engineering Engine: The SE model provides the 17 technical processes and their relationship with each other. The model is called an "SE engine" in that the appropriate sets of processes are applied to the products being engineered to drive the technical effort.

Systems Engineering Life-Cycle: Concept Studies (Phase A), Preliminary Analysis and Definition (Phase B), Design (Phase C), Development (Phase D), Mission Operations (Phase E) and Disposal (Phase F) are the systems engineering life-cycle phases. Development includes Acquisition, Fabrication, and Integration; Verification and Preparation for Deployment; and Deployment and Operations Verification.

Systems Engineering Management Plan (SEMP): The SEMP identifies the roles and responsibility interfaces of the technical effort and how those interfaces will be managed. The SEMP is the vehicle that documents and communicates the technical approach, including the application of the common technical processes; resources to be used; and key technical tasks, activities, and events along with their metrics and success criteria.

System Safety Engineering: The application of engineering and management principles, criteria, and techniques to achieve acceptable mishap risk, within the constraints of operational effectiveness and suitability, time, and cost, throughout all phases of the system life cycle.

System Structure: A system structure is made up of a layered structure of product-based WBS models. (Refer to WBS definition.)

Technical Performance Measures: The set of critical or key performance parameters that are monitored by comparing the current actual achievement of the parameters with that anticipated at the current time and on future dates. Used to confirm progress and identify deficiencies that might jeopardize meeting a system requirement. Assessed parameter values that fall outside an expected range around the anticipated values indicate a need for evaluation and corrective action. Technical performance measures are typically selected from the defined set of Measures of Performance (MOPs).

Technology Readiness Level: Provides a scale against which to measure the maturity of a technology. TRLs range from 1, Basic Technology Research, to 9, Systems Test, Launch, and Operations. Typically, a TRL of 6 (i.e., technology demonstrated in a relevant environment) is required for a technology to be integrated into an SE process.

Technical Risk: Risk associated with the achievement of a technical goal, criterion, or objective. It applies to undesired consequences related to technical performance, human safety, mission assets, or environment.

Validation (of a product): Proof that the product accomplishes the intended purpose. Validation may be determined by a combination of test, analysis, and demonstration.

Validated Requirements: A set of requirements that are well-formed (clear and un-ambiguous), complete (agrees with customer and stakeholder needs and expectations), consistent (conflict free), and individually verifiable and traceable to a higher-level requirement or goal.

Verification (of a product): Proof of compliance with specifications. Verification may be determined by test, analysis, demonstration, and inspection.

Waiver: A documented agreement intentionally releasing a program or project from meeting a requirement. (Some Centers use deviations prior to Implementation and waivers during Implementation).

WBS Model: Model that describes a system that consists of end products and their subsystems (perform the operational functions of the system), the supporting or enabling products (for development; fabrication, assembly, integration, and test; operations; sustainment; and end-of-life product disposal or recycling), and any other work products (plans, baselines) required for the development of the system.

APPENDIX C TBDS AND TBRS

C.1 Scope

This appendix lists all items in this document that need to be determined (TBD) and or that need to be resolved (TBR).

C.2 List of TBDs

Table C-1—TBDs

TBD Number	Description	Document Paragraph	Planned Closure
5	Space Network Interface Requirements	3.12.2.1, 4.0	Now that the GSRD is baselined, we can begin to define these interfaces more clearly. Plan to close by CDR.
6	Space Network Interface Requirements	3.12.2.2, 4.0	Now that the GSRD is baselined, we can begin to define these interfaces more clearly. Plan to close by CDR.
7	Near Earth Network Interface Requirements	3.12.3.1, 4.0	Now that the GSRD is baselined, we can begin to define these interfaces more clearly. Plan to close by CDR.
8	Ground Software / Payload Avionics Software Interface	3.13.1.1, 4.0	Work with Payload Avionics Software Team to determine what requirements exist to ensure proper and thorough interface requirements exist. Plan to close by CDR.
10	Maximum file size per segment when uploading or downlinking a file via the experimental path	3.5	Plan to close by end of June 2010, as experimental path requirements become clearer.
13	Type of encryption required for sending commands via the experimental paths (if encryption is in fact required)	3.3.7, 4.0	Work with Mission Operations Team to determine the type of encryption necessary. Plan to close by end of June 2010, as experimental path requirements become clearer.
14	Decompose SRS-3.2.6.9 to a lower-level Ground Software requirement, if needed. This parent SRS requirement MAY NOT be allocated to Ground Software. SRS-3.2.6.9 traces up to FSRD-1567, and the rationale for FSRD-1567 states: "The intent of this requirement is to drive communications between avionics and the SDRs for experiments." SRS-3.2.6.9: The Software **shall** implement IP per IETF STD-0005, "Internet Protocol (IP)."	3.11.3, 4.0	Work with PI Team to determine if this requirement is truly a requirement on the Ground Software, and if so, what the Ground Software must do. Plan to close by end of June 2010, as experimental path requirements become clearer.
15	Decompose SRS-3.2.6.8 to a lower-level Ground Software requirement, if needed. This parent SRS requirement MAY NOT be allocated to Ground Software. SRS-3.2.6.8: The Software **shall** implement TCP per IETF STD-0007, "Transmission Control Protocol (TCP)."	3.11.4, 4.0	Work with PI Team to determine if this requirement is truly a requirement on the Ground Software, and if so, what the Ground Software must do. Plan to close by end of June 2010, as experimental path requirements become clearer.

16	Decompose SRS-3.2.6.7 to a lower-level Ground Software requirement, if needed. This parent SRS requirement will LIKELY NOT be allocated to Ground Software. SRS-3.2.6.7: The Software **shall** perform Fast Fourier Transforms on raw analog-to-digital conversion (ADC) samples streamed from the SDRs.	3.11.5, 4.0	Work with PI Team to determine if this requirement is truly a requirement on the Ground Software, and if so, what the Ground Software must do. Plan to close by end of June 2010, as experimental path requirements become clearer.
17	Maximum file size for uplinking files via the primary commanding path. A recommendation of 100 kilobytes is based on reasonable transfer time (approximately 21 minutes of AOS is required to upload a 100 kilobyte file) and also based on FCF experience.	3.5.1, 4.0	Work with all project stakeholders relating to file transfer to determine the maximum file size for uploading via the primary commanding path. Plan to close by CDR.

C.3 List of TBRs

Table C-2—TBRs

TBR Number	Description	Document Paragraph	Planned Closure
1	Missing SRS parent for GSRS-3.3.5: The Ground Software **shall** send commands to the payload during an on-board command sequence execution.	3.3, 4.0	A draft Change Request (CR) for the SRS will be available for review at Project CDR.
2	Missing SRS parent for GSRS-3.3.7: The Ground Software **shall** encrypt all commands sent via the experimental paths. Also, is this really a requirement? May be necessary per NPR 2810, but no corresponding SRD or SRS parent requirements!	3.3, 4.0	A draft Change Request (CR) for the SRS will be available for review at Project CDR.
3	Missing SRS parent for GSRS-3.4.5: The Ground Software **shall** collect and display metrics and statistics regarding the health of the data links as defined in the Command and Telemetry Databook, GRC-CONN-DBK-0128.	3.4, 4.0	A draft Change Request (CR) for the SRS will be available for review at Project CDR.
4	Missing SRS parent for GSRS-3.5.2: The Ground Software **shall** upload files of 12 MB or less with no errors transmitted via the SN experimental path.	3.5, 4.0	A draft Change Request (CR) for the SRS will be available for review at Project CDR.
5	Missing SRS parent for GSRS-3.5.3: The Ground Software **shall** upload files of 12 MB or less with no errors transmitted via the NEN experimental path.	3.5, 4.0	A draft Change Request (CR) for the SRS will be available for review at Project CDR.
6	Missing SRS parent for GSRS-3.5.5: The Ground Software **shall** receive files of size 12 MB or less with no errors from the flight system via the SN experimental path.	3.5, 4.0	A draft Change Request (CR) for the SRS will be available for review at Project CDR.
7	Missing SRS parent for GSRS-3.5.6: The Ground Software **shall** receive files of size 12 MB or less with no errors from the flight system via the NEN experimental path.	3.5, 4.0	A draft Change Request (CR) for the SRS will be available for review at Project CDR.

8	Need to resolve if GSRS-3.11.2 pertains to ground software (or perhaps is a CCC hardware requirement, or an experimenter function, and therefore does not belong in this Ground Software Requirements Specification). GSRS-3.11.2: The CCC **shall** have multiple logical addresses to support Delay-Tolerant Networking (DTN).	3.11	Work with PI Team to determine if this requirement is truly a requirement on the Ground Software, and if not, where this responsibility belongs (CCC Specification, Mission Operations Requirement, etc.). Plan to close by end of June 2010, as experimental path requirements become clearer.

APPENDIX D LIST OF SRS REQUIREMENTS NOT FLOWN DOWN

Table D-1—SRS Requirements Not Flown Down

SRS Req Number	SRS Requirement Text	Reason Not Flown Down to GSRS
SRS-3.2.1.4	The Software **shall** control movement of the Ka-band and medium gain S-band Antennas over the MIL-STD-1553 data interface with the gimbal motor controller per the gimbal controller electronics user guide, DUDG10351000-14. *Rationale: Gimbals will be used to move the antenna assembly. The gimbal controller electronics has a MIL-STD-1553 data interface. The ground will send up preplanned tracking information.*	This parent requirement should not be allocated to ground software. The ground software does not control the gimbal controller electronics; this requirement is for the interface between the PAS and the Gimbal Controller Electronics. Other GSRS requirements cover the ground portion of this requirement (to send up pre-planned tracking information). See SRS-3.2.4.1 and corresponding GSRS-3.13.2.1.
SRS-3.2.6.15	The Software **shall** store all data originating from the Flight System and received from the ISS Huntsville Operations Support Center (HOSC), Space, and or Near-Earth Network. *Rationale: Data **shall** be stored at the CCC.*	This requirement is levied on the CCC, NOT on the ground software. This requirement will trace to the CCC Specification.
SRS-3.1.2	The Software **shall** operate SDRs in the combinations and configurations specified in FSRD Table 3.2.2.1-1, "CoNNeCT Operational Configurations". *Rationale: The software must be able to configure the system to handle all the different valid simultaneous combinations of SDR operations at various data rates and simplex/duplex transmission.*	This parent requirement should not be allocated to ground software. The operational configurations listed in the FSRD do not impose any requirements on the ground software. No upper-level GSRD parent exists for this requirement. The ground software will allow all commands necessary to put the payload in the required operational configurations specified in the FSRD by allowing all commands listed in the Command and Telemetry Databook (refer to GSRS-3.3.1). The ground software does not need to allow or disallow operational configurations; it will be covered by flight software and/or operational procedures on the ground.