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Software Defined GPS Receiver for the International Space Station

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What Is CoNNeCT?

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- ISS: International Space Station
  - Flight Platform for the SCaN platform: CoNNeCT
- SCaN: Space Communications and Navigation
  - Part of NASA SOMD: Space Operations Mission Directorate
  - NASA technology program of which CoNNeCT is part
- CoNNeCT
  - Communications, Navigation, and Networking reConfigurable Testbed
  - JPL is flying a Software Defined Radio (SDR) on ISS for SCaN
  - Harris and General Dynamics also have SDRs on the platform
- Software Packages for the SDR are called "Waveforms"
  - JPL Waveforms operate under the Space Telecommunications Radio System (STRS) Operating Environment (OE), an emerging standard for space SDRs
- CoNNeCT Phase I – Hardware – winding up now
- CoNNeCT Phase II – Waveforms (applications) – starting up now

CoNNeCT Flight System

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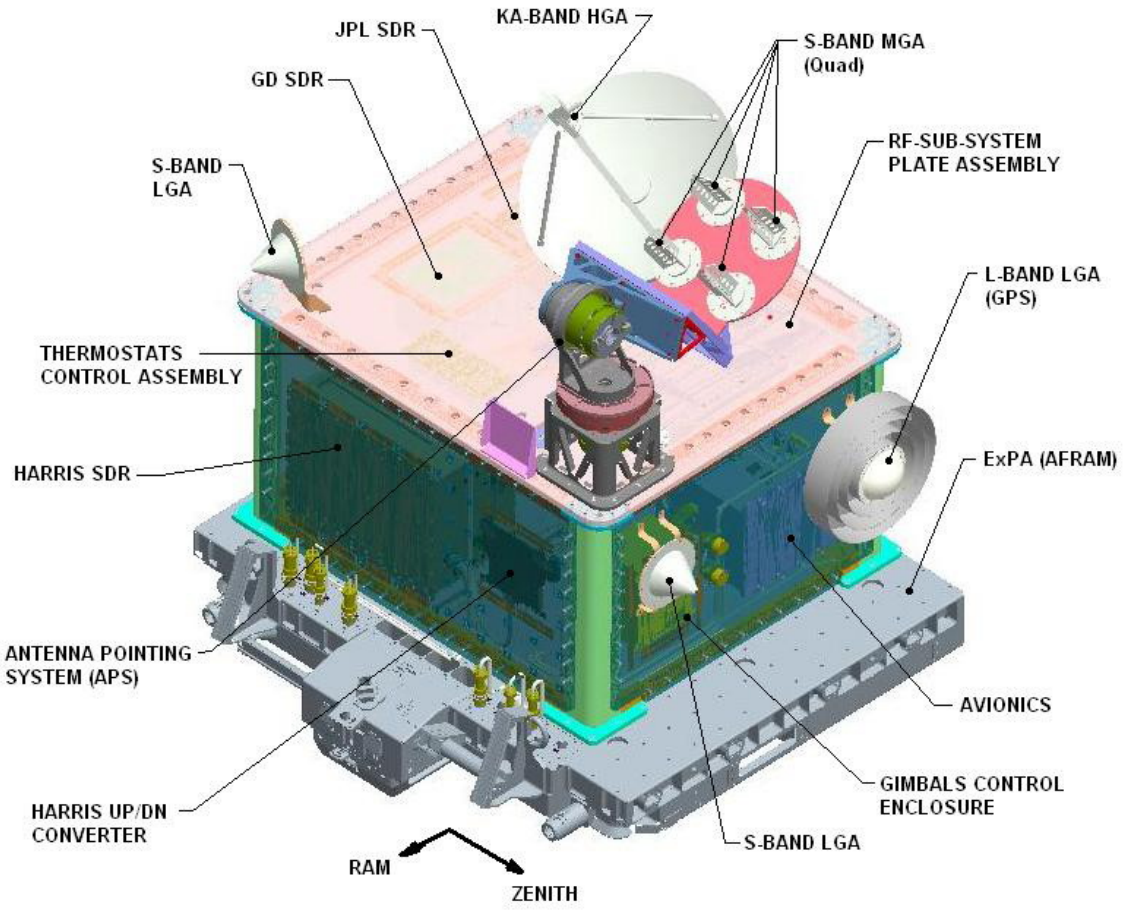

Location of FS on ISS

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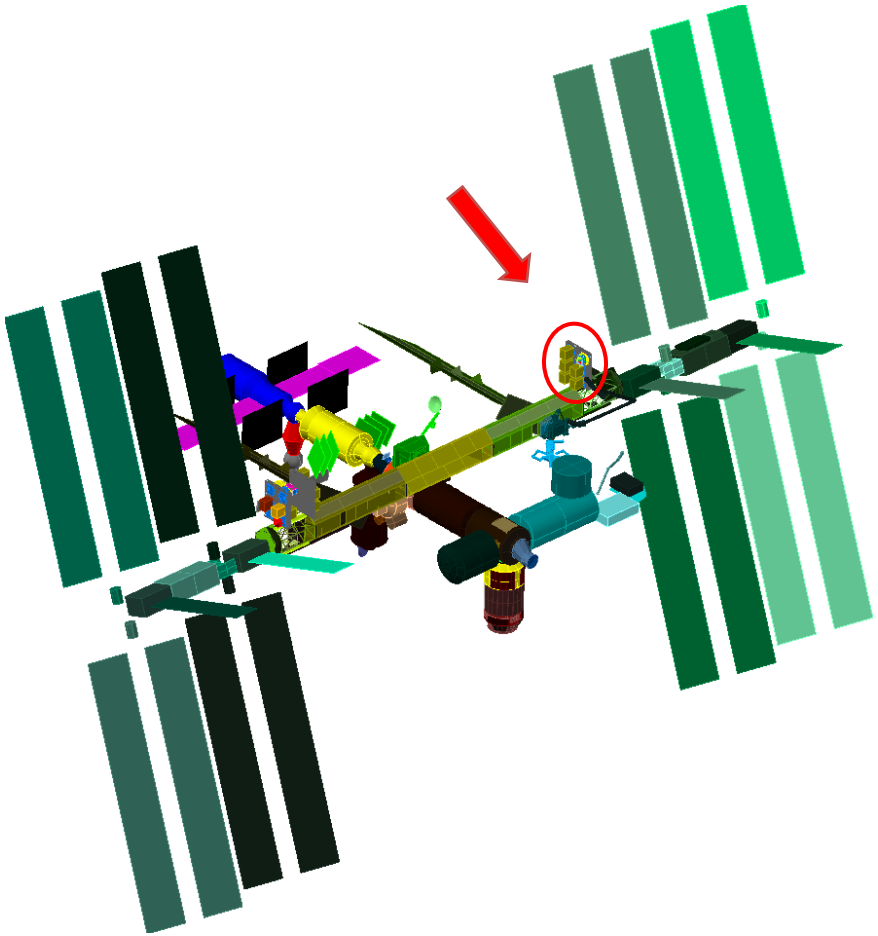

JPL SDR

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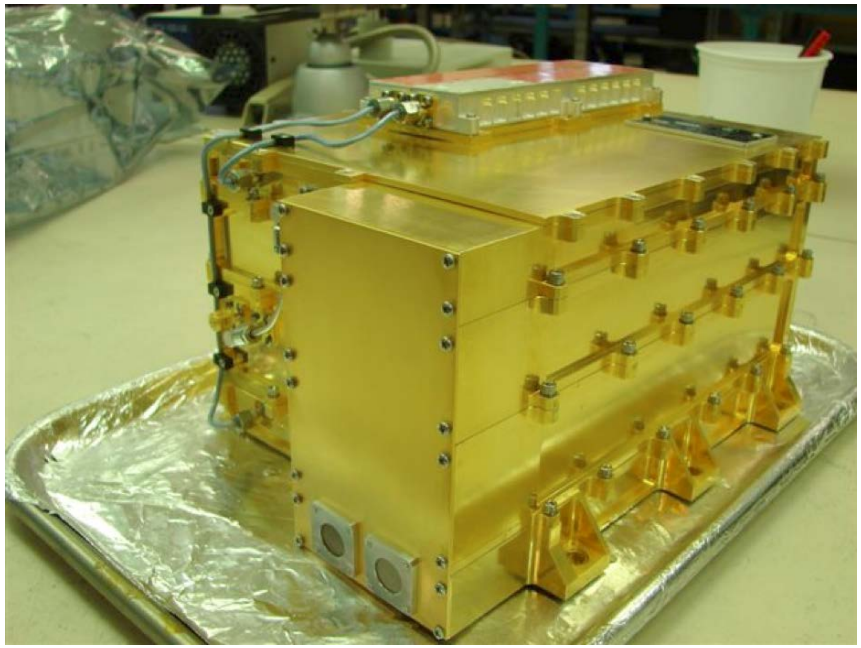
- Has been delivered to GRC for integration
- GRC will deliver to Japan in summer 2011
- Launch to the International Space Station (ISS) on a JAXA H-II Transfer Vehicle (HTV-3) in January 2012
- JPL SDR Includes
  - BPM (Baseband Processor)
  - RFM
  - GPSM (L-Band slice)
  - SSPA
  - PSM



L-Band Slice - Antenna

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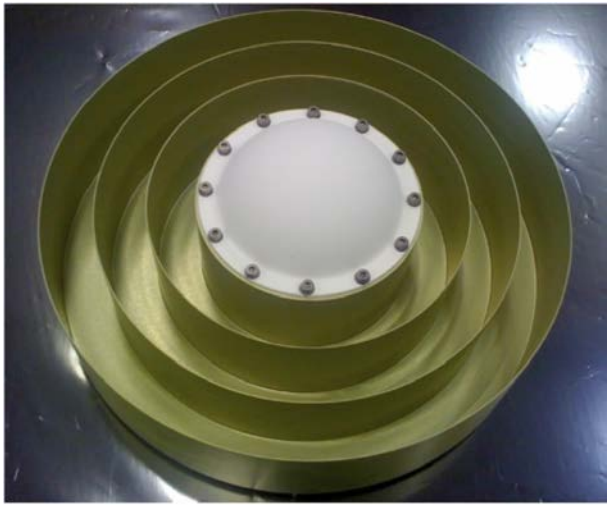
- Delivered with JPL SDR
- Three quadrature samplers
  - L1, L2 at 19.328 MHz
  - L5 at 38.656 MHz
- Three frequency antenna, LNA, filter



Baseband Processor Module

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- Sparc 697, 66 MHz (derated 100 MHz part)
  - 128 Mbyte SDRAM
  - 512 Mbyte Flash
- Two Virtex II 3000
  - 160 Mbyte SDRAM ea.
  - 512 Mbyte Flash ea.
  - 92 wire data bus between

GPS Waveform Requirements

- Builds and runs in STRS / OE
- Runs on delivered hardware
- Acquires and tracks L1, L2, L5
- 10-meter positions
- Time synchronization
- Autonomous operation
  - Commanding possible
- Post Processing
  - BJ Packets (team standard)
- Interface test delivery July 2011
- Flight delivery May 2012

GPS Waveform Features

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- Acquisition in frequency domain L1 using FFTs
  - Fast across PRN and code phase space
  - Orbiting Dopplers
- Hand over to track L1 C/A (all GPS)
  - Goal is all in view, 10-12 PRN
- L1 aids L2C and L5
  - Goal is all in view
  - L2C (Block II R-M) > 12 deployed (summer ‘12), 5-6 in view
  - L5 (Block II F) 6-7 deployed (summer ‘12), 2-3 in view
- Data out on SpaceWire
  - Tracking observables
  - Onboard positions

GPS Waveform Performance

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- Range tracking at the meter level
  - Track in FPGA-based feedback loop @ 50 Hz aided by 1 Hz corrections from software
  - Phase tracking possible, not required
  - Multi-frequency ionosphere removal
- Nav solutions, 10 meters 3-D @ 10 sec interval
  - Satellites selected for best geometry If needed
  - Verified with GIPSY in post processing

Flight Operations

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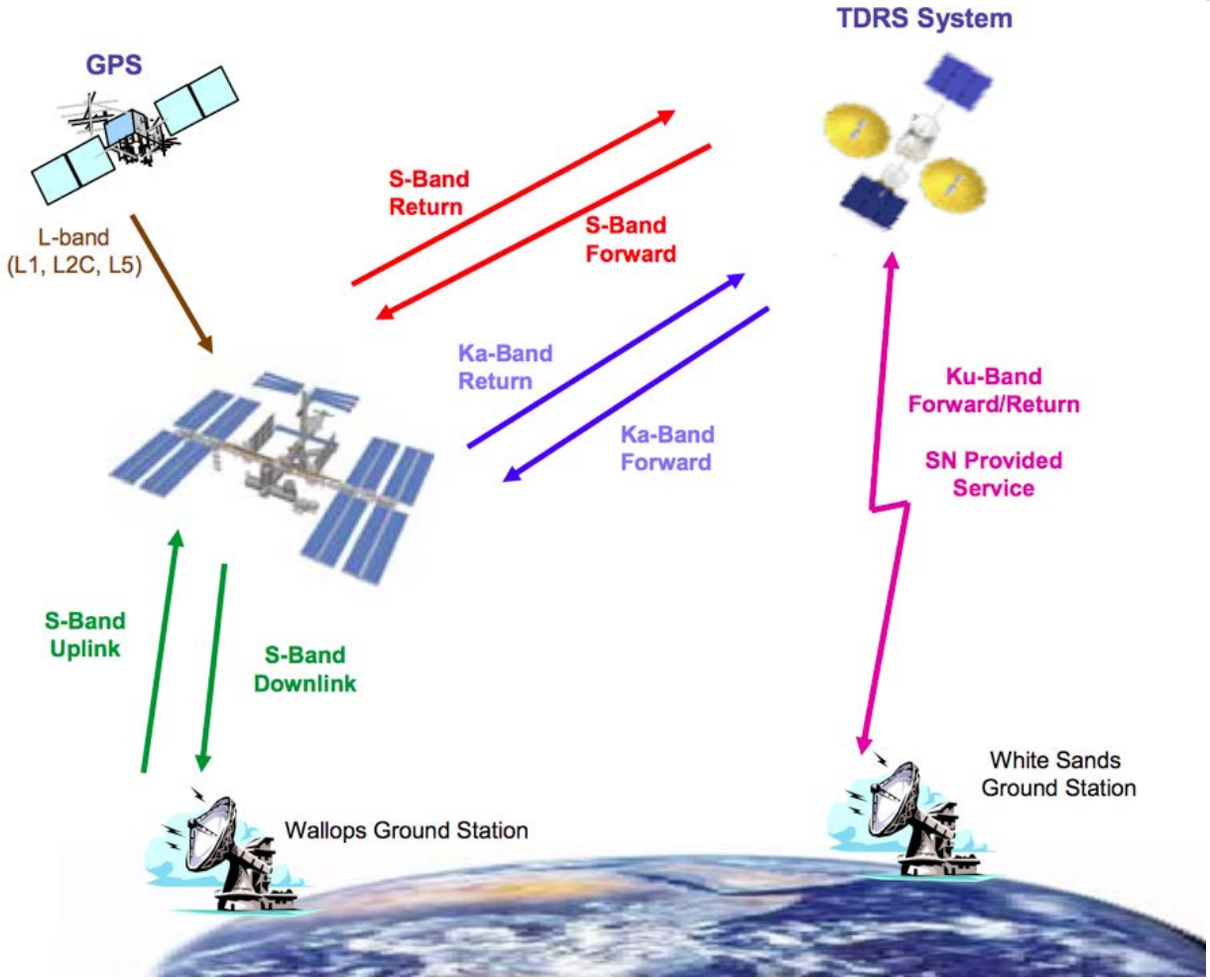

Flight Experiment

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- Deliver the GPS Waveform to CoNNeCT at Glenn Research Center, Cleveland, OH, April 2012
- Operate GPS Waveform after upload
- Verify L1, L2, L5 operation
  - L5 operation in space a possible first
- Schedule several half hour and some 48-hour test runs
  - Ask for GPS to be "left on" when nothing else is happening.
- Post process the data using GIPSY at JPL
- (ISS is a challenging environment for precise positioning)
- Reporting
- Possibility for a GPS Waveform iteration

TASS

- TDRSS Augmentation Service for Satellites
  - Provides worldwide ephemeris and clock improvement for GPS constellation from JPL via TDRSS
- Use the GPS oscillator to sample the S-Band TASS signal, recover and use corrections live
- Demonstrates SDR flexibility
- Demonstrates TASS from orbit (a first)
- (TASS experiment involves re-establishment of TASS infrastructure)

Potential CoNNeCT Flight Experiments

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- Ability to post process raw samples collected in space
  - "bit grabbing"
  - Or at other processing phases: correlators, observables, etc.
- Explore acquisition and tracking issues with orbital dynamics
- Map antenna field of view
- Map ISS multipath
- Use direct or reflected signals to characterize ISS attitude, dynamics, and maneuvers
- Precision timing
- Use GPS Waveform as "black box"
  - Use GPS observables for other applications

Potential CoNNeCT Flight Experiments

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- Utilization of correction signals (i.e. TASS, S-Band)
- Radiometric technology development
  - Other applications besides navigation
- Potentially improved avoidance of space junk due to better trajectory knowledge
- Tracking of new civilian signals and other constellations
  - Galileo
  - QZSS
  - "in band" to existing samplers
- Radio Science
  - Atmospheric occultations
  - Ionospheric occultations
  - sea-surface reflections (requires more antennas)
- Relative positioning
  - ISS end of rendezvous and docking

The SDR Idea

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- Hardware is largely generic
- Software and bitfiles can be changed
  - Tweak algorithms
  - Change function
  - Implement new techniques
  - Fine tune to particular application
  - Access to data from sampler to output as needed

Summary

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- JPL CoNNeCT SDR to be installed on ISS 2012
  - JAXA launch in January 2012
- GPS Waveform upload in April 2012
- Experiment May – August 2012
- One of many CoNNeCT waveforms
  - Demonstrates SDR flexibility and capability
- Other waveforms and experiments solicited