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# Space Telecommunications Radio System (STRS) Architecture Goals/Objectives and Level 1 Requirements

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## 1.0  Introduction

### 1.1  Purpose and Objectives of Document

The Space Telecommunications Radio System (STRS) Architecture Requirements Document provides the basis for the development of an open architecture for NASA Software Defined Radios (SDRs) for space use. The STRS project is currently under the direction of the Space Communication and Navigation (SCaN) Program. The STRS program encompasses many aspects related to the use of SDRs for NASA including:

1. Development of the STRS standard for SDRs

2. Inclusion of non-NASA entities for standards development and implementation, including other Government agencies, international and domestic industry, SDR forums and organizations, and academia

3. Development of design tools and validation test beds for standard-compliant SDRs

4. Development of standard-compliant hardware and software library components from which a variety of SDR types may be tailored for specific missions

5. Development of a Business Case Analysis for both SDRs in general and SDR standardization, including case studies of past NASA programs

6. Development of an SDR acquisition model tailored to the specific needs of SDR design, development, test and evaluation programs

7. Performance of an SDR application study using the NASA Space Exploration Mission Model for recommending SDR designs for specific missions and mission types

8. Development of Design Reference Implementation Specifications for reference in creating specific SDR designs

9. Compilation of an SDR technologies database identifying imminent and long term technologies needed to realize near-term and future SDR designs

10. Compilation of an industry and Government organizations SDR designs database identifying specific SDR design implementations currently available, in-work, and planned

11. Evaluation of the DoD Joint Tactical Radio System Program for cooperative efforts

The requirements stated within this document only address item #1: Development of the STRS standard for SDRs.

### 1.2  Scope of Document

This document describes the requirements of the Space Telecommunication Radio System Architecture. These requirements were developed as follows: The Top-Level Customer Guidelines are provided by NASA Headquarters. They provide requirements intended to guide the broader and longer-

term aspects of the SDR Architecture. The goals and objectives are derived from the Top-Level Customer Guidelines. They provide broad, fundamental direction and purpose. They are not meant to be verifiable. Level 1 requirements are derived from the goals and objectives and are verifiable but are not intended to be verified directly. They will be decomposed into further requirements (Level 2 requirements) which will be verified. The Level 1 requirements are considered verified after all of the decomposed (Level 2) requirements are verified.

### 1.3   Document Overview

The document is divided into sections. Section 1 introduces the reader to the document. Section 2 provides the list related documentation. Section 3 describes the Top-Level Customer guidelines. Section 4 describes the STRS goals and objectives. Section 5 describes the derived system requirements that identify the architecture consideration for this study. Section 6 provides the list abbreviations and acronyms related to the document.

## 2.0   Related Documentation

**Document Number**            **Document Title**
STRS-DA-00001                  Space Telecommunications Radio System STRS Definitions and Acronyms

## 3.0   Top Level Customer Guidelines

Guidelines were provided by NASA Headquarters and are stated below without modification. They have been designated the "Customer Guidelines".

Compared to traditional NASA-developed communications assets, the standard SDR architecture should provide for:

1. Flexibility with broad application through adaptability and evolution to many NASA mission types from 2015 to 2030 (flight years)
2. Lower agency-level cost and risk across all missions
3. Faster development from mission requirements determination through flight hardware delivery
4. Use of a high degree of non-proprietary design, development and operation
5. Multi-Center participation in architecture development
6. Be adaptable to evolving requirements through 2030
7. Accommodate technology advances through 2030

## 4.0   STRS Goals and Objectives

The goals and objectives clarify and expand on the Top-Level Customer Guidelines. They provide broad, fundamental direction and purpose. They are not meant to be verifiable.

### 4.1   Usable Across Most NASA Mission Types (Scalability and Flexibility)

*Rationale*: The architecture approach allows the adoption of different implementations for most mission classes. The architecture will not be usable if excessive burden (such as Size, Weight, and Power (SWaP) and complexity) is needed for a single mission to realize the multi-mission benefits. It also should be usable with the computing elements capable of operating in the space environment. This includes the capability to eliminate or mitigate long and short term radiation effects, perform in a vacuum, and operate in extreme temperatures. The radio should also survive the effects of launch including Near Strike Lightning (NSL) to the extent that full performance can be restored. The capabilities of elements that can operate in this environment lag behind the capabilities of ground environment elements. The

impact to the STRS architecture will be the performance and capacity of the components that are rated for space environment. The architecture is expected to apply to the majority of missions with the realization that a few missions should be allowed waivers to develop a non-fully STRS conformant radio.

## 4.2  Decrease Development Time and Cost

*Rationale*: NASA HQ has given us the challenge to lower cost and risk and decrease the development time of software defined radios. Complex reliable software can become very costly in terms of dollars and development time. With standard functions and interfaces defined by the architecture, code is more easily reused.

## 4.3  Increase Reliability of Software Defined Radios

*Rationale*: Managing the complexity of the design through a common architecture and reducing the amount of interdependence on other systems will enhance reliability. Common qualification processes and procedures will allow for improved testing methods as flaws in previous procedures are discovered and new methods are developed.

## 4.4  Accommodate Advances in Technology With Minimal Rework (Extensibility)

*Rationale*: Technology advances will continue to provide greater processing power and memory and require less size, weight, and power. The architecture should also be able to accommodate the current and future evolution to advanced SDR concepts such as Ideal Software Radios (direct digital sampling at the antenna port) and Cognitive Radios, and should be extendable to interface with optical communication systems.

## 4.5  Adaptable to Evolving Requirements (Adaptability)

*Rationale*: Future missions may have requirements for operations or capabilities that have not currently been considered. For example, a higher level of security support may be required and the architecture should adapt to accommodate this new need.

## 4.6  Enable Over the Air Interoperability With Existing Assets (Interoperability)

*Rationale*: The existing communication infrastructure typically needs to be operational for many years. As radio technology evolves, it is usually not feasible to upgrade all existing assets in order to operate over the air with new systems.

## 4.7  Leverage Existing or Developing Standards, Resources, and Experience (State-of-the-Art and State-of-Practices)

*Rationale*: Space radio vendors are building and deploying software defined radios. Given the limited number of radios that will be procured by NASA, aligning with current approaches to the extent possible is necessary. Leveraging their software and hardware development and products to the extent reasonable may reduce NASA's costs and risks. Deviating from current practices would increase design cost and schedule and decrease reliability.

## 4.8  Maintain Vendor Independence

*Rationale*: Not relying on a single vendor will reduce operation and maintenance costs and reduce the risk that the vendor will not support future modifications which will be inherent to SDR operations.

### 4.9 Enable Waveform Application Portability

*Rationale*: The number of waveforms being used by NASA is limited and unlikely to increase or dramatically change. Reusing all or part of the code for this limited number of waveforms will decrease development time and cost and increase reliability.

# 5.0 STRS Level 1 Requirements

STRS Architecture Requirements support a NASA perspective that often spans multiple missions. These requirements address how the various mission classes are expected to use the architecture. The following sections list the Level 1 requirements, which were derived from the Goals/Objectives.

These requirements are intended to address the STRS Architecture, not a specific implementation. An implementation may not require all aspects of the architecture; therefore, all requirements may not apply to each STRS-compliant software defined radio. The architecture specification will evolve depending on available technology and capabilities. Some requirements may not apply to near term applications.

### 5.1 Layered Architecture

The STRS Architecture shall be layered to isolate waveform applications from hardware specific implementations.

*Rationale*: Layering provides a means of maximizing hardware abstraction, portability, and technology insertion. Layering promotes waveform application portability to alternate platforms that conform to the architecture.

### 5.2 Open Architecture

The STRS Architecture shall utilize an Open System Architecture approach.

*Rationale*: A System Architecture approach is comprehensive set of functions, components, and design rules according to which radio communication systems can be organized, designed, constructed, deployed, operated, and evolved over time. A useful architecture partitions functions and components such that a) functions are assigned to components clearly and b) physical interfaces among components correspond to logical interfaces among functions. When functions, interfaces, components, and/or design rules are defined and published, the architecture is open. Open architectures facilitates interoperability among commercial and Government developers and minimizes the operational impact of upgrading hardware and software components.

### 5.3 Flexibility in Form Factor

The STRS Architecture shall allow the radio to be flexible in physical form factor.

*Rationale:* The radio will need to be configured into different physical form factors to meet mission size, weight, and power requirements. These form factors will require the ability to be sized based on the hardware required to implement the waveform functions. The architecture is specified as platform independent and scalable to address mission requirements.

### 5.4 Remote Reconfiguration

The STRS Architecture shall allow the radio to maintain reliable operation during remote partial and full reconfiguration of firmware and software.

*Rationale:* Firmware and software reconfiguration in the operational environment enables modification of radio units post-launch to meet varying mission needs without loading new firmware or software.

## 5.5 Remote Reprogrammability

The STRS Architecture shall allow the radio to maintain reliable operation during remote partial and full software and firmware uploads.

*Rationale*: This capability will allow the radio units to maintain communication and operational status during the reload process. The upgrade can then be implemented upon the next boot or startup. Reprogrammability provides the ability to correct latent software defects or implement new capabilities.

## 5.6 External Hardware Control

The STRS Architecture shall allow the radio to control external hardware in real-time.

*Rationale*: This capability will allow the radio to set and modify parameters to external hardware. For instance, tuning external RF hardware within specified frequency bands to avoid external interference sources and changing the output level of the power amplifier. This potentially eliminates additional front-end hardware sets.

## 5.7 Standard Spacecraft Interfaces

The STRS Architecture shall allow the radio to use standard spacecraft interfaces.

*Rationale*: The radio will be employed on platforms using standard spacecraft interfaces for power. The radio will need to exchange voice, video, and data with spacecraft systems using the common spacecraft software and hardware interfaces. Utilization of common spacecraft busses also enables the radio and other devices on the spacecraft bus to share excess resources such as processing power.

## 5.8 Existing Waveform Support

The STRS Architecture shall allow the radio to operate legacy, current standard, and defined waveforms.

*Rationale*: The radio must be capable of interoperability with current and legacy waveforms to support existing networks while providing a transition path to future systems.

## 5.9 Multiple Waveform Support

The STRS Architecture shall allow the radio to operate more than one waveform.

*Rationale*: Missions typically require communications using more than one waveform, such as a mission that requires different waveforms during different phases or a mission that must use both GPS and TDRS. By having a single radio be capable of running more than one waveform, this can reduce the number of radios for a mission.

## 5.10 Simultaneous Operation of Multiple Waveforms

The STRS Architecture shall allow the radio to operate multiple waveforms simultaneously.

*Rationale*: Missions typically require Telemetry, Tracking and Control (TT&C) as well as mission data transmission capability simultaneously. The radio could also be used for simultaneous GPS reception, thus eliminating the need for a separate receiver.

## 5.11 Multi-Service Support

The STRS Architecture shall allow the radio to use both narrowband and wideband waveforms for voice, video, and data space communications.

*Rationale*: The NASA users operating across the operational continuum must communicate with users that employ radio systems with a wide variety of waveforms and technological maturity.

## 5.12  Suitable for Any Radio Frequency Bands

The STRS Architecture shall allow the radio to operate with any frequency band within VHF to high frequency optical.

*Rationale*: The architecture should not limit the range of frequencies that radio implementations can operate with. NASA missions typically need to use low frequency bands for telemetry, and high frequency bands for science data. Future NASA missions will probably need significantly larger science data transfers from space, requiring even higher frequency bands to be implemented. It is envisioned that future NASA missions will utilize optical communications, for direct to Earth and for inter-satellite links. As a result, the STRS baseband unit should be capable of interfacing to optical communications hardware.

## 5.13  Multiple Frequency Bands

The STRS Architecture shall allow the radio to operate in several communication bands simultaneously.

*Rationale:* Different missions may require communication via different relay satellites or ground stations. Longer duration missions especially may need to adapt to using different frequency bands. For the foreseeable future, the frequency band will probably be determined by the pre-launch installed RF components in order to reduce weight, power, and complexity.

## 5.14  Multi-Channel Capability

The STRS Architecture shall allow the radio to operate multiple simultaneous channels in a single communication band.

*Rationale:* For example, this allows for the case where a mission requires that high criticality data be sent using a different channel than lower criticality data. Multiple simultaneous channels can also allow for increased throughput or redundancy.

## 5.15  Commanded Built-In-Test and Status Reporting

The STRS Architecture shall allow the radio to provide a Built-In-Test (BIT) and status of the radio functionality, and last known configuration when interrogated remotely.

*Rationale:* This capability provides a means of accessing data that can be used to identify faults, as well as providing valuable configuration information. This will increase reliability and availability by increasing understanding of the nature of a problem leading to a faster recovery, as well as supplying additional information to assist in improving future designs and procedures.

## 5.16  Operational Diagnostics

The STRS Architecture shall allow the radio to detect extended loss of operation either due to signal degradation or due to internal malfunction.

*Rationale:* This capability will increase reliability and availability by allowing faster detection of a problem leading to a quicker recovery. This is not a BIT but a behavior based on operational activity. The radio detects a problem and then may issue BITs to attempt to determine if the signal loss is due to hardware or external factors.

## 5.17  Automated System Recovery/Initialization

The STRS Architecture shall allow the radio to autonomously recover from fault conditions after reboot or power cycle.

*Rationale:* Recovery of the radio to an operational state after a fault condition (e.g., power loss, failed uploads, software errors, Single Event Upsets) will support critical continuity of operations. The radio must be able to return to full operation (restores back to last radio configuration/parameters/operational settings prior to fault condition) without need for external equipment or procedures. A radio may recover from an internal error without the need to reboot or power cycle, however that is not a requirement of the architecture.

## 5.18 Navigation Support

The STRS Architecture shall allow the radio to use current, and be adaptable to new, radiometric tracking and navigation waveforms and services.

*Rationale*: Radiometric data is collected to provide measurements used to produce estimates of the user's trajectory, including position, velocity, and time. Integrating the communication and tracking system into a single radio reduces the overall required RF spectrum, mass, power, and volume allocations. Special considerations will be required in the design and implementation of the radio to implement the integrated system.

## 5.19 Network Support

The STRS Architecture shall allow the radio to use current, and be adaptable to new, networking protocols.

*Rationale:* This includes Consultative Committee for Space Data Systems (CCSDS) and Internet Protocol (IP) including a network infrastructure comprised of dispersed network elements using various communications transport capabilities. CCSDS and IP are in common use in many existing systems and have been used in several NASA missions. New delay tolerant protocols are being considered and the architecture must adapt to support these and other future protocols.

## 5.20 Security Compatibility

The STRS Architecture shall allow the radio to be compatible with current, and be adaptable to new, security measures.

*Rationale:* The radio will require the functionality of certain legacy equipment for backwards compatibility as well as current security measures required to protect capability and waveforms.

## 5.21 Secure Transmission

The STRS Architecture shall allow the radio to use secure transmission.

*Rationale:* Transmission security shall deny unauthorized access to information while being transported over the radio to protect capabilities and waveforms.

## 5.22 Processor Sharing

The STRS Architecture shall allow the radio to be reconfigurable to provide additional computing resources at times when communications are low or zero.

*Rationale:* The radio may not need to perform its communications functions at all times. Agency cost and risk can be reduced by sharing these unused computing resources with other devices (e.g., science experiment computer) using standard spacecraft interfaces.

## 5.23 Autonomous Link Optimization

The STRS Architecture shall allow the radio to autonomously monitor the communications environment and self-adapt to optimize the communications link.

*Rationale*: Optimization can increase availability of the link, allowing the radio to be used in missions where link conditions could vary. This optimization can include changes to the modulation and coding schemes (e.g., use a lower coding rate in favorable link conditions). This capability makes it possible to "fine-tune" the communication link much more accurately than an operator could perform a similar function.

# 6.0 Traceability Matrix

This traceability matrix was generated to understand how the STRS Goals and Objectives traced and mapped to the STRS Level 1 Requirements. The purpose of this matrix is to assure that all Requirements support at least one Goal/Objective, and that all Goals/Objectives are captured in Requirements. The lack of an "X" does not necessarily mean that a mapping does not exist between the requirement and the Goal/Objective, but that it is not one of the primary mappings.

| | STRS GOALS AND OBJECTIVES / STRS LEVEL 1 REQUIREMENTS | 4.1 Usable across most NASA mission types (scalability and flexibility) | 4.2 Decrease development time and cost | 4.3 Increase reliability of Software Defined Radios | 4.4 Accommodate advances in technology with minimal rework (upgradeability) | 4.5 Adaptable to evolving requirements (adaptability) | 4.6 Enable over the air interoperability with existing assets (interoperability) | 4.7 Leverage existing or developing standards, resources, and experience (state-of-art and state-of-practices) | 4.8 Maintain vendor independence | 4.9 Enable waveform portability |
|---|---|---|---|---|---|---|---|---|---|---|
| 5.1 | Layered Architecture | X | X | | X | X | | | X | X |
| 5.2 | Open Architecture | | X | | X | X | | X | X | X |
| 5.3 | Flexible in Form Factor | X | | | | | | | | |
| 5.4 | Remote Reconfiguration | X | | X | | | | | | |
| 5.5 | Remote Reprogrammability | X | | X | X | X | | | | |
| 5.6 | External Interface Control | | | | | X | | | | |
| 5.7 | Standard Spacecraft Interfaces | | X | X | | | | X | X | |
| 5.8 | Waveform Support | X | | | | | X | | | |
| 5.9 | Multiple Waveform Support | X | | | | | | | | |
| 5.10 | Simultaneous Operation of Multiple WFs | X | | | | | | | | |
| 5.11 | Multi-Service Support | X | | | | | X | | | |
| 5.12 | Suitable for All Frequency Bands | X | | | X | X | X | | | X |
| 5.13 | Multiple Frequency Bands | X | | | | | | | | |
| 5.14 | Multi-Channel Capability | X | | | | | | | | |
| 5.15 | Commanded BIT and Status Reporting | | | X | | | | | | |

| STRS GOALS AND OBJECTIVES / STRS LEVEL 1 REQUIREMENTS | | 4.1 Usable across most NASA mission types (scalability and flexibility) | 4.2 Decrease development time and cost | 4.3 Increase reliability of Software Defined Radios | 4.4 Accommodate advances in technology with minimal rework (upgradeability) | 4.5 Adaptable to evolving requirements (adaptability) | 4.6 Enable over the air interoperability with existing assets (interoperability) | 4.7 Leverage existing or developing standards, resources, and experience (state-of-art and state-of-practices) | 4.8 Maintain vendor independence | 4.9 Enable waveform portability |
|---|---|---|---|---|---|---|---|---|---|---|
| 5.16 | Operational Diagnostics | | | X | | | | | | |
| 5.17 | Automated System Recovery/Initialization | | | X | | | | | | |
| 5.18 | Navigation Support | X | | | | X | | | | |
| 5.19 | Network Support | X | | | | X | | | | |
| 5.20 | Security Compatibility | X | | | | X | | | | |
| 5.21 | Secure Transmission | X | | | | | | | | |
| 5.22 | Processor Sharing | X | | | | | | | | |
| 5.23 | Autonomous Link Optimization | X | | X | | | | | | |

# Appendix A—Abbreviations and Acronyms

| | |
|---|---|
| API | Application Programmer Interface |
| BIT | Built-In-Test |
| CCSDS | Consultative Committee for Space Data Systems |
| DoD | Department of Defense |
| IP | Internet Protocol |
| NSL | Near Strike Lightning |
| RF | Radio Frequency |
| SCaN | Space Communication and Navigation |
| SDR | Software Defined Radio |
| STRS | Space Telecommunications Radio System |
| SWaP | Size, Weight, and Power |
| TT&C | Telemetry, Tracking And Control |
| VHF | Very High Frequency |

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**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**
The Space Telecommunications Radio System (STRS) Architecture Requirements Document provides the basis for the development of an open architecture for NASA Software Defined Radios (SDRs) for space use. The main objective of this document is to evaluate the goals and objectives and high level (Level 1) requirements that have bearing on the design of the architecture. The goals and objectives will provide broad, fundamental direction and purpose. The high level requirements (Level 1) intend to guide the broader and longer term aspects aspects of the SDR Architecture and provide guidance for the development of level 2 requirements.

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