Open Architecture for Space Software-Defined Radios

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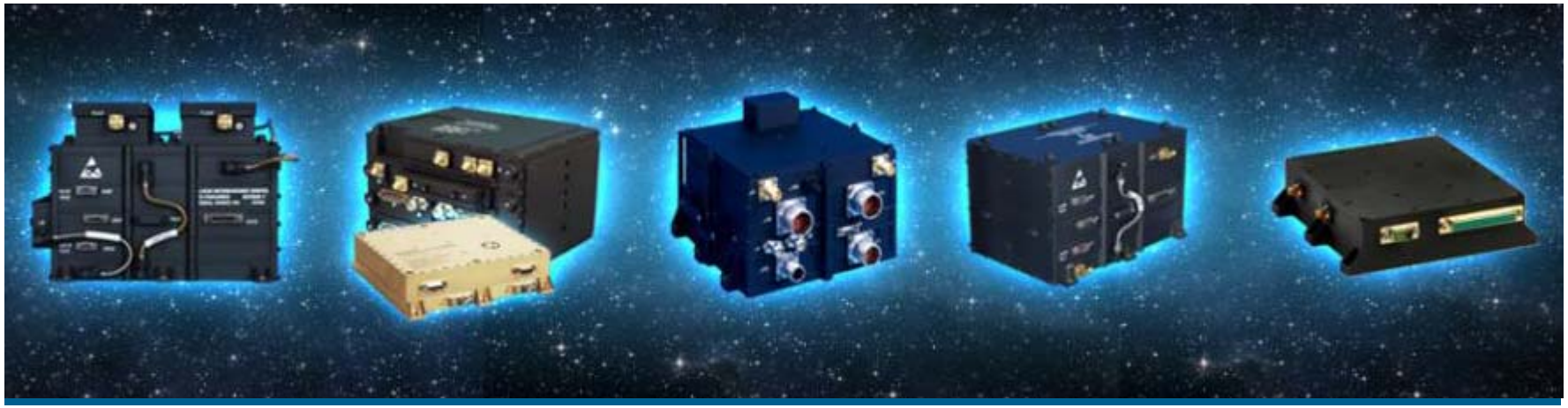
Agenda

- Introduction
- General Dynamics' Heritage Space Applications
- Foundation for Software-Defined Radios
  - General Dynamics' Starlight™ Architecture
  - Reconfigurable Radios
- NASA's STRS – Space Telecommunications Radio System
  - Hardware Architecture
  - Software Architecture
  - Reference Implementations
- CoNNeCT Program
- Future Developments

Space Electronics and Services



- Industry leading provider of Space Products:
  - GPS Receivers
  - Tracking, Telemetry and Control (TT&C) hardware
  - Command and Data Handling
  - Space Network Routers
- Software Defined Radio

- GPS Blocks 1/2/3
- International Space Station
- Hubble Space Telescope
- GOES, EOS - Weather and Earth Observation SATs
- Mars Rovers – Spirit and Opportunity
- Cassini, STEREO, Messenger
- Fermi (GLAST), LRO/LCROSS, WISE
- Worldview, NPP, GeoEye-1
- THEMIS Bus Avionics Unit

GD Space SDR Products – StarLight™

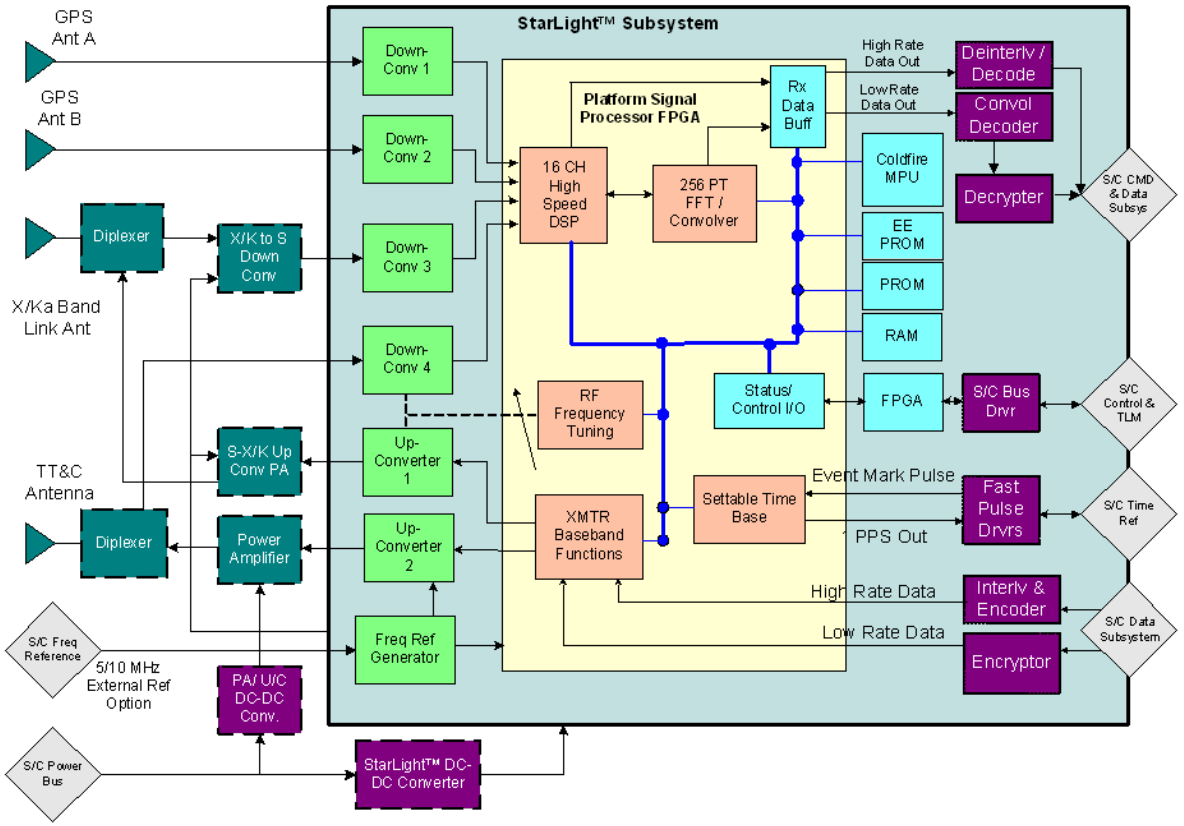
Family of Reconfigurable Transceivers for Space Missions

Programmable GD RH-Coldfire processor

Flexible Waveform Options

Fully Reconfigurable on Orbit

Multiple waveforms ported to StarLight™



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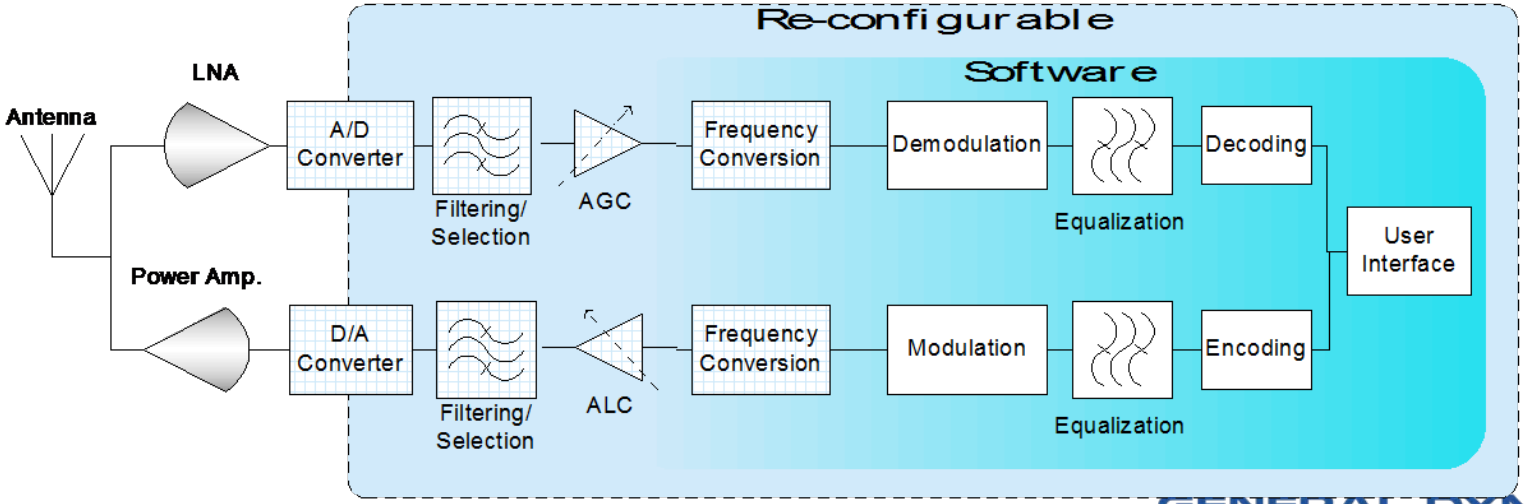
Software-Defined Radio Technology

- Collection of hardware and software technologies to perform COMM and NAV functions
- Hardware – Signal processing, RF, power, thermal
  - Shift from dedicated hardware (e.g., ASIC) to more flexible, reprogrammable hardware (e.g., FPGA)
  - Traditional hardware approach retained at RF front end (ADC, DAC, filters, amplifiers)
  - MEMs technology beginning to emerge to enhance frequency tunability
- Software – Application, Managing
  - Application Software – communication and navigation functions (e.g., waveforms)
    - *Waveform -comprises the end to end functionality (i.e., modulation, coding, frequency conversion, filtering) and bidirectional transformations applied to information content that is transmitted over the air*
  - Management Software – Controls the application software on the radio platform.
    - *Loads/unloads application code and data to/from memory*
    - *Responsible for interprocess communications,*
    - *Provide platform services (timing, file manager, events)*



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STRS Open Architecture Highlights

Space Telecommunications Radio System

Hardware

- Module definitions are provided to organize common functions
- Module interfaces abstract the module functionality for data flow to waveform components
  - Enable multiple vendors to substitute 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

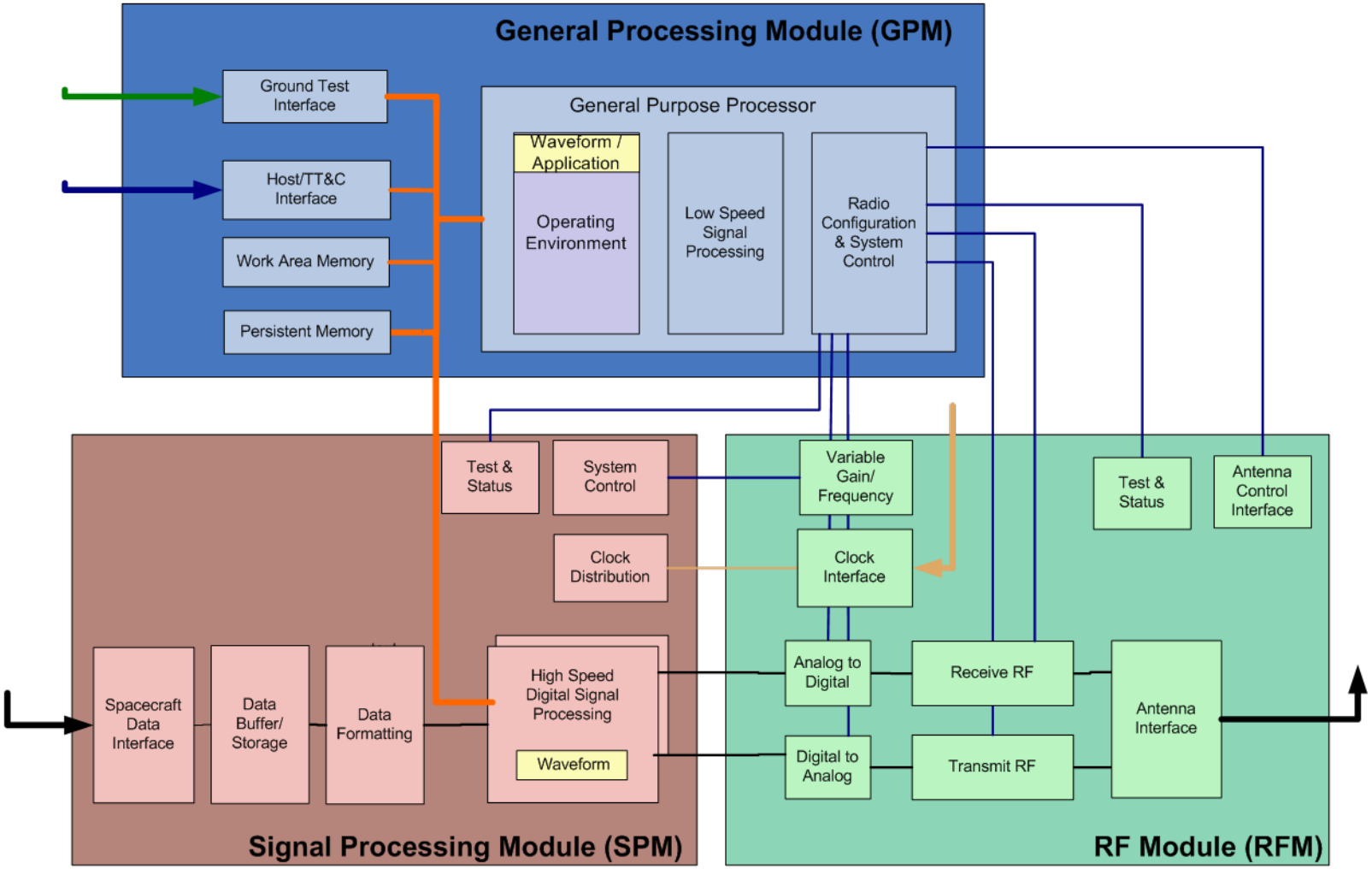
Software

- Layers define interfaces between components
- Some layers are defined to separate SW from SW; others to separate SW from HW (i.e., abstract)
- APIs separate waveform from operating environment for waveform portability/reuse
- The STRS Infrastructure uses the HAL information to initialize the hardware drivers to ensure that the control and data messages are 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

SDR/STRS Hardware Functional Diagram



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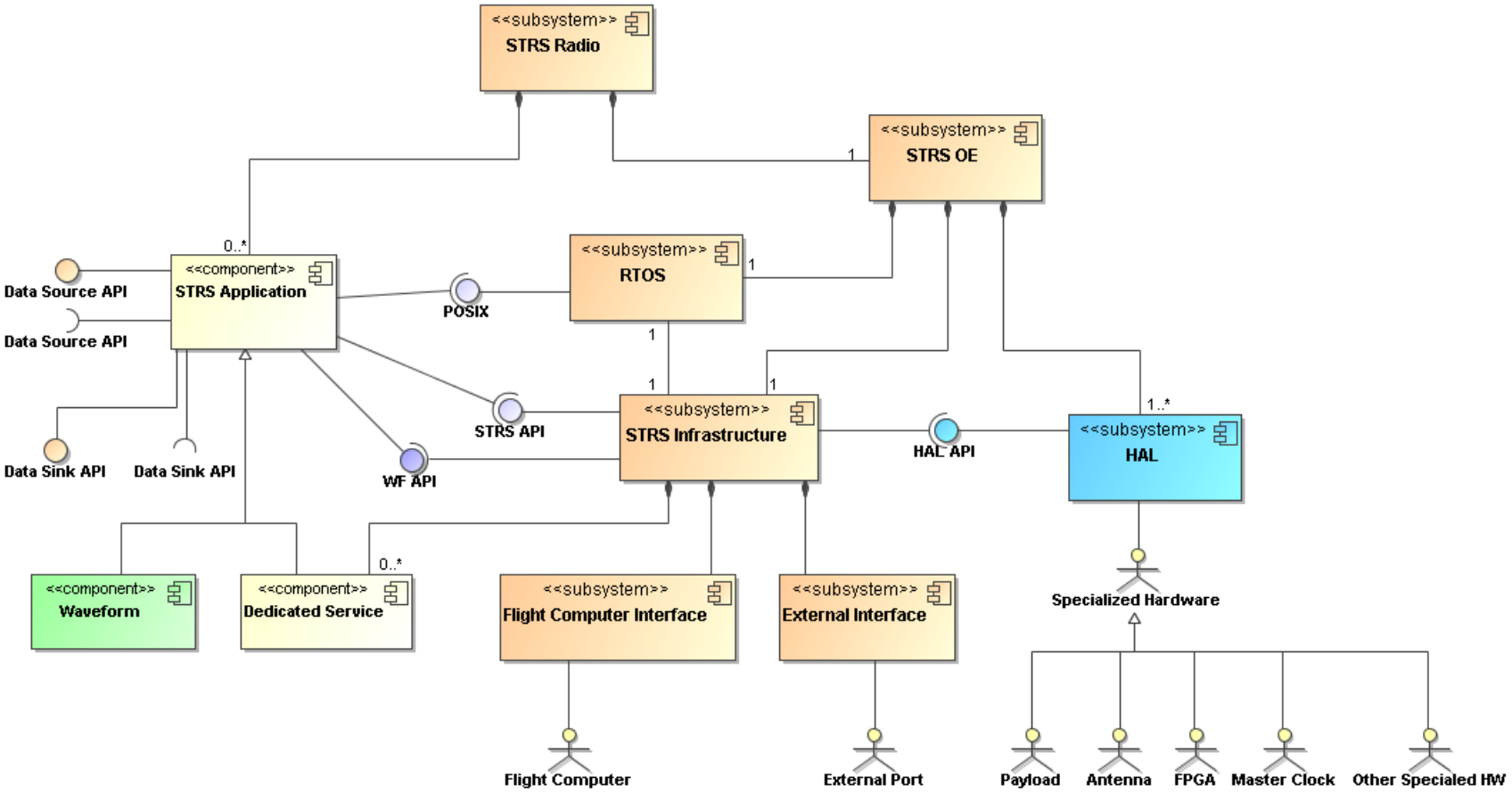
STRS Software Architecture



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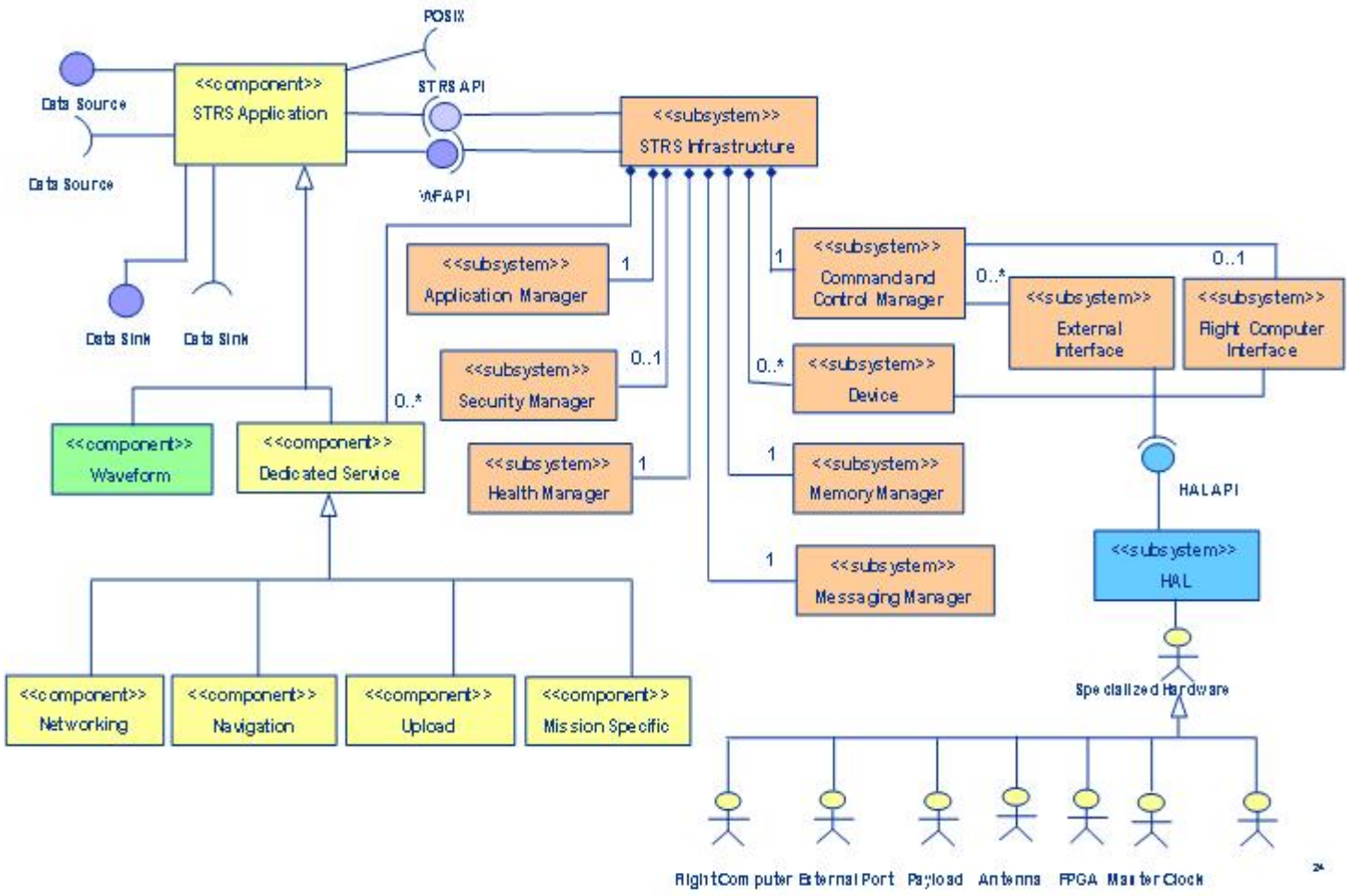
STRS Infrastructure Subsystems

Operating Environment (OE)



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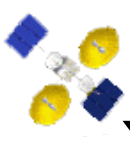
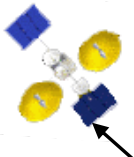
CoNNeCT System Concept

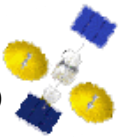


TDRS-Z
(275°W)



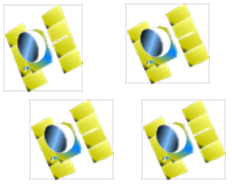
TDRS-W
(171/174° W)

On-Orbit Networking Technologies
Disruptive Tolerant Networking Studies
On-board routing, security



TDRS-E
(41°/46° W)
(TDRS K&L)

Global Positioning System (GPS) Constellation



S-Band

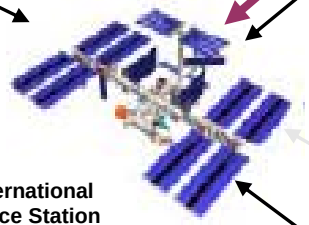
S-Band

Ka-Band

S-Band

L-Band

Space Network Communications S-band and Ka-band
Mission Concept & Operations
Adaptive SDR/STRS-based systems
Operational flexibility and capability
Demonstrate Cx, C3I functionality aspects



International Space Station

Next Generation Navigation Techniques
GPS L1 and future L2 and L5
Orbit determination and relative navigation studies

TDRS Space-to-Ground Links

S-Band

S-Band

AFSCN

Advance SDR/STRS Communications Technology to TRL-7,
Compliant to STRS Common Architecture
Reprogrammable radio functions
Advancement and improvement of the STRS Standard
Multiple sources of STRS compliant radios

S-Band

IP Networks

CONNECT SN Data Path

CONNECT NEN Data Path

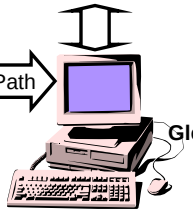
Wallops Island Ground Station

Commercial/ International

ISS TT&C Path

NASA/MSFC/ JSC (HOSC/POIC)

TSC TT&C Path



CoNNeCT Control Center Glenn Research Center (GRC)

White Sands Complex

Near Earth Network Communications

S-band Near Earth Network Communications
Lunar Surface/Relay Emulation Experiments

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CONNECT Software Defined Radios

The CoNNeCT Payload has 3 STRS compliant SDRs

Both GD and Harris are supplying radios, and one additional SDR is a NASA-sponsored radio provided by the Jet Propulsion Laboratory

Each SDR will implement specific waveforms and operate in specific frequency bands

GD S-band SDR

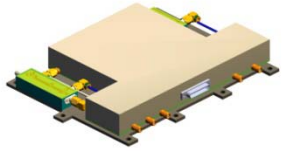
- The GD CONNECT Starlight software defined radio is a reprogrammable S-band transceiver w/ space heritage
- The SDR will be compliant with the STRS architecture, and will have a TDRSS DG1, Mode 1,2 & 3, & DG2 compatible waveforms installed and tested when delivered

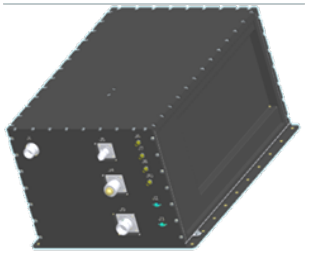
JPL S-band, L-band SDR

- The JPL CONNECT software defined radio is a reprogrammable S-band and L-band transceiver w/ space heritage
- The SDR will be compliant with the STRS architecture, and will have a GRC/GSFC TDRSS S-band DG2 compatible waveform installed after delivery

Harris Ka-band SDR

- The Harris CONNECT software defined radio is a reprogrammable Ka-band transceiver
- The SDR will be compliant with the STRS architecture, and will have a TDRSS Ka-band DG2 compatible waveform installed and tested when delivered





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Future Space Communications Architecture

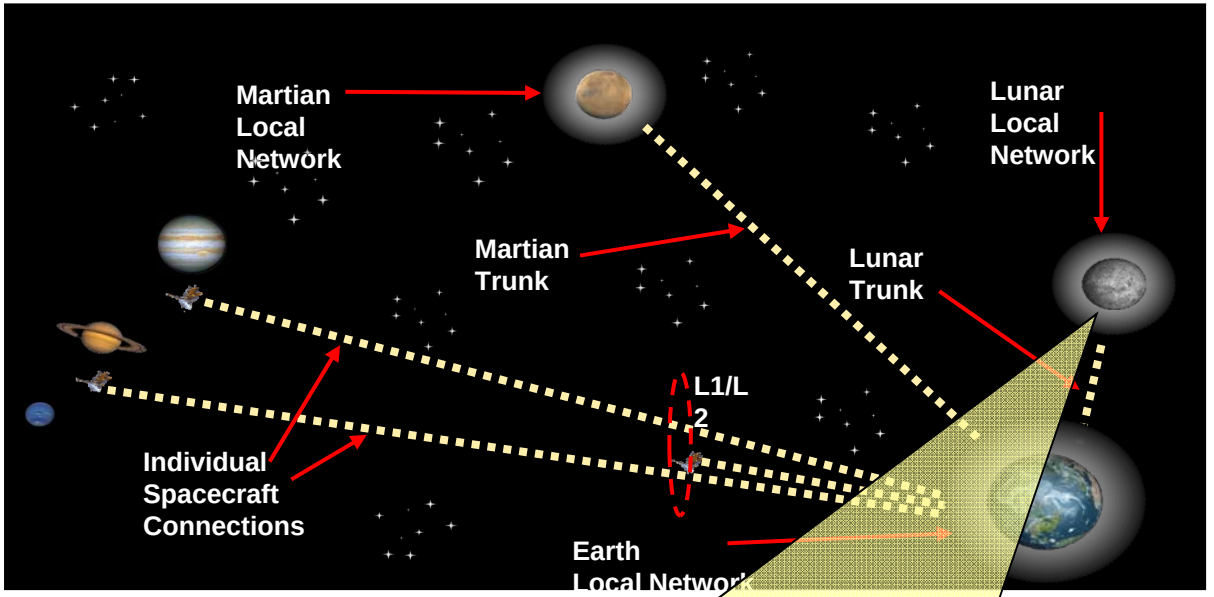
Mission Types

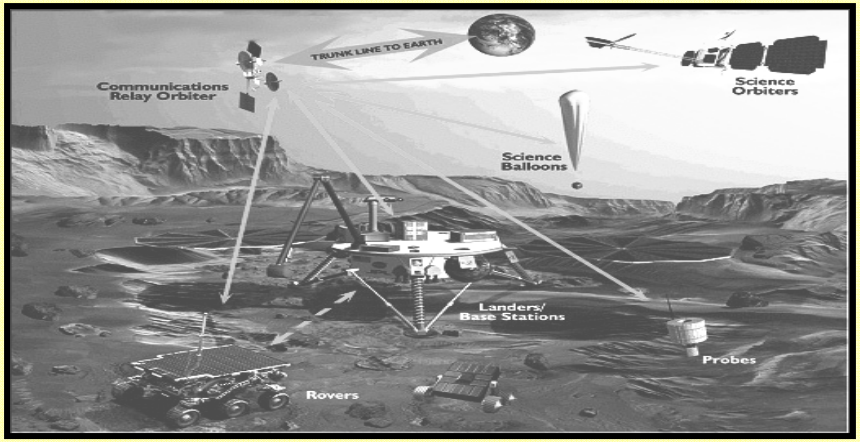
Crewed Vehicles
- Transport Vehicles
- CEV S-Band Xpdr
- Space Stations/Outposts
  - e.g. C2V2 RFI
- Crew Activity (i.e., EVA)

Spacecraft Links
- Science Satellites
- Orbiting Relay Satellites

Surface Radios
- Rovers
- Science Elements
- EVA

Emerging Applications
- Fractionated Constellations
- IPv6 networking
- Ground Station Extensions





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