Multi-GNSS Software Radio Waveform Development for the Space Station

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Author Acknowledgements

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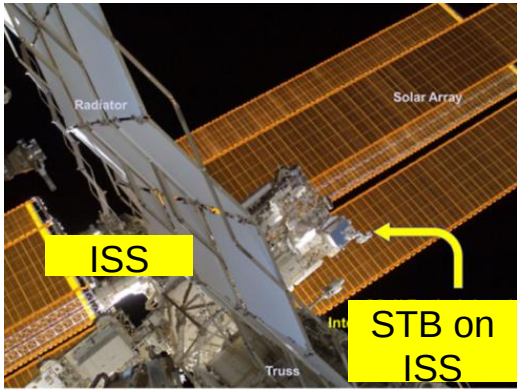
Qascom
Trust is Nice, Control is Better.

esa

JPL
Jet Propulsion Laboratory
California Institute of Technology

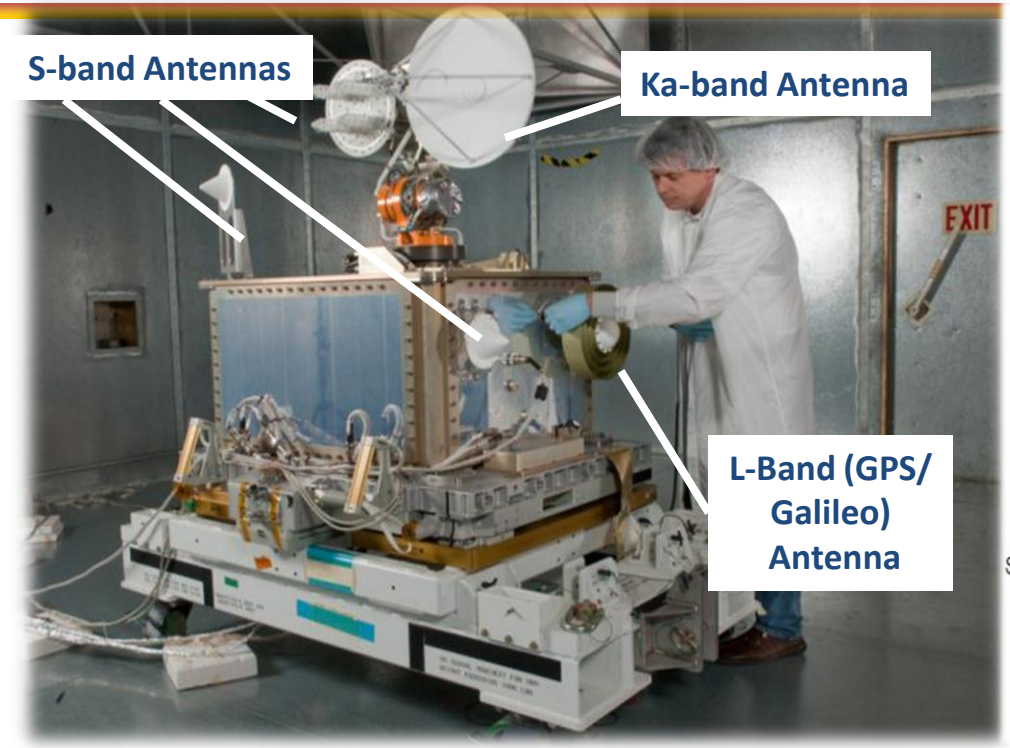
GAlileo **R**eceiver for the **ISS** (GARISS)

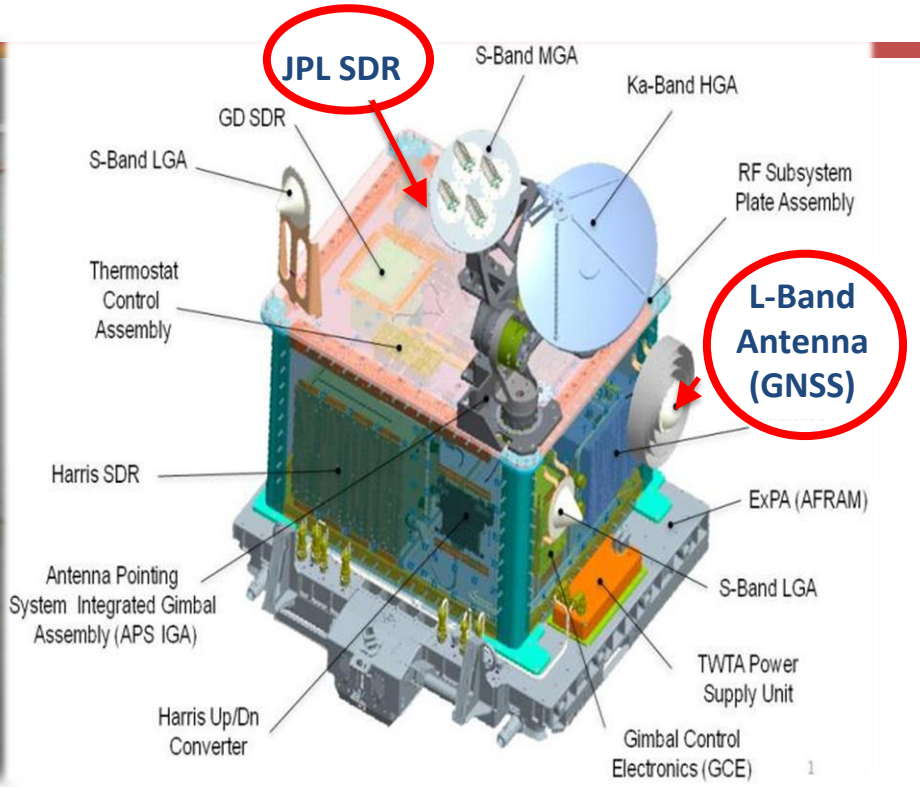
- **Objectives:**
  - **Demonstrate combined GPS/Galileo (L5/E5a) navigation receiver on-orbit with upload of Software Radio waveform**
  - **Add waveform to Space Telecommunications Radio Systems (STRS) waveform repository**
- **Approach/Benefits:**
  - **Adapt existing Galileo PNT code to Software Defined Radio (SDR) inside ScAN Test Bed (STB) onboard International Space Station (ISS)**
  - **Demonstrate operations, conduct PNT experiments on ISS**
  - **Flexibility of SDR technology, STRS operating environment,**
- **Timeline:**
  - **Initial discussions at International meetings (mid-2014)**
  - **Project formulation/export license (mid-2016)**
  - **Waveform design and development (late 2016-mid 2017)**
  - **Qualification and test the Galileo/GPS waveform (mid 2017-late 2017)**
  - **On-orbit testing and experiments (2018 through payload decommissioning in Feb. 2019)**



GARISS waveform development is an element of NASA/ESA cooperation involving multiple centers, Qascom

NASA's SCaN Testbed



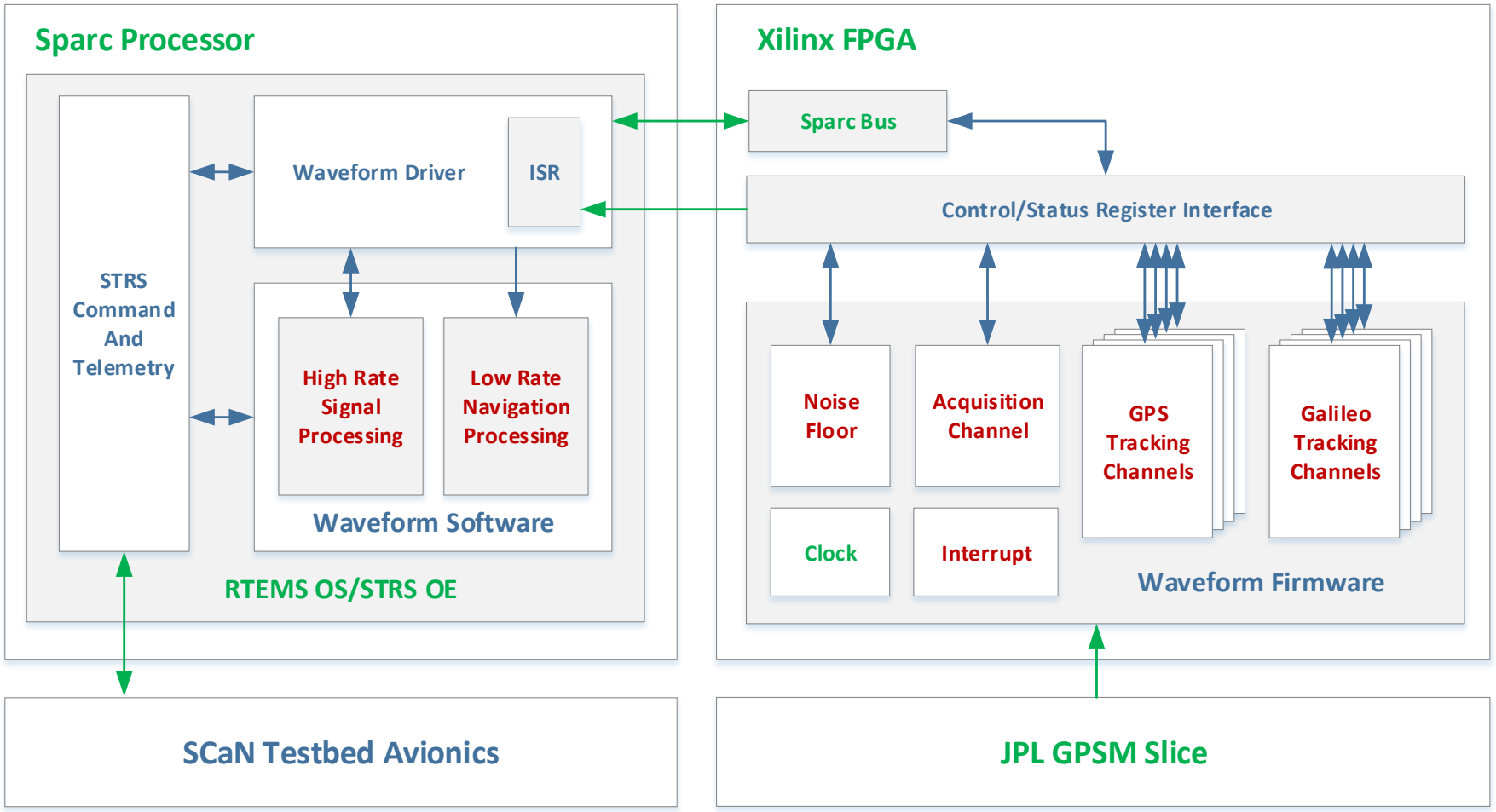


Space Communication and Navigation (SCaN) Testbed

Installed on the Space Station in July 2012

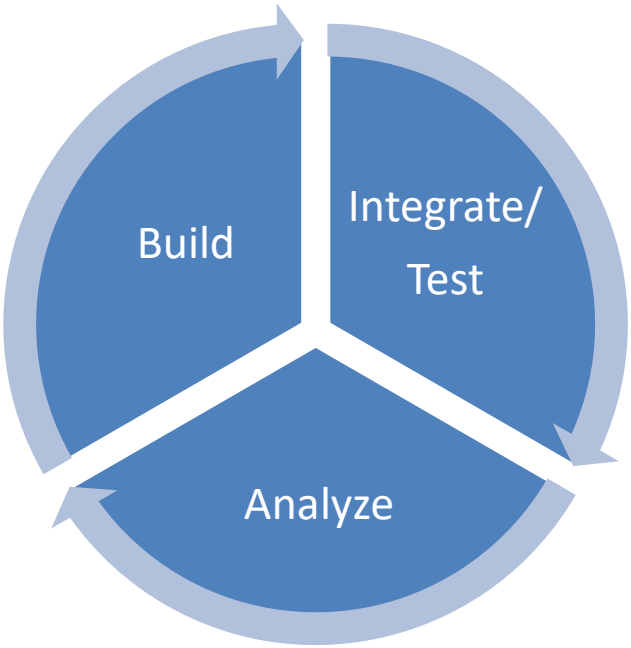
Fully reprogrammable Software Defined Radio capability at L-band

GARISS Waveform Design for the SCaN Testbed



GARISS Development Processes

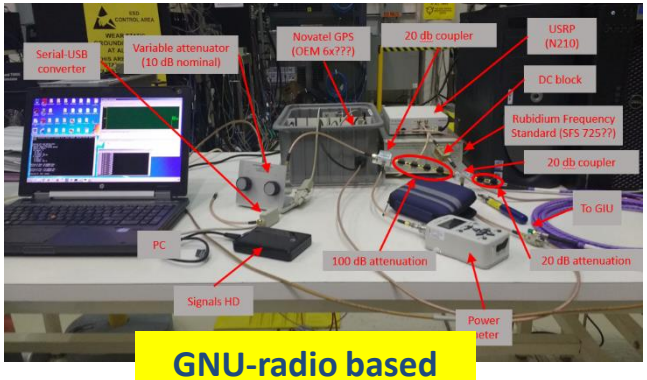
- **Base NASA JPL platform contributions:**
  - GPS Module, bus logic, STRS Operating Environment (OE)
- **ESA contract to Qascom for core waveform design contributions**
  - Allocation of functions to serial and Field Programmable Gate Array (FPGA) processors
  - Core SW development/Core FW development
  - Regression tests
  - Live-sky test/experiment definition, analysis
  - On-orbit test/experiment definition, analysis
- **NASA GRC technical contributions**
  - Platform abstraction
  - Interrupt Service Routine (ISR) development
  - Waveform integration
  - Ground Integration Unit (GIU) test execution
  - On-orbit test execution, analysis



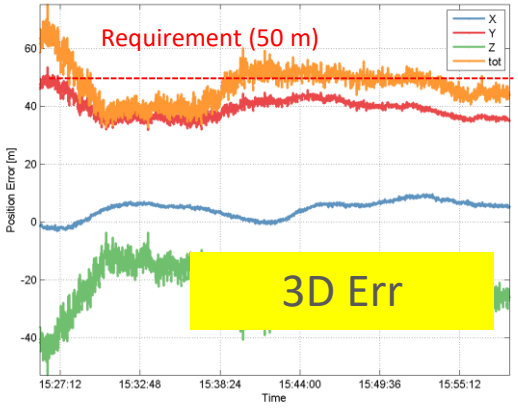
NASA/ESA effort brings together products and efforts from multiple labs and contractors including industry, NASA GRC, JPL, and JSC

Ground Development and Testing

- Build/test/analyze cycle
- Extensive debugging with recorded data
- Successful acquisition, track and PVT with STB Ground Integration Unit (GIU) using roof antenna (March 2018)
- 3D error meets 50m RMS positional error requirement

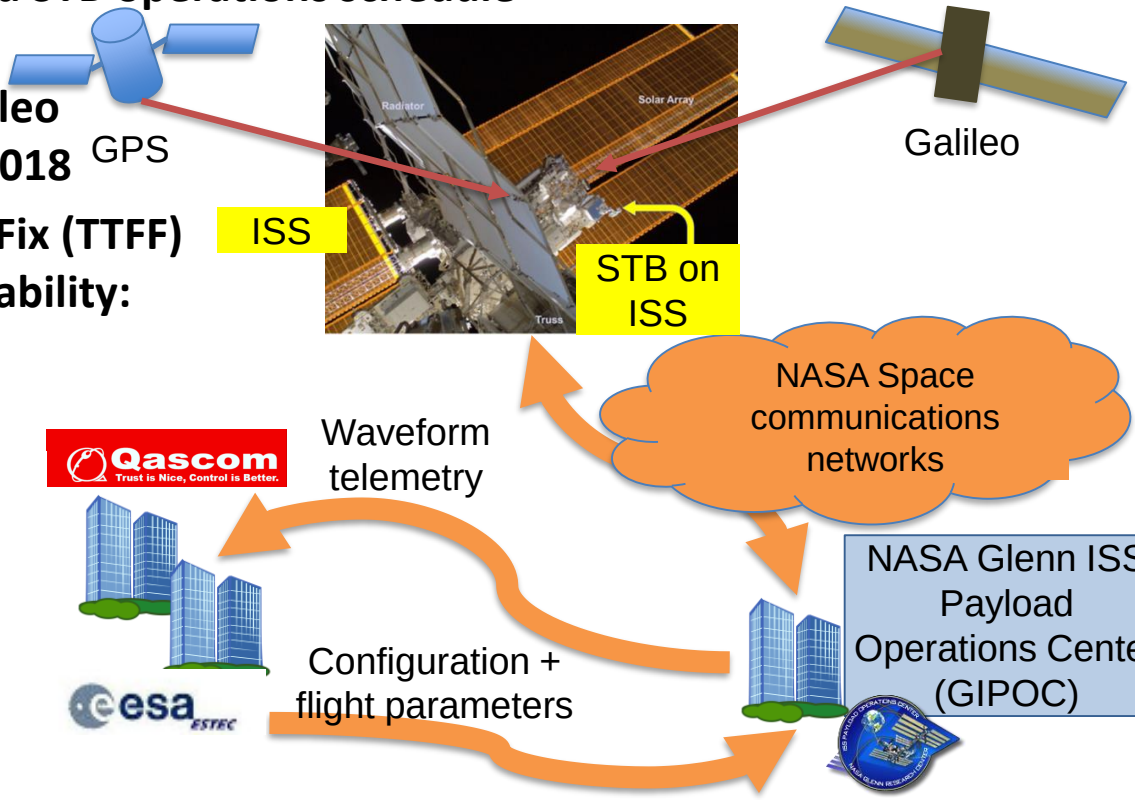


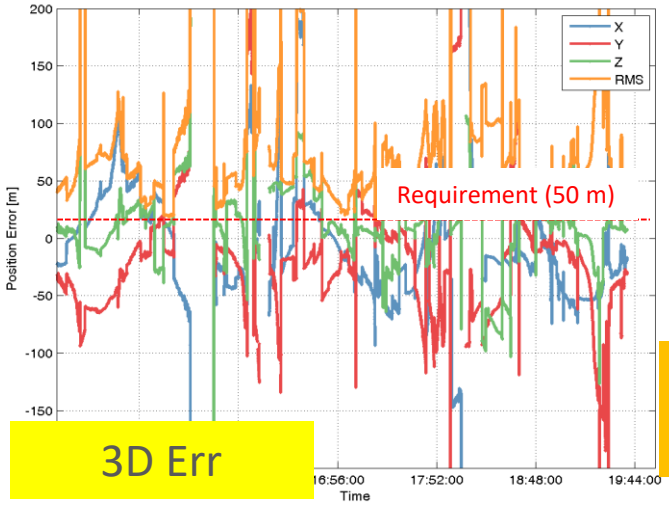
GNU-radio based scenario playback



On-orbit Operations, Experiment and testing

- Transfer waveform from ground support equipment to STB
- Operate waveform per ISS and STB operations schedule
- Collect/process log data
- Full function for GPS and Galileo processing established at May 2018
- Acquisition and Time to First Fix (TTFF) requirements are met, PVT availability:
  - GPS-only > 20%
  - Galileo -only > 40%

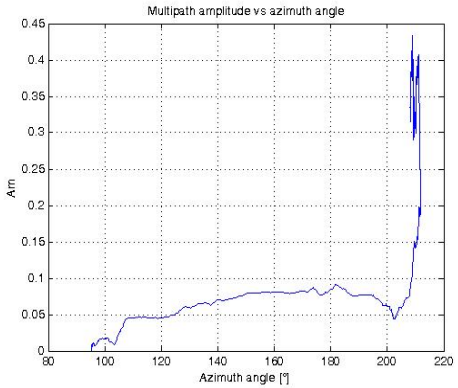




- Combined Galileo/GPS PVT availability > 90%
- ~64m RMS positional error (3D)

Path Forward and Conclusions

- **Precision Orbit Determination (POD) with extended data collection**
- **Multipath analysis**



Multipath amplitude vs Azimuth

- **GARISS waveform development is an element of NASA/ESA cooperation involving multiple centers, industry partner**
- **GARISS leverages SCAN testbed, STRS development framework**
- **Demonstrates use of SDR waveform upload to install radio capabilities post-launch**
- **Demonstrated effectiveness of multi-constellation/GNSS solutions**
- **First-ever on-orbit direct acquisition of L5/E5a (no L1 aiding)**

GARISS waveform development—another step towards demonstrating benefits of multi-GNSS Space Service Volume