

NASA's SDR Standard: Space Telecommunications Radio System

5th Annual Software Radio Summit

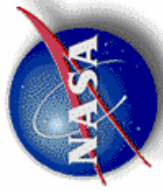
Presented by:

Richard C. Reinhart and Sandra K. Johnson

**NASA's John H. Glenn Research Center
Cleveland Ohio**

February 21, 2007



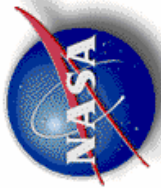


Abstract – not part of presentation

A software defined radio (SDR) architecture used in space-based platforms proposes to standardize certain aspects of radio development such as interface definitions, functional control and execution, and application software and firmware development. NASA has charted a team to develop an open software defined radio hardware and software architecture to support NASA missions and determine the viability of an Agency-wide Standard. A draft concept of the proposed standard has been released and discussed among organizations in the SDR community. Appropriate leveraging of the JTRS SCA, OMG's SWRadio Architecture and other aspects are considered.

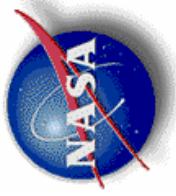
A standard radio architecture offers potential value by employing common waveform software instantiation, operation, testing and software maintenance. While software defined radios offer greater flexibility, they also poses challenges to the radio development for the space environment in terms of size, mass and power consumption and available technology. An SDR architecture for space must recognize and address the constraints of space flight hardware, and systems along with flight heritage and culture.

NASA is actively participating in the development of technology and standards related to software defined radios. As NASA considers a standard radio architecture for space communications, input and coordination from government agencies, the industry, academia, and standards bodies is key to a successful architecture. The unique aspects of space require thorough investigation of relevant terrestrial technologies properly adapted to space. The talk will describe NASA's current effort to investigate SDR applications to space missions and a brief overview of a candidate architecture under consideration for space based platforms.

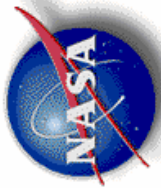


Overview

- Communications Technology at Glenn Research Center
- Mission Drivers and Applications for SDR and SDR Open Architecture
- NASA's SDR Reference Architecture
- Relationship among Standards Bodies – NASA, OMG, SDRF, IEEE, JTRS
- STRS Test-bed
- Concluding Remarks

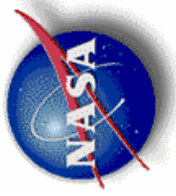


Glenn Research Center Communications Technology Overview



GRC Aerospace Communications

- Develop next generation space communication systems and networking technologies for NASA Missions and to enhance NASA's Space Communications Infrastructure.
 - Software Radio/Digital Communications
 - Antennas (high gain deployable, steerable/directional arrays)
 - Power Amplifiers
 - System Architectures, Networking, and Analysis
- Develop communication and networking systems technologies to enhance the National Airspace System.



GRC Aerospace Communications Research & Technology

Capabilities

Network & Architectures



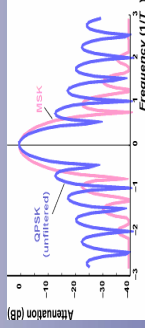
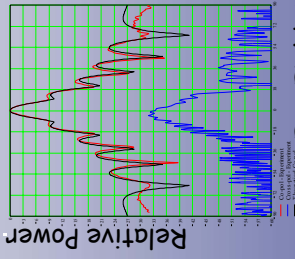
Space & Aero System Architectures
Systems Analysis
Tech Assessments

Digital Communications Software Defined Radios



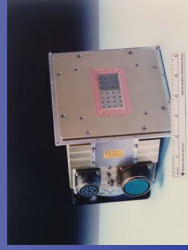
High Speed modems and specialized digital hardware
Space Network Interface Card

Systems Analysis Simulation and Modeling



Far-Field Angle - Degrees

Antennas, Optical and RF devices



GaAs MMIC Ka-Band Phased Array



Ferroelectric Scanning Reflectarray Antenna



Aero Phased Array

Facilities/Testbeds/Validation

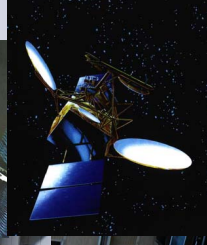
Laboratories



Antenna Range



Mobile Test Platforms



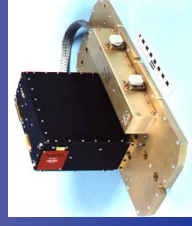
ACTS Satellite

Flight Experiments

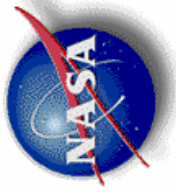


- Learjet
- DC-8
- 757

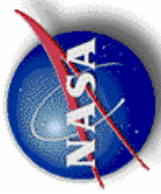
Power Amplifiers & Electronic Devices



Cassini TWTA



Mission Drivers and Applications for SDR and SDR Open Architecture



Future Space Communications Architecture

A Network of Networks

Mission Types

- Crewed Vehicles
- Transport Vehicles
- Space Stations/Outposts
- Crew Activity (i.e. EVA)

Spacecraft Links

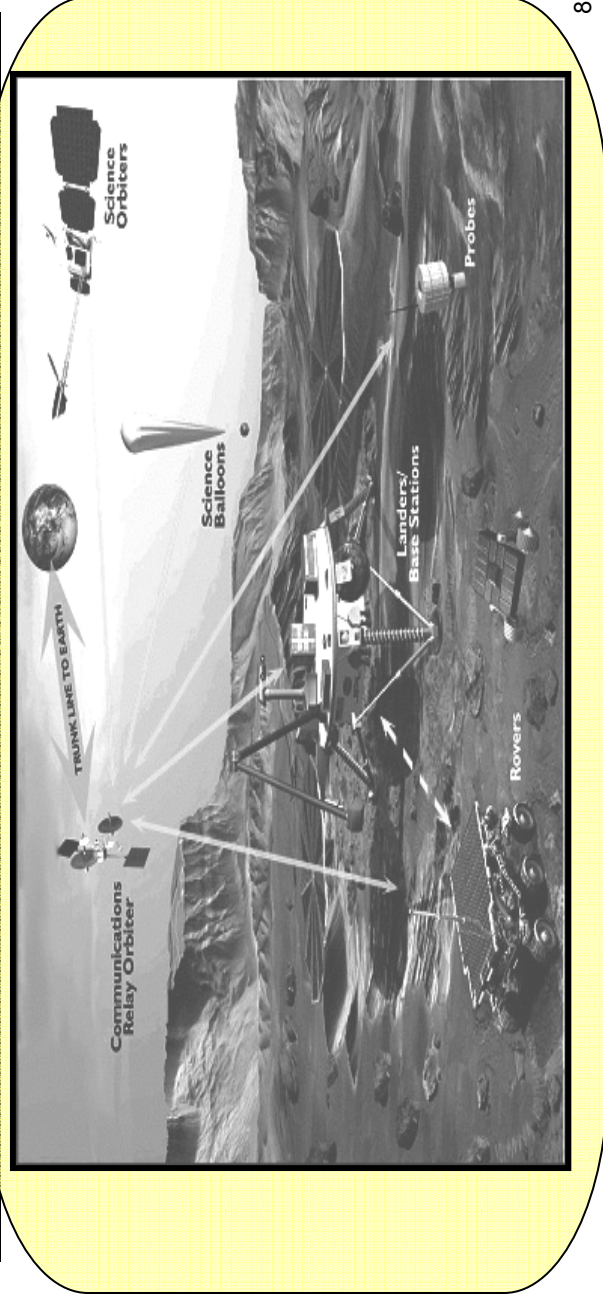
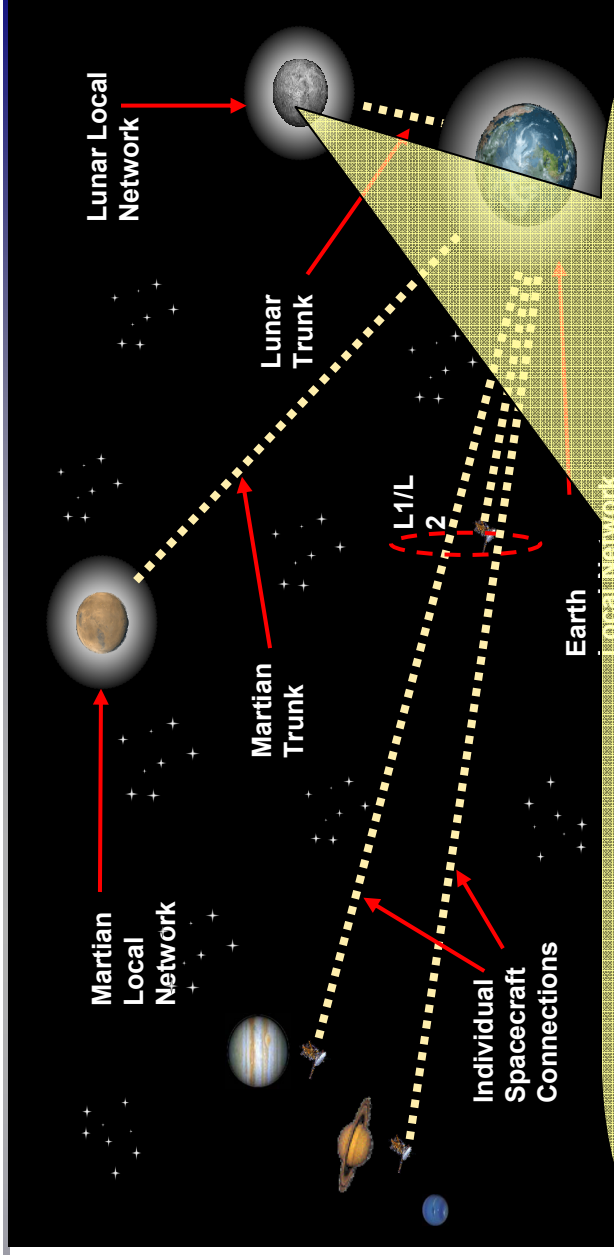
- Science Satellites
- Orbiting Relay Satellites

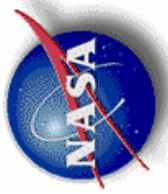
Surface Radios

- Rovers
- Science Elements
- EVA

Other...

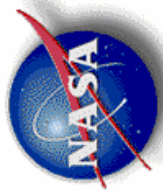
- Launch Vehicles
- Sub-Orbital Vehicles
- Ground Stations





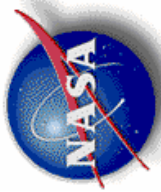
Technology to meet NASA's Communication Needs

- **Objective: Provide flexible and evolvable systems to change the way space missions develop and operate space transceivers for communications, navigation and networking.**
 - Be usable across most NASA mission types
 - Decrease development time and cost
 - Accommodate advances in technology with minimal rework
 - Adaptable to evolving requirements
 - Enable over the air interoperability with existing assets
 - Leverage existing or developing standards, resources, and experience (state-of-art and state-of-practices)
- **Solution: Software defined radio based on a common, open architecture**

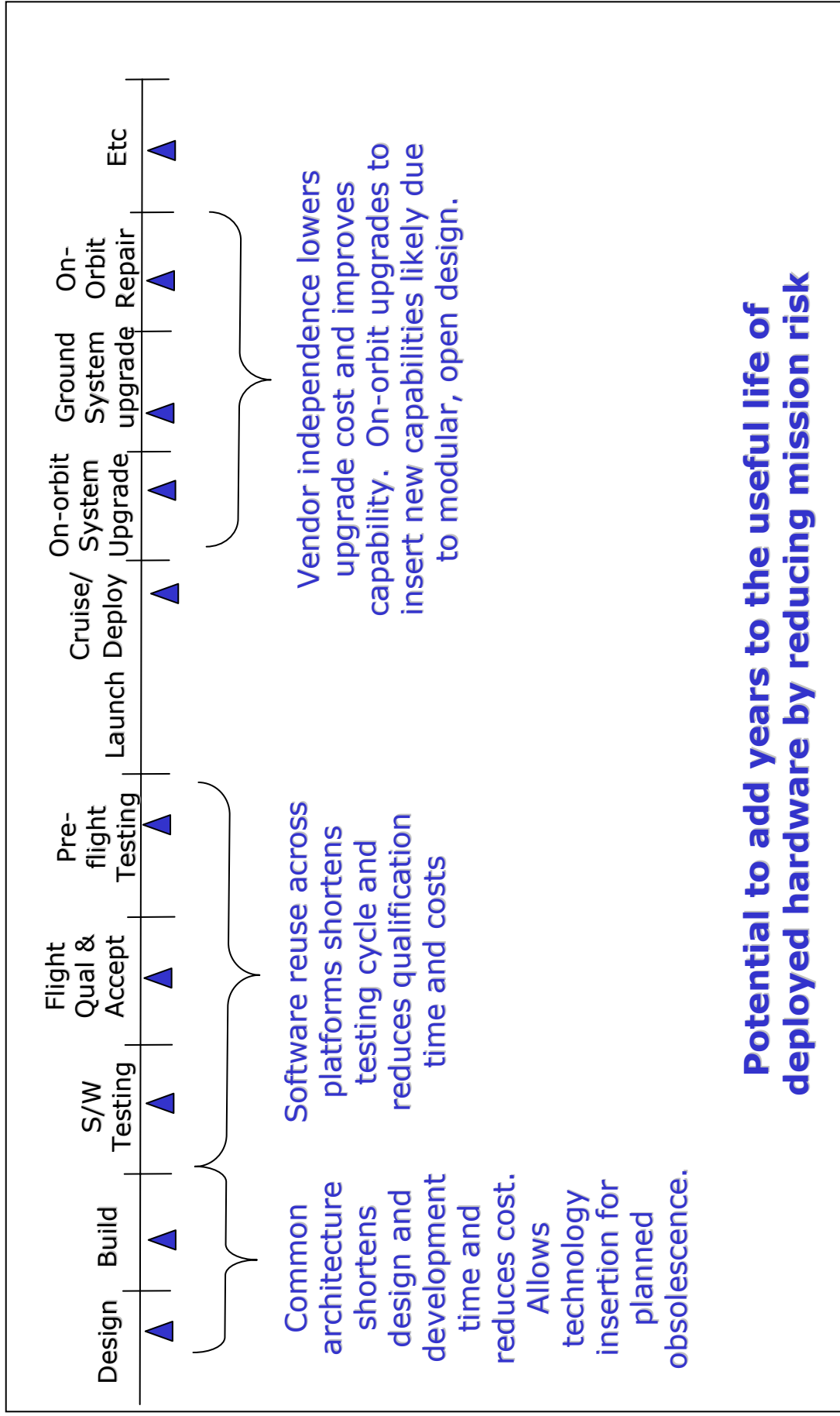


Drivers for NASA Space SDR

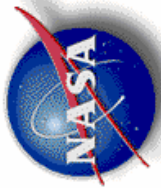
- **Radiation Suitable Processing**
 - Less capable than terrestrial, often lagging by a generation or two.
 - Limits both the footprint and complexity of the infrastructure.
- **Spacecraft Resource Constraints**
 - Spacecraft size, weight, and power limitations on spacecraft.
 - Open architecture overhead must be balanced against these spacecraft constraints.
- **Reliability**
 - Designed to prevent single point failures.
 - Manned missions have high reliability requirements, especially for safety critical applications.
- **Specialized Signal Processing Abstraction**
 - Waveforms to be deployed on specialized hardware (FPGAs, ASICS)
- **Space Waveforms**
 - Data rates range from low (kbps) to high (Gbps). Frequencies from low (MHz) to (GHz)
- **Small Space Market**



Timeline of Open Architecture SDR Benefits Before and After Launch



Potential to add years to the useful life of deployed hardware by reducing mission risk



Open Architecture for Space, Why now?

Signal Processing
Advancements

Software/Firmware

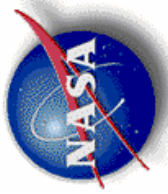
Emerging Open Architectures

New Radio Technology

Commonality/
Technology Insertion

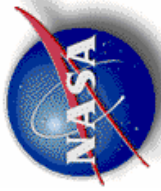
Adaptable Operations, Fault
Recovery, Flexibility

- Technology advancements in signal processing hardware make it possible for space based reconfigurable platforms
- Technology allows use of more software intensive systems for communication and navigation functions.
- Standard architectures for SDR emerging
 - JTRS, OMG, SDR Forum, etc....
- TRL Advancement of SDRs in Space
- Architecture serves as a framework for commonality/interoperability among suppliers to get Agency wide benefit among future radio developments
- SDRs + Standard Architecture = Software Reuse



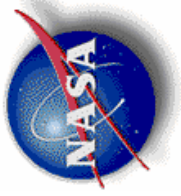
Key Findings and Recommendations to NASA's Space Communication Architecture Working Group

- **Recognize that SDRs will play a key role in future NASA missions**
 - SDR technology demonstrated in flight testing and operations
 - Today's space radios typically have significant functionality implemented in software
 - Standardized SDRs may provide cost savings over time and multiple projects
 - However, business case needs to be compelling
 - Commonality should reduce development risk and NRE costs
- **Adopt the STRS Standard as a reference HW and SW SDR Standard and the associated Design Reference Implementations as such**
 - Promote a broad environment of acceptance and evolution of the Standard
- **Phase in compliance to the STRS Standard over time**
 - Encourage, but do not require, compliance to early versions of the Standard
 - The STRS Standard will be flexible and will be allowed to evolve as appropriate
- **Support technologies required to improve SDR performance for space**
 - radiation mitigation, processor throughput, FPGAs, ADC rates, memory, etc.

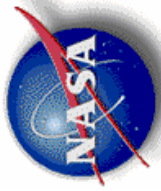


SDR Standards Coordination

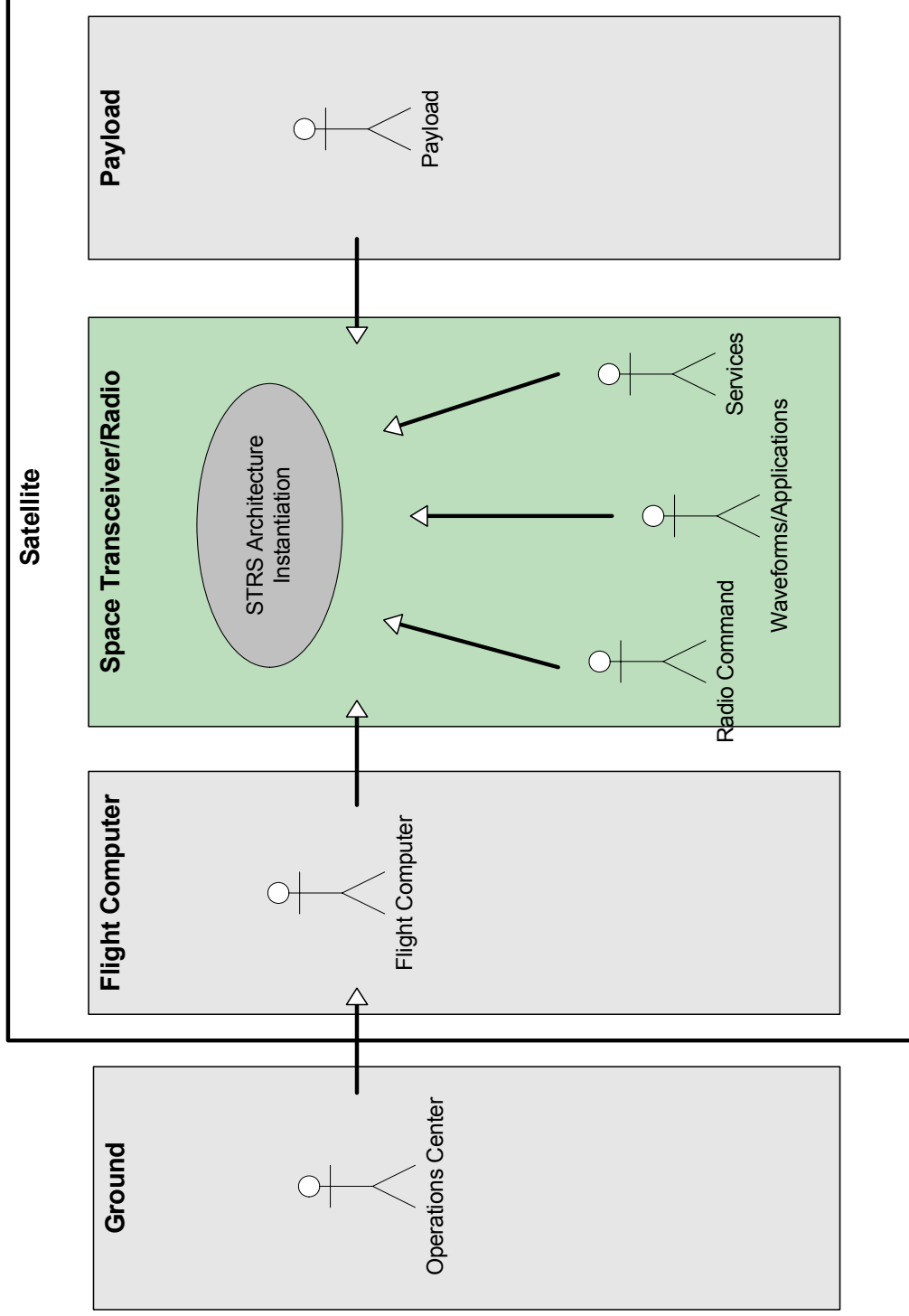
- Organizations pursuing SDR Standards
 - Software Communications Architecture (SCA:JPEO/JTRS)
 - Specialized Hardware Processors Extension to the SCA (SHPE:JPO)
 - PIM/PSM For Software Radio Components (P2SRC:OMG)
 - P1900 (IEEE EMC Society)
 - Space Telecommunications Radio System (STRS:NASA)
- NASA participates in many of the SDR Standard activities in various ways
 - A Space Working Group has been established within the SDR Forum
 - Feedback on STRS v1.0 draft description document released in Jan06 is in process
- NASA's STRS considered aspects of SCA and early versions of SWRADIO.
 - NASA will strive to leverage commercial standards as they meet the requirements of space missions
- NASA will continue to monitor SCA, OMG, and P1900 advancements
 - NASA investigating the application of current SWRADIO PIM/PSM for Software Radio Components in conjunction with SDR Forum, Space Working Group



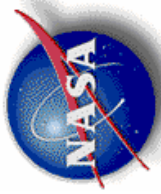
NASA's SDR Reference Architecture for Space



STRS SDR System Context

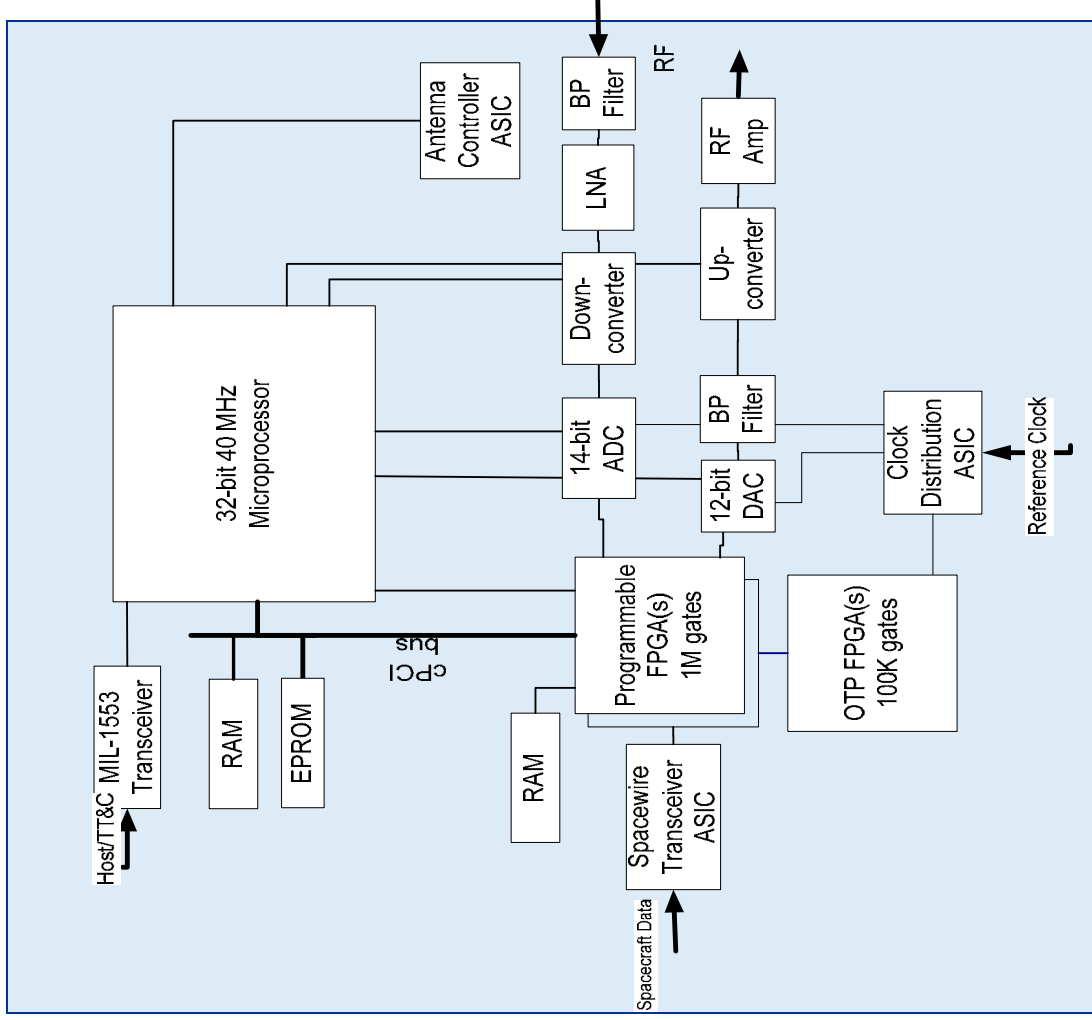


The radio interfaces with several actors

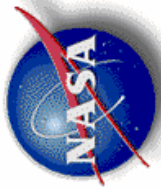


Custom Architecture Hardware Representation

- Typically component-based representation
- Cost/power efficient implementation
 - Managing software limited to specific and few functions
- Built to mission requirements
- Leverage years of space flight heritage
- Designers allowed to use custom interfaces as necessary
 - Testing and support cost increase
- Proprietary implementation and sw upgrades linked to specific vendor
- Lacks planned software/design reuse among different vendors and different NASA orgs
- Vendors holds module/functional repository for respective products instead of NASA.

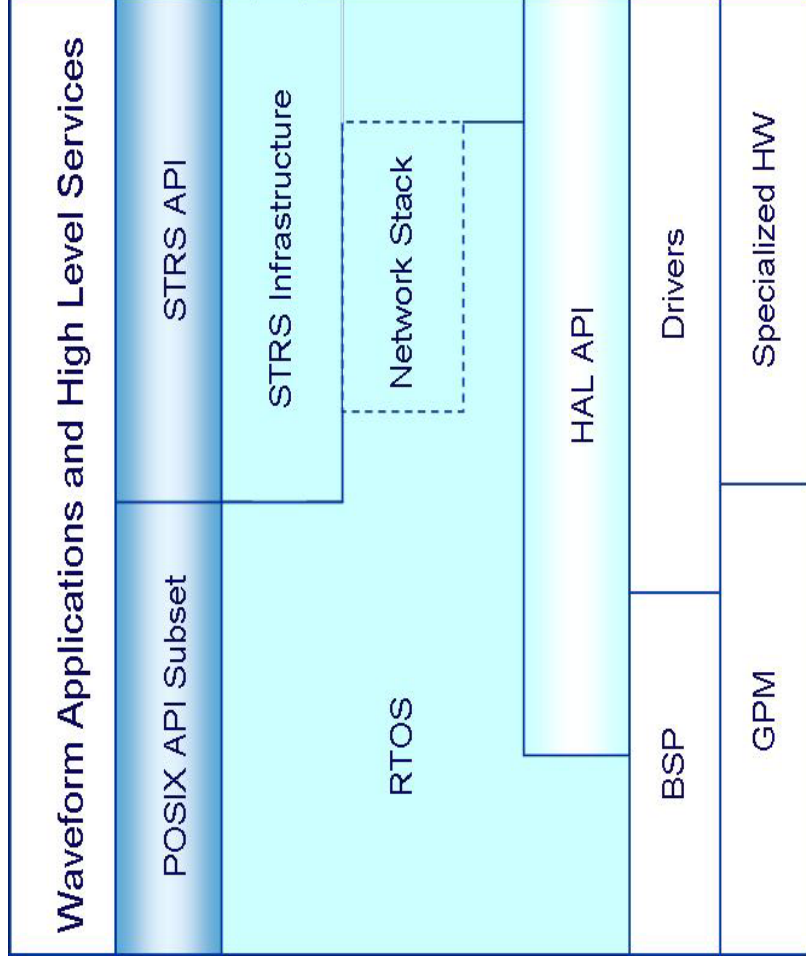


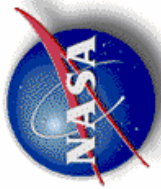
Proprietary, Closed Hardware Architecture Example



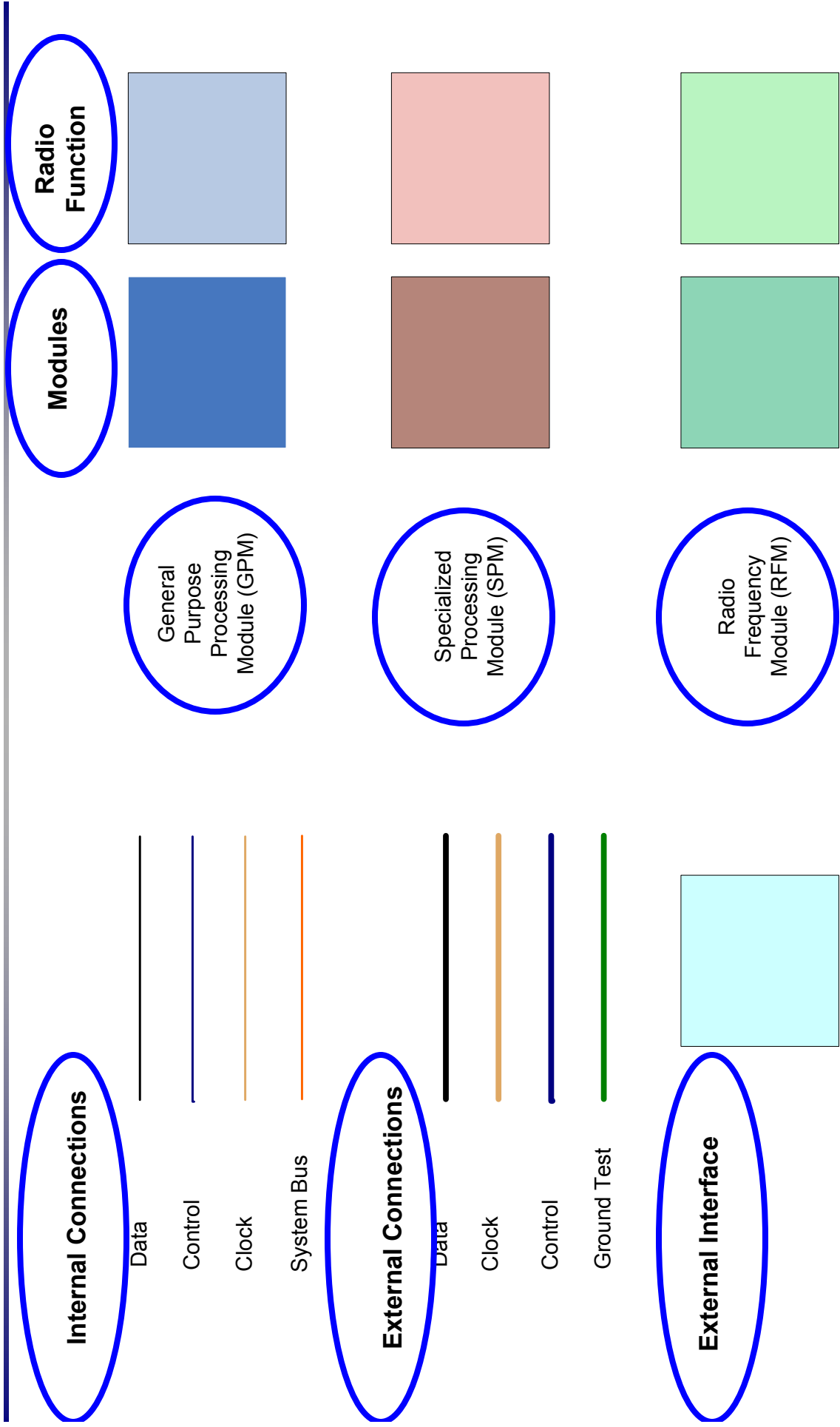
STRS Layered Software Model

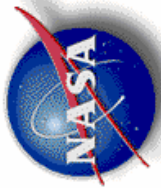
- **Waveform Applications**
 - Isolate from hardware
 - Uses POSIX APIs to access RTOS
 - Uses STRS APIs to access STRS infrastructure
 - Promote waveform portability/layering
- **High Level Services**
 - Control waveform
 - Monitor waveform (QoS)
- **STRS Infrastructure**
 - System management
 - Device control
 - Data transfer
 - Optimized for platform
- **RTOS**
 - Real-Time Operating System (COTS)
 - System implementing a subset of POSIX
 - Network Support
- **BSP (Board Support Package)**
 - Hardware Abstraction Layer (HAL)
 - Drivers
- **Hardware**
 - Hardware communications equipment (e.g. FPGA, DSP, A to D, and D to A)
 - HW Interface Definition – Facilitate HW tech insertion from multiple vendors (e.g. ICD)



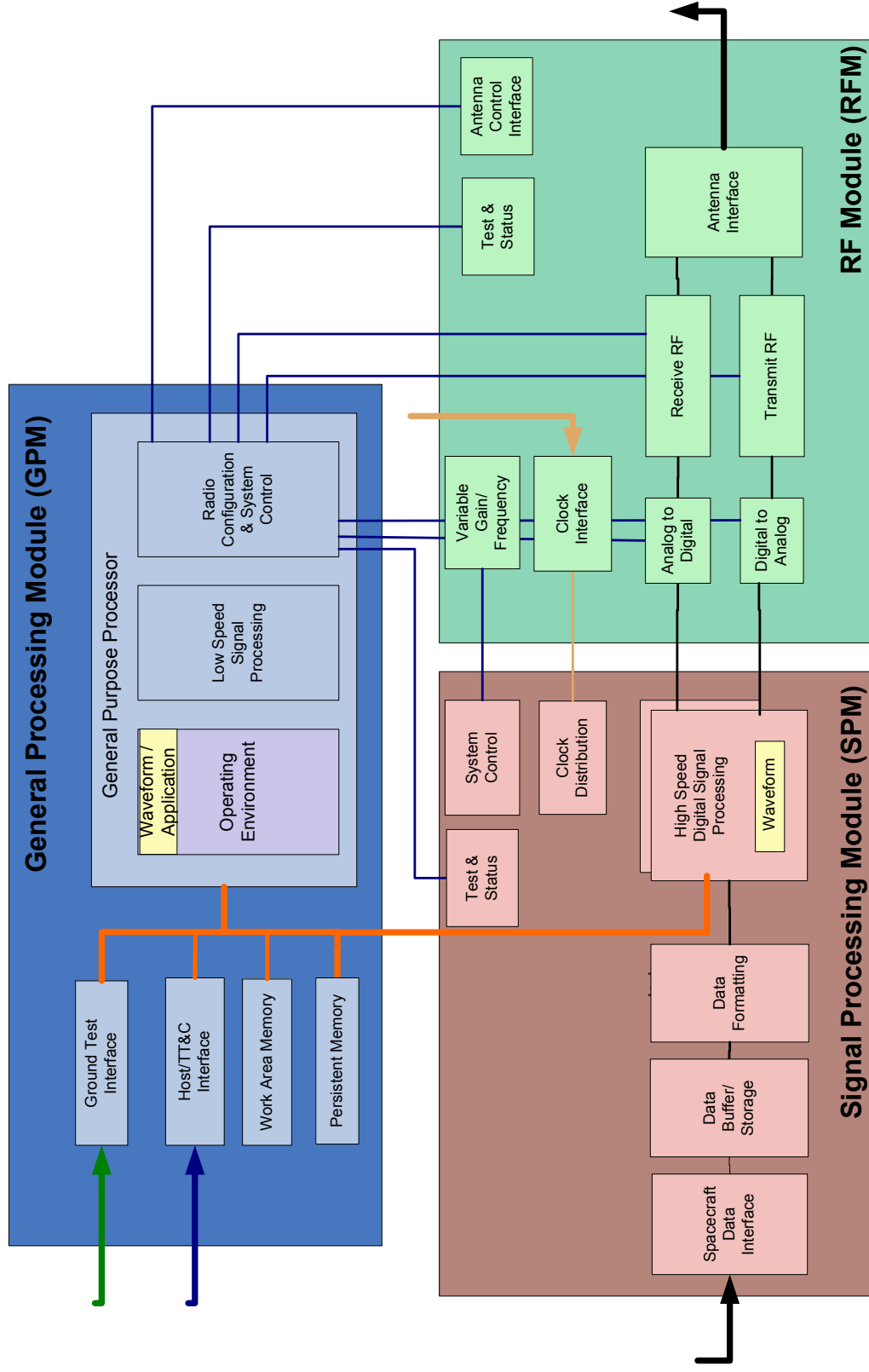


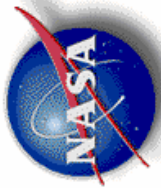
STRS Open Architecture Hardware Representation



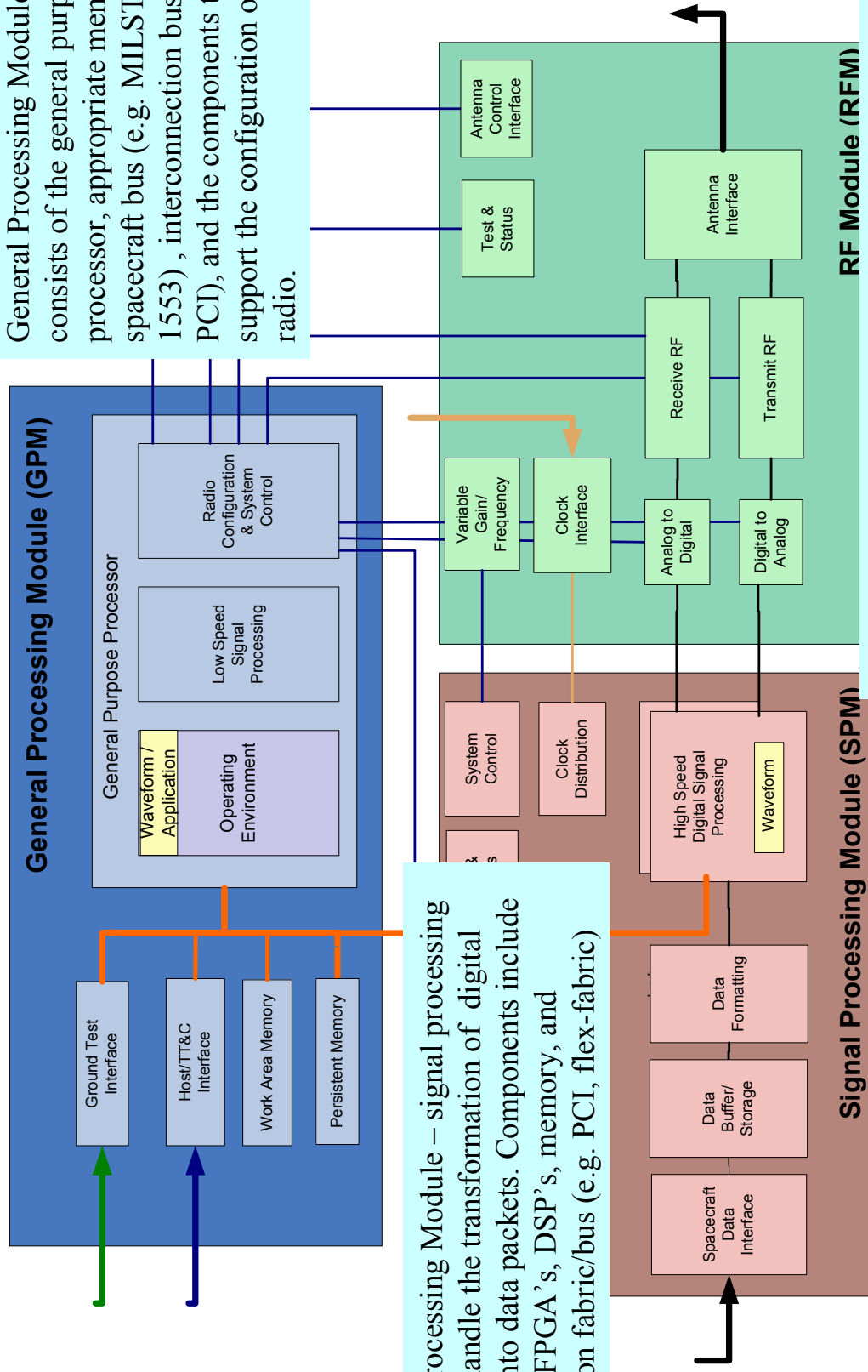


SDR/STRS Hardware Functional Diagram





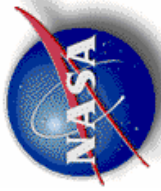
SDR/STRS Hardware Functional Diagram



General Processing Module – consists of the general purpose processor, appropriate memory, spacecraft bus (e.g. MILSTD-1553), interconnection bus (e.g. PCI), and the components to support the configuration of the radio.

Signal Processing Module – signal processing used to handle the transformation of digital signals into data packets. Components include ASIC's, FPGA's, DSP's, memory, and connection fabric/bus (e.g. PCI, flex-fabric)

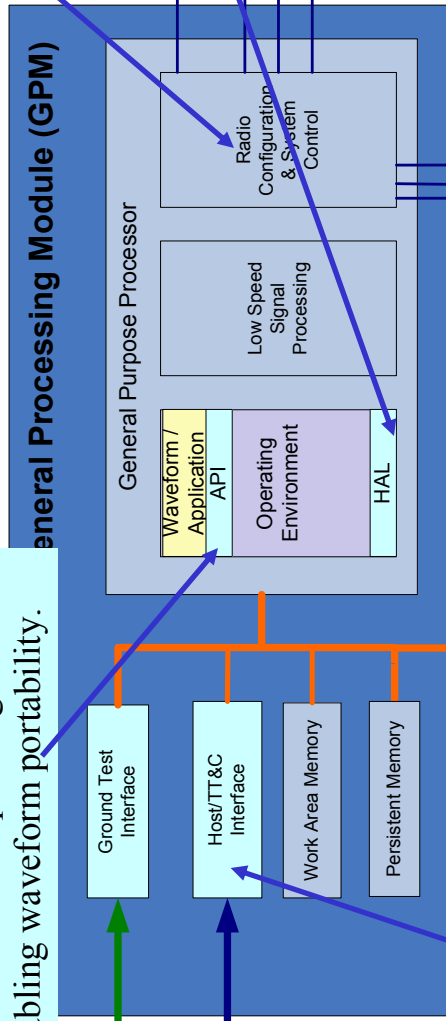
RF Module – handles the RF functionality to transmits/receive the digital signal. Its associated components include RF switches, diplexer, filters, LNAs and power amplifiers.



STRS Hardware Functional Diagram

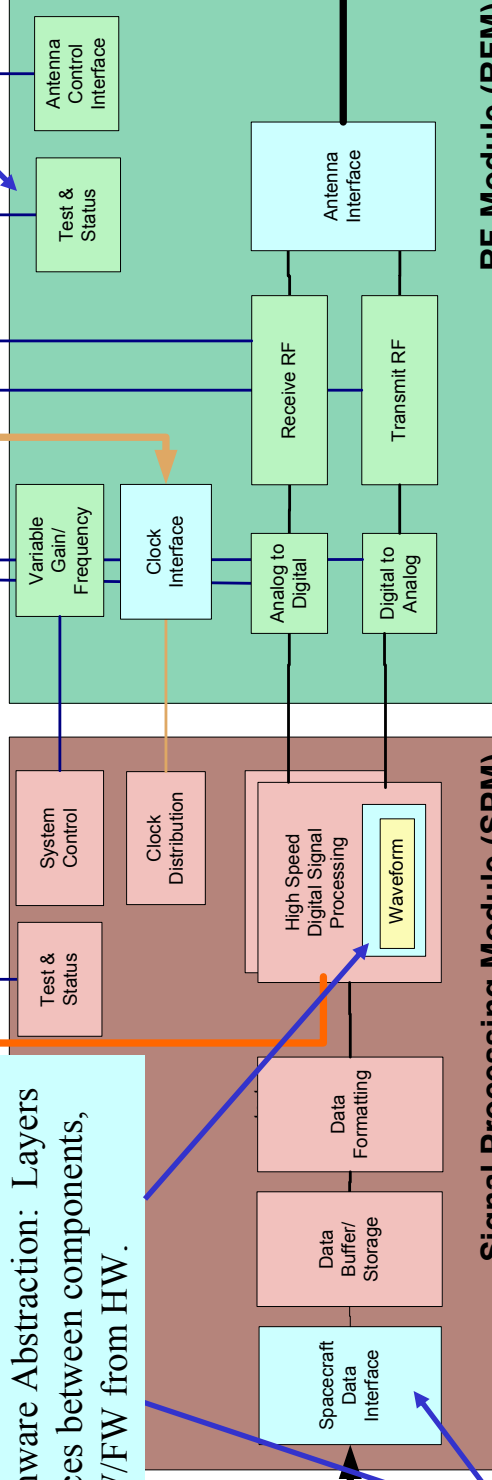
APIs separate waveform from operating environment – enabling waveform portability.

Managing Software runs on GPM
 HAL API is published so that specialized HW developed by multiple vendors can be integrated with another vendor's STRS infrastructure.

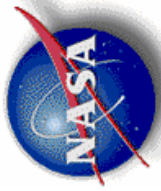


Test & Status on each module

Software/Firmware Abstraction: Layers define interfaces between components, separating SW/FW from HW.

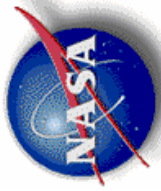


Module Interfaces abstract and define the module functionality for data flow to waveform components. Enables multiple vendors to provide different modules or add modules to existing radios. Electrical interfaces, connector requirements, and physical requirements are specified/published by the platform provider.



STRS Software Rule Set Sample

- The API layer shall consist of published STRS APIs and a defined subset of industry standard POSIX APIs
- The STRS infrastructure shall implement the STRS APIs and system management, device control, data transfer functions
- All STRS waveform applications shall use the STRS API suite to instantiate and control the waveform functionality
 - The STRS API provides the interfaces that allow applications to be instantiated and use platform services - these APIs also enable communication between waveform and application components
- Operating environment consists of STRS infrastructure, real time OS, board support packages, hardware abstraction layers
- STRS configuration files shall contain platform and waveform specific information to allow customization of installed waveforms.
 - The configuration file contains the parametric values for configurable components as well as filenames for loadable devices (FPGA, DSP, etc.)



STRS Open Architecture Highlights

Hardware

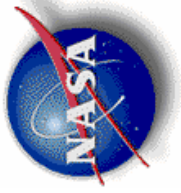
- Module definitions provided to organize common functions
- Module interfaces abstracts the module functionality for data flow to waveform components
 - Enable multiple vendors to provide different modules or add modules to existing radios.
 - Provide common test interface/procedures
- Hardware Interface Definition (HID)
 - The electrical interfaces, connector requirements, and physical requirements are specified by the platform provider.
 - HID shall be published for each module so 3rd party developers have the structure under which they can develop new modules

Software

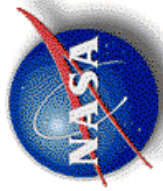
- Layers define interfaces between components
- Certain layers separate SW from SW and other SW from HW (i.e. abstract)
- APIs separate waveform from operating environment for waveform portability/reuse
- The STRS Infrastructure will use the HAL information to initialize the hardware drivers such that the control and data messages will be appropriately delivered to the module.
 - Method/function used, calling sequence, return values, an explanation of its functionality, any preconditions before using the method/function, and the status after using the method/function
 - Hardware address and data interfaces, interrupt input and output, power connections, control and data lines necessary to operate in the STRS platform environment (firmware code portability)

STRS Repository

- Collection of hardware and software modules, definitions, documents for mission reuse

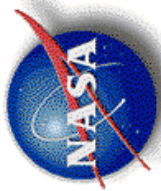


STRS Test-Bed

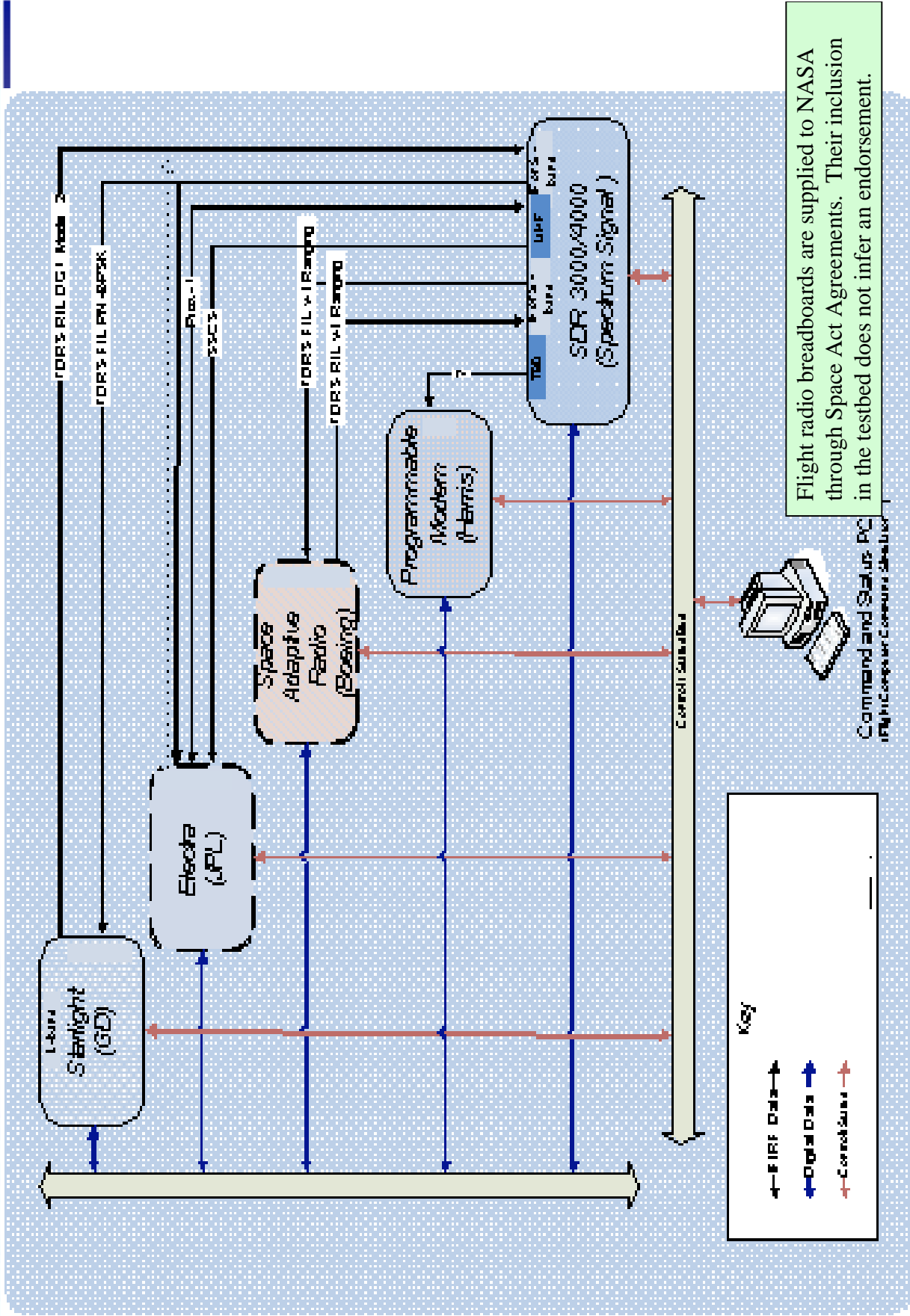


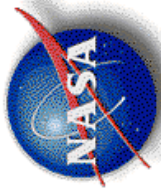
STRS Integration Test Bed Objectives

- Evaluate reconfigurable radio technology that has potential to meet the communication needs of NASA
 - Multiple SDRs from industry to understand varying radio architecture.
 - Encourage greater industry participation in the STRS architecture development effort
 - Failsafe operation techniques software defined radio technology
 - Demonstrate interoperability between multiple SDRs
- Provide development and test environment for
 - STRS Architecture Development
 - Reference Implementations on space-breadboard platforms
 - Waveform and application development
- Move software among different platforms to demonstrate software abstraction
- Laboratory validation of ConOps
- STRS Compliance Testing and flight radio validation

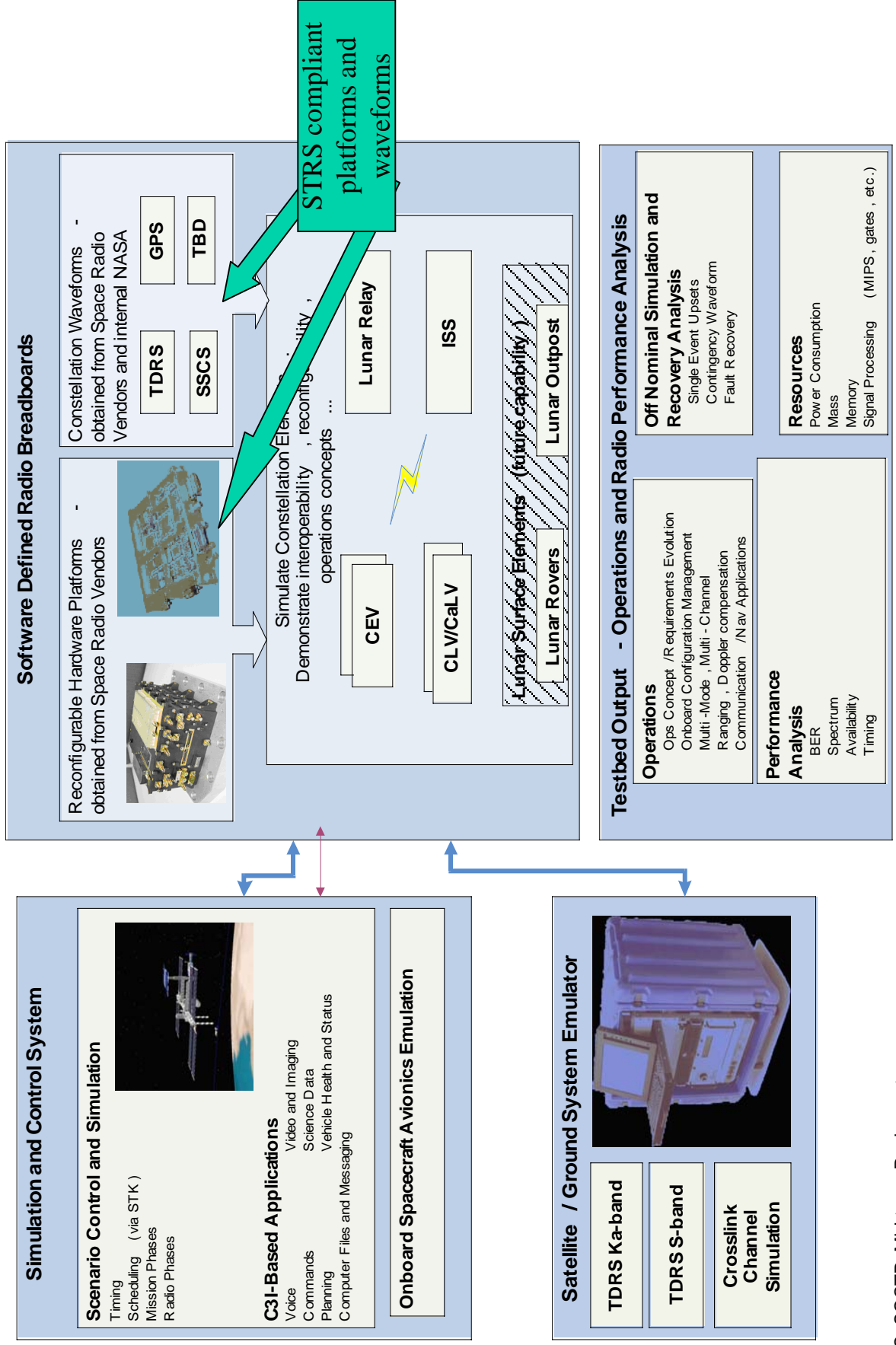


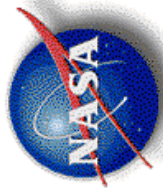
STRS Testbed Platform and Waveform Development Plan





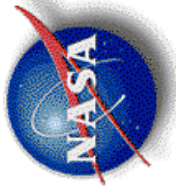
STRS SDR Test-Bed Environment





SDR & STRS Architecture Conclusions

- Reconfigurable SDR will enable new mission concepts
 - Remote/autonomous operations
 - Future cognitive radios
- STRS Architecture provides commonality among reconfigurable SDRs developed by NASA
 - Provides a coordinated method across the agency to apply SDR technology
 - Program/mission risk reduction
 - Allows technology infusion
 - Reduces vendor dependence
- STRS Architecture will evolve before becoming a required Standard
 - Waveform Control
 - Navigation, Security, Networking...
 - Business case for Standard Architecture pending...
 - Leverage best aspects of DoD's JTRS SCA and industry practice
- Exploration Vision will present new opportunities to apply SDR



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