GPS and Galileo developments on board the International Space Station with the Space Communications and Navigation (SCaN) testbed

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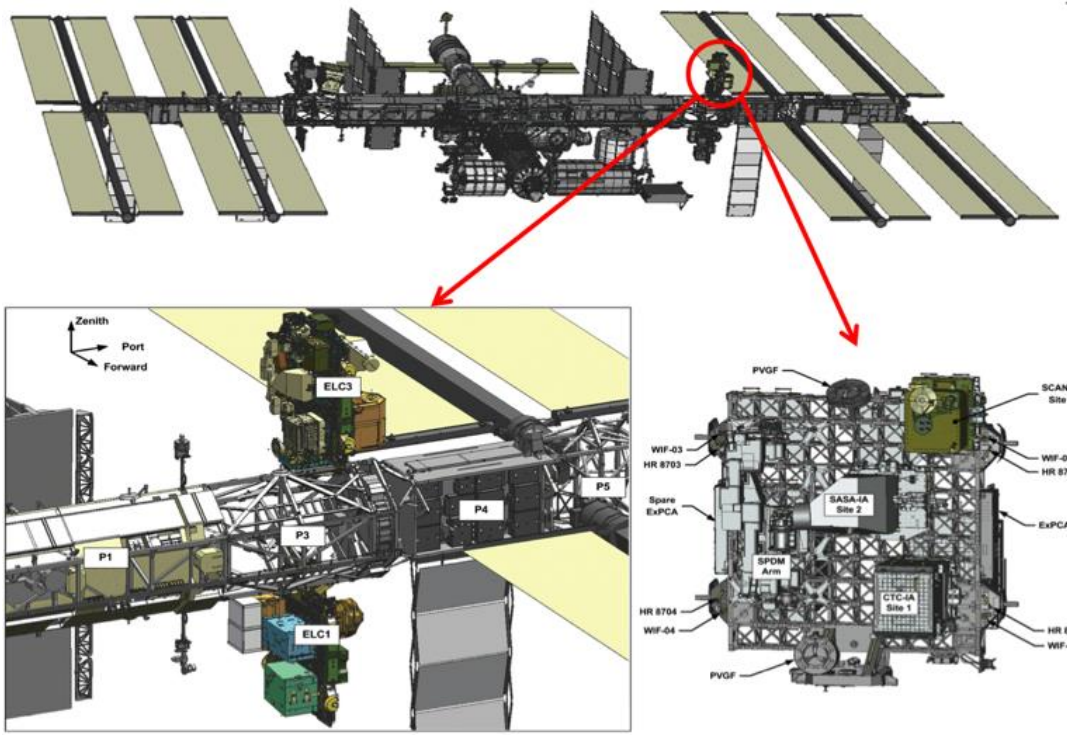
Agenda

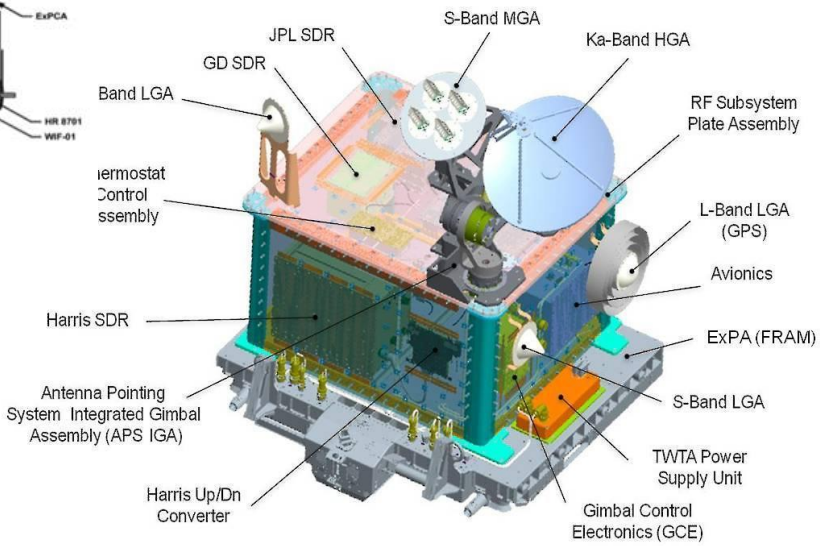
- Introduction to the Space Communications and Navigation (SCaN) testbed and the experimentation
- Objectives and challenges of the mission
- Preliminary Design Considerations
- Initial results from GPS and Galileo observations in space
- Identified approach to Verification and Validation (V&V) activities
- Conclusions and way forward

Introduction to the SCaN testbed



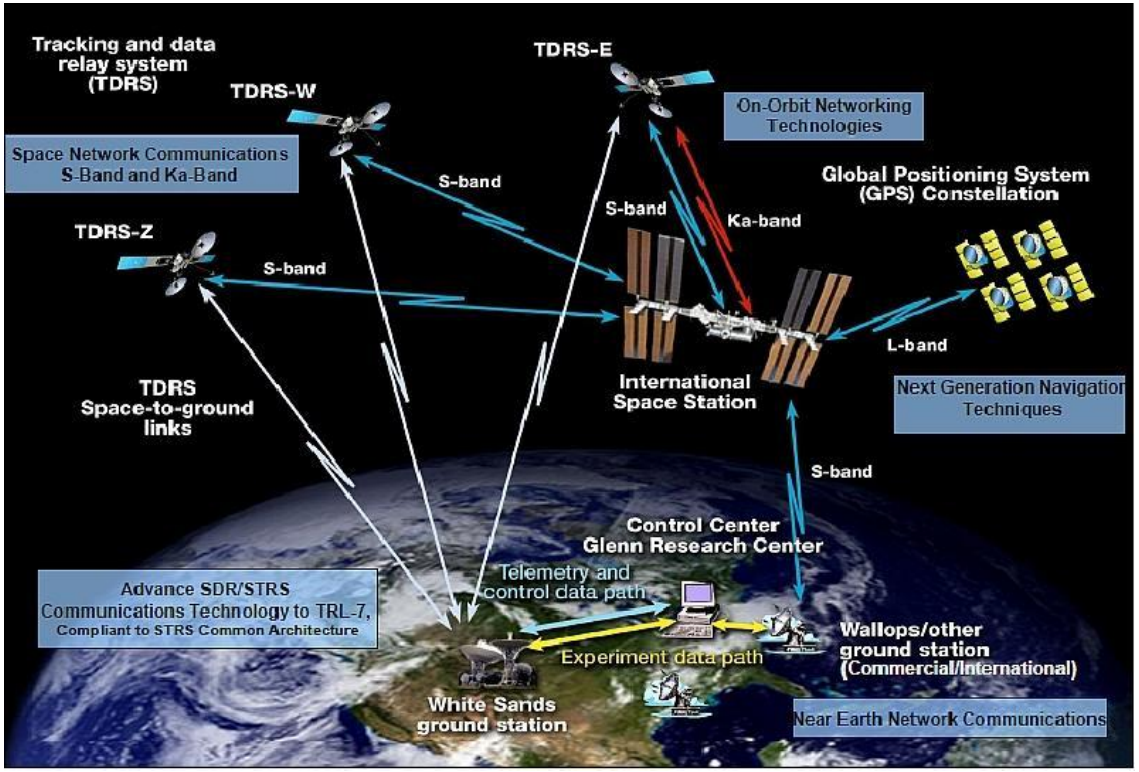
- Navigation Capability:
  - L1
  - L5

- Communication Capability:
  - S band
  - Ka band



and Security

Communication and ground support subsystem

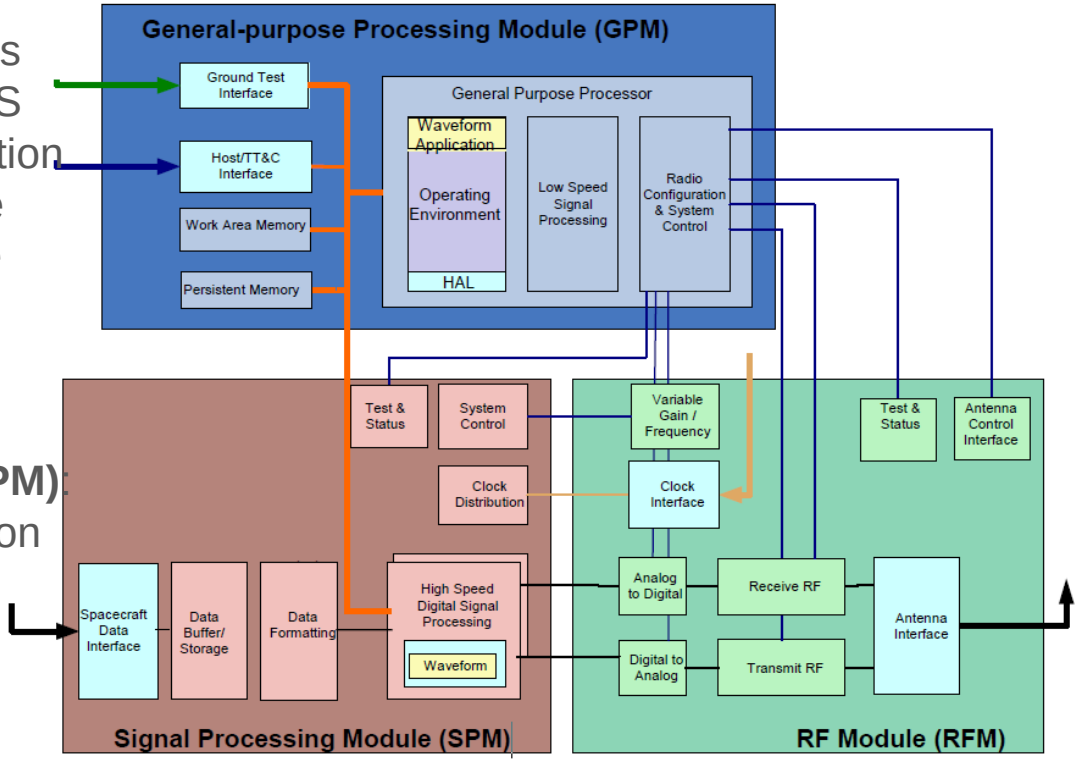


Communications options

- There are two communication paths for the SCaN Testbed mission.
  - **Primary Link:** the ISS S-band and Ku-band links.
  - **Experimental Link:** with the SN and the NEN. This link will be scheduled directly by the STCC with the supporting elements.

Waveform and STRS standard

- **STRS Framework** abstracts the application software from the radio platform hardware
- The STRS software architecture uses three primary interfaces (1) the STRS API, (2) the STRS hardware abstraction layer (HAL) specification, and (3) the Portable Operating System Interface (POSIX).
- The SDR Signal Processing HW is organized in:
  - **Signal Processing Module (SPM)**: high rate WAVEFORM application components
  - **General-purpose Processing Module (GPM)**: low rate signal processing WAVEFORM component and the managing SW.



Satellite Navigation Systems and Security

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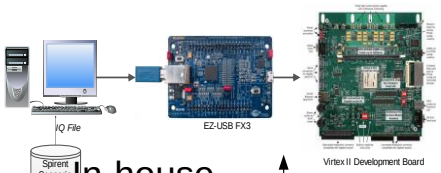
Mission objectives and challenges

- Develop a GPS and Galileo multiconstellation Waveform
- Analyse both L1 and L5 opportunity
- Establish an international framework of cooperation between NASA and ESA
- Design innovative schemes for GNSS space acquisition and tracking considering the onboard limited resources
- Identify a strategy for integration, verification and validation considering the international cooperation and physical access constraints
- Perform in-orbit performance assessment and trade-off investigations
- Conclude and define future mission requirements and opportunities

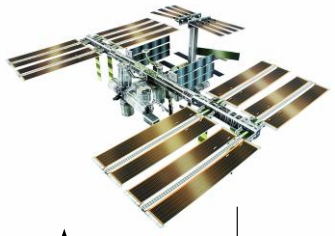
Mission Schedule

- *Schedule for 2016 and 2017 actvities*



In-house verifications QASCOM/ESA

Pre-flight Qualifications at NASA GRC



Waveform upload NASA GRC

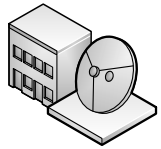
Task 1: Design

Task 1: Design and development

Task 2: Development and Integration

Task 2: V&V

Task 3: Experimentation



Data Processing ESA/NASA

KP

SRR/ PDR

CDR

TRR

QR

AR

lug. ’16 | ott. ’16 | gen. ’17 | apr. ’17 | lug. ’17 | ott. ’17

Satellite Navigation Systems and Security

Preliminary design considerations

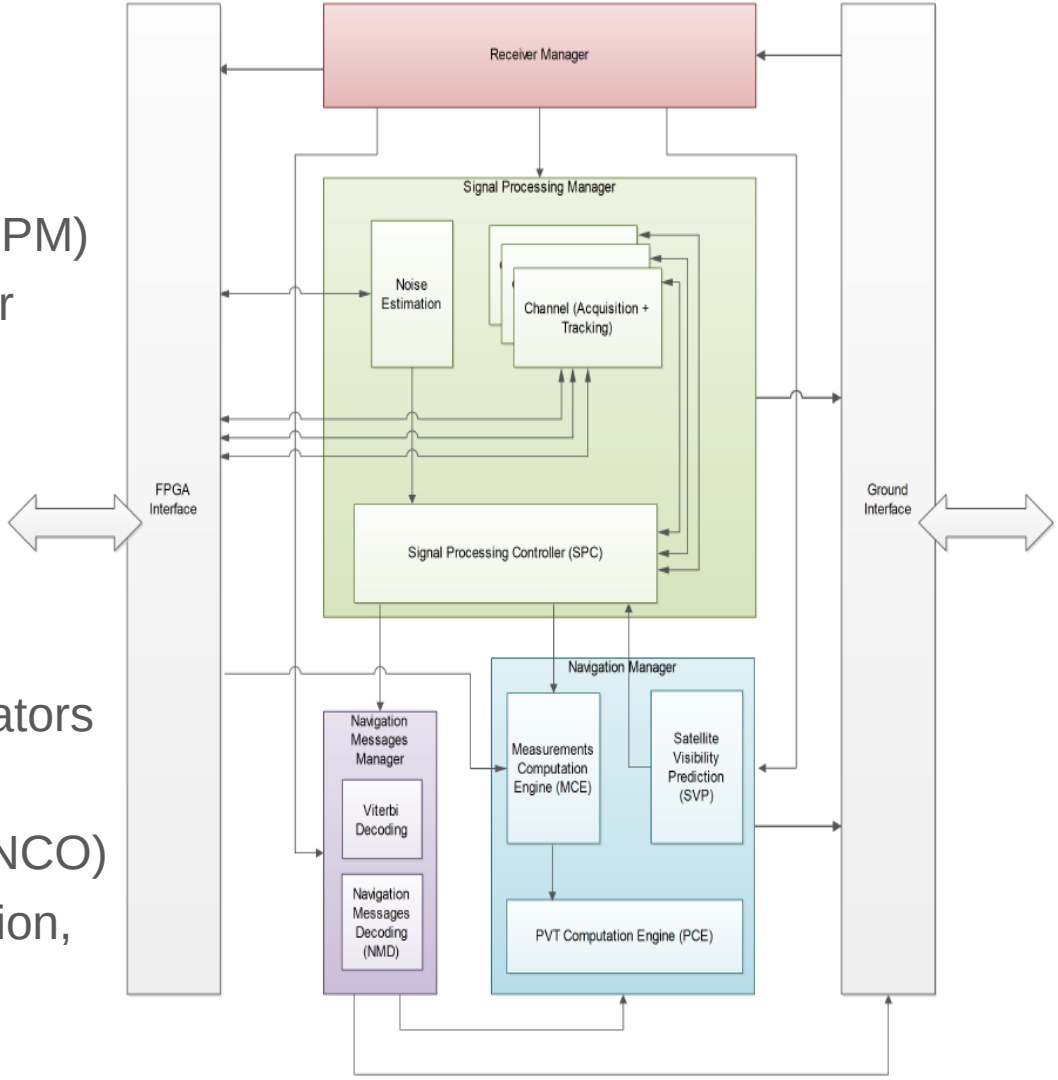
- **High Level Mission Concepts**
  - First Dual Constellation SDR Receiver in Space
  - Collection and Performance assessment of Galileo (and GPS) raw measurements (Pseudo Range, Carrier phase, etc.) in space,
  - Computation of positioning in space (Position, Velocity and Time) and assessment of its performance.
  - Aiding from ground via primary path
  - Time Aiding from ISS avionics interface
  - Final Choice for the L5/E5a Band
    - **Cons:** Less LOS, Lower PVT Availability, Higher FPGA resources, Limited equipment for L5 simulation
    - **Pros:** Better Power Budget, Better Code/Carrier accuracy, New Concept for Space Test
- **System Design Concepts**
  - Communication subsystem and Ground Support Operations
  - Navigation Subsystem (waveform)

Communication subsystem and Ground Support Operations

- **Communication Subsystem**
  - Primary path communications link through international space station
    - Link traverses NASA Space Network including TDRSS
    - Data latency roughly 1 hour
  - Experimental communications link DTE from ISS
    - Supports higher rates but with significantly less availability
- **Ground Support Operations**
  - XML Configuration (Ground to Space), 1 day Experiment
    - Tracking Parameters
    - Receiver Configuration
    - Aiding Data (Keplerian Parameters, GGTO,
  - Binary Protocol for GNSS Data Observations and SW Logs

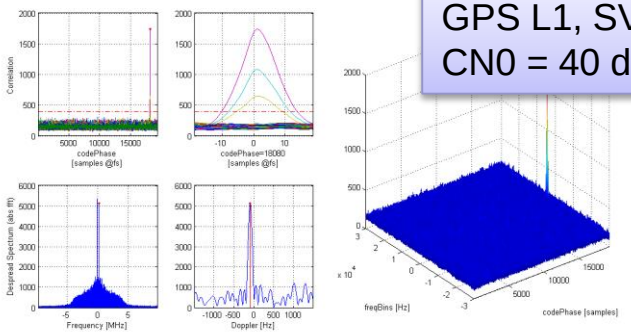
Navigation subsystem

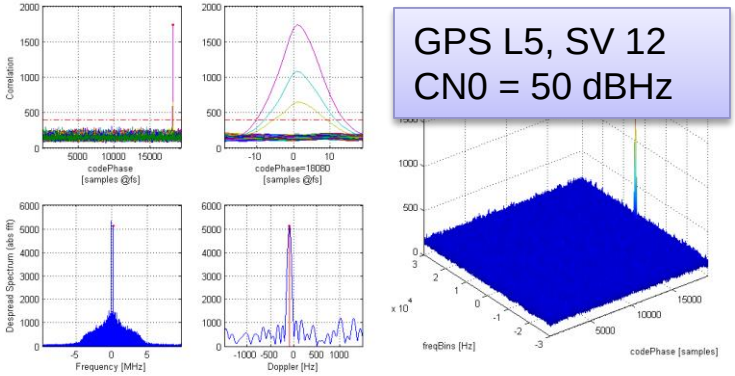
- **SW Main Modules**
  - Receiver Manager (RM)
  - Signal Processing Manager (SPM)
  - Navigation Messages Manager (NMM)
  - Navigation Manager (NM)
- **FW Main Modules**
  - Clock management
  - Samples counter
  - Carrier and code phase integrators
  - Spreading code generator
  - Numeric controlled oscillator (NCO)
  - Parallel correlation for acquisition,
  - Serial correlation for tracking,



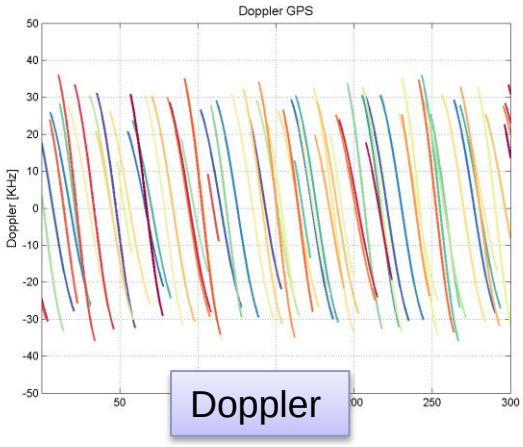
Results from GPS and Galileo Observations in Space

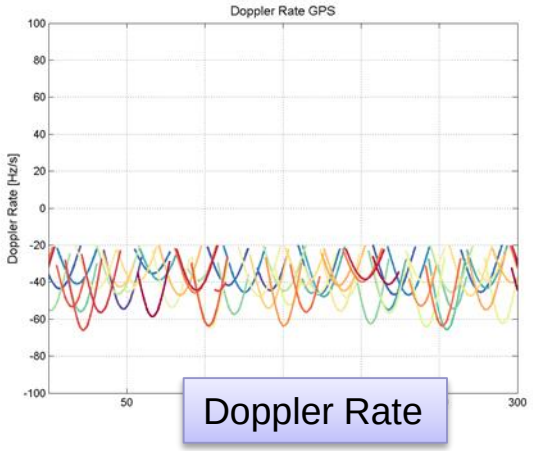
- First Acquisition Test of GPS and Galileo SIS





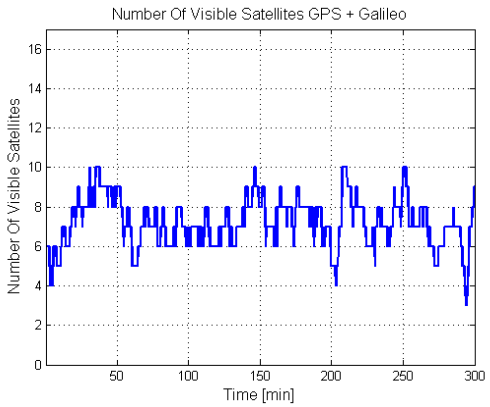
- Doppler and Doppler Rate analyses
  - Max Doppler Observed ±36 KHz
  - Doppler Rate -20 Hz/s to +70 Hz/s



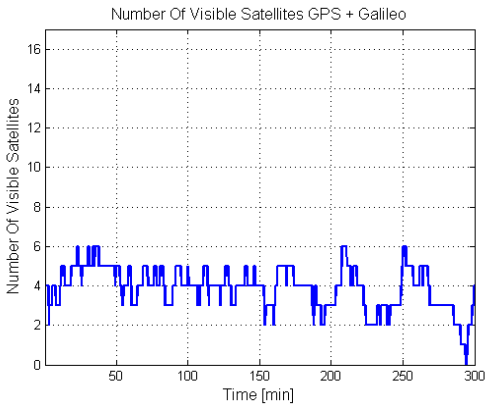


Results from GPS and Galileo Observations in Space

- **Preliminary Dual Frequency Visibility Analysis**
  - Visibility Analysis for all satellites above 30 deg
    - L1/E1
      - PVT Availability is **> 99%**
      - Mean Time with at least 4 Satellites in view **6 h**
    - L5/E5a
      - PVT Availability is **64%**
      - Mean Time with at least 4 Satellites in view **12 minutes**



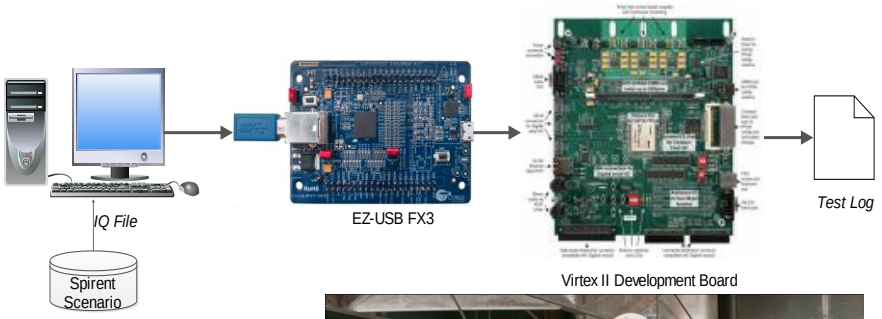
GPS L1 + Galileo E1
PVT Availability: 99.76%
MeanTime 4 Sats : 21548.5s = 359.14 min = 6 h



GPS L5 + Galileo E5a
PVT Availability: 64.79%
MeanTime 4 Sats : 691.0864s = 11.52min

Approach to verification and validation

- **Unit Level Testing:** will be executed for the two component of the Waveform (Software and Firmware). The Testing will be executed at Qascom premises in selected boards that are representative of the JPL SDR architecture.
- **System Level Testing:** will be executed at NASA premises. The objective is the verification of the integrated waveform components. Two integrated systems are available: the Experiment Development System (EDS) and the Ground Integration Unit (GIU). EDS will be verified with LVDS simulators. The GIU with RF simulation.
- **Experimentation**: this activity consists in the in-orbit validation and experimentation of the Waveform.



SCAN Testbed

JPL radio EDS with RF subsystem

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Conclusions

- Preliminary design has been identified to match both mission (SDR and STRS) and experiment objectives
- In-orbit acquisition demonstrates the feasibility to acquire, track and experiment both GPS and Galileo L5 signals
- An approach for integration and verification and validation that can satisfy both technical challenges and the international ESA-NASA context has been identified
- In-Orbits experimentations are foreseen for early 2017, when 15 E5a Galileo satellites will be available and 12 L5 IIF Block GPS Satellites
- The SCaN testbed and its evolutions are a unique opportunity to experiment navigation and communication SDR technologies in the space environment also in an international context.

Thank you!

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