The ACES GNSS Subsystem and its Applications for Remote Sensing

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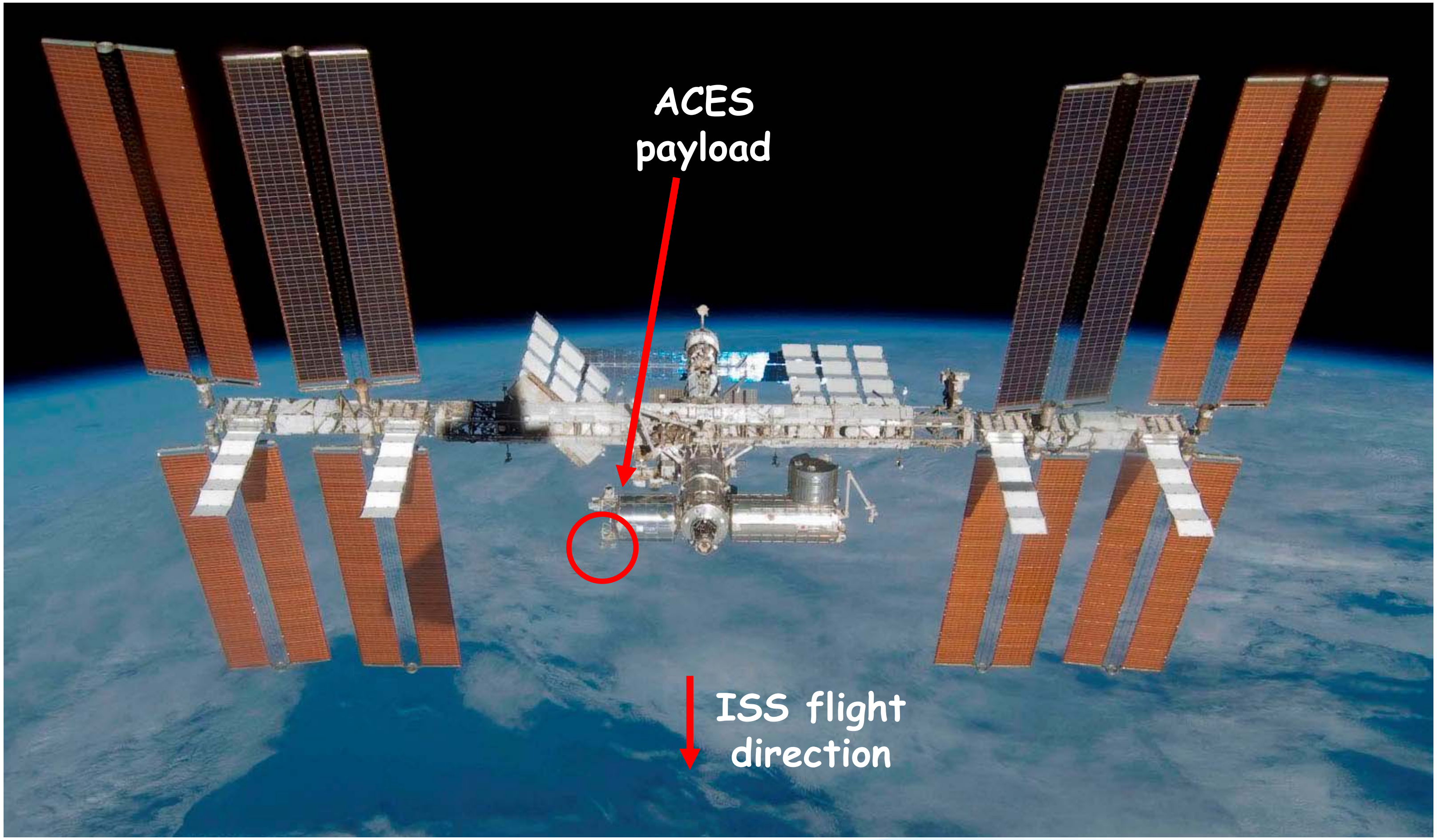
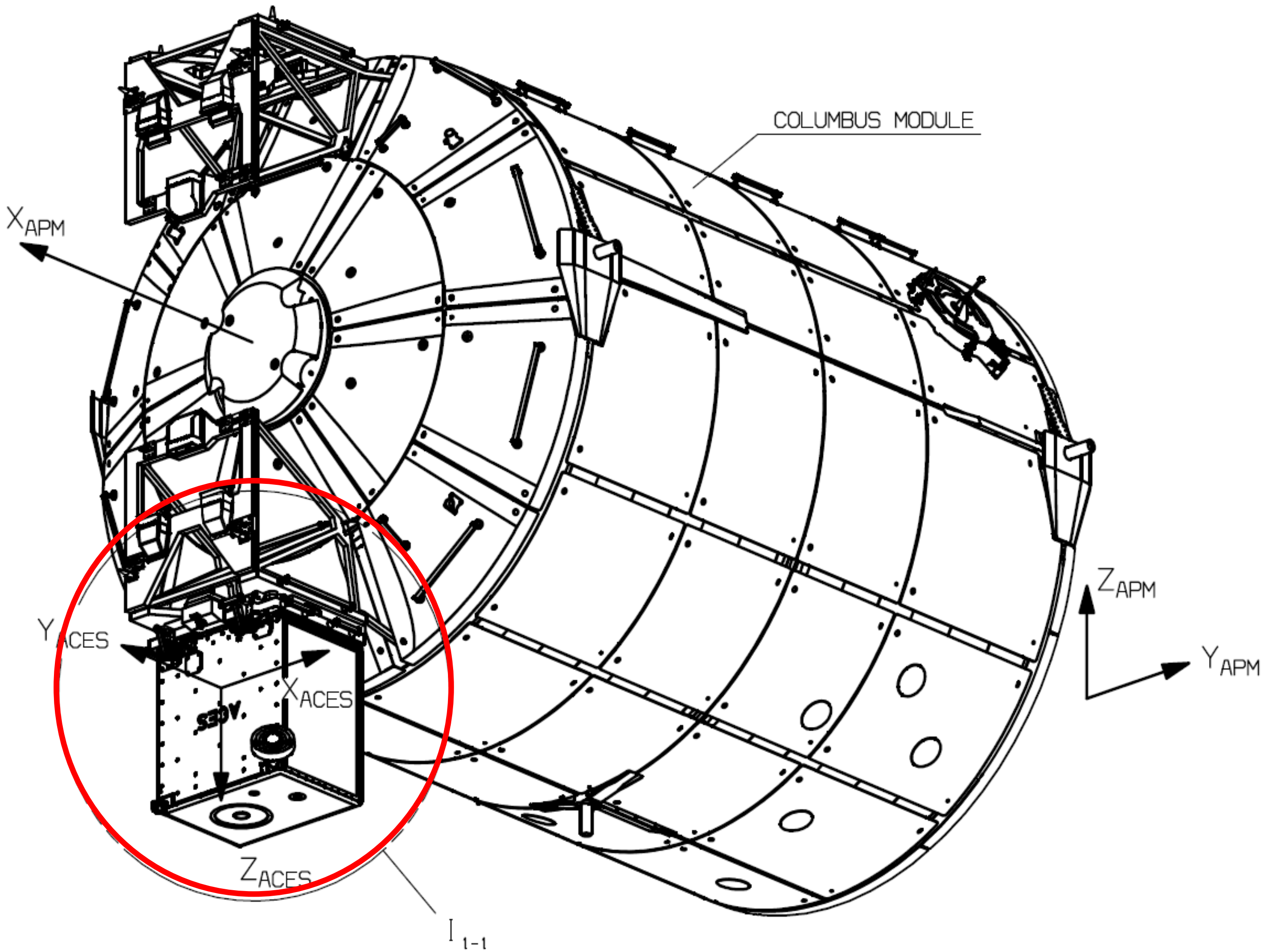
ESA mission Atomic Clock Ensemble in Space



ACES external payload of Columbus Module



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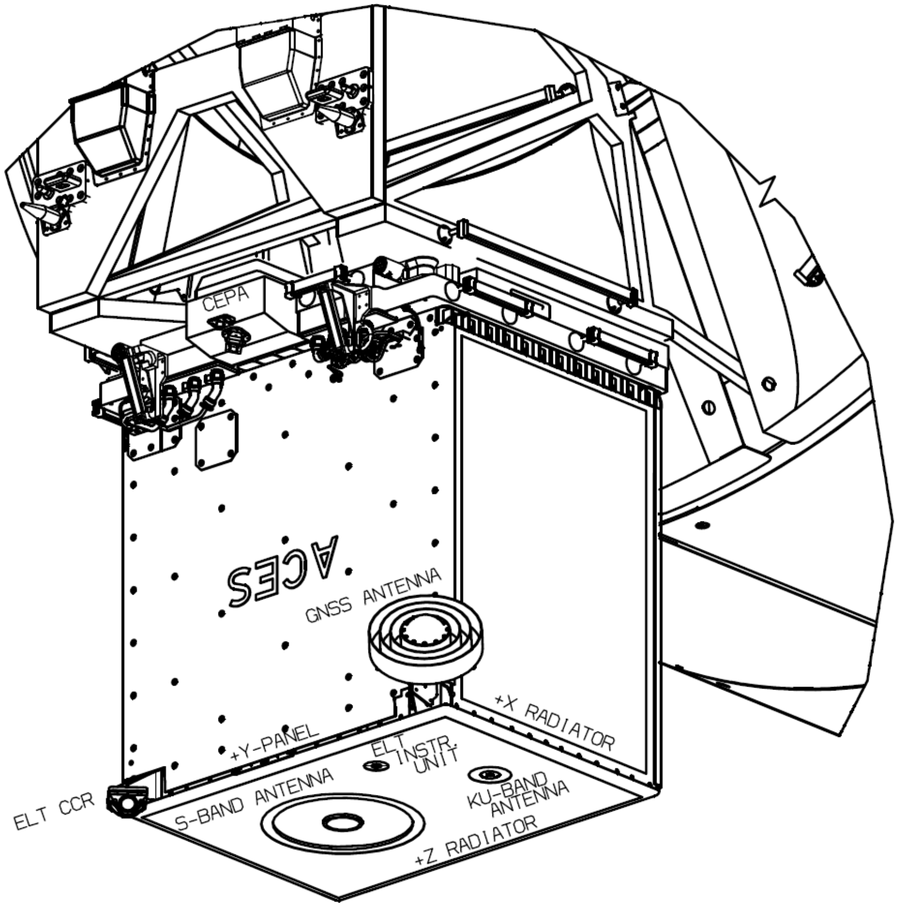
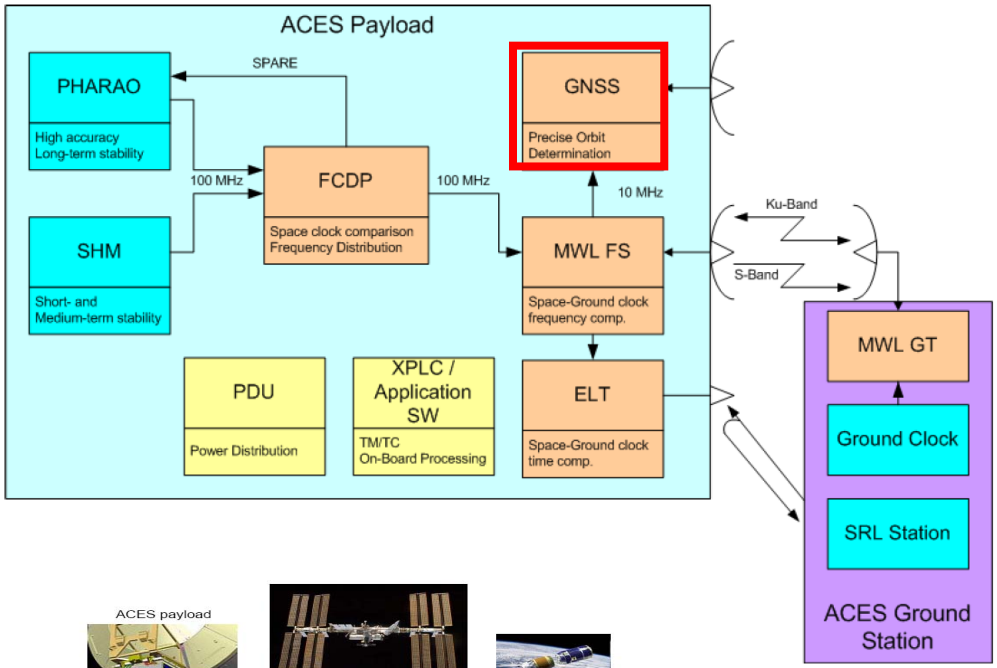
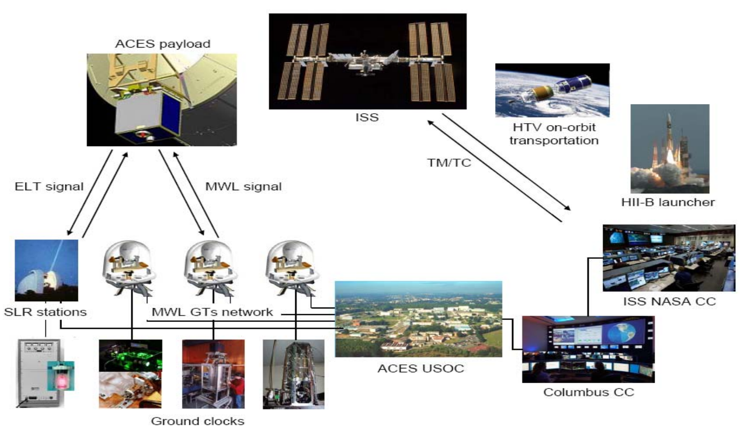


- **Test of a new generation of space clocks with frequency instability & inaccuracy at the level of 10^{-16}**
- **Stable and accurate time and frequency transfer via a dedicated Microwave Link**
  - **space-to-ground clock comparison**
  - **common view ground clock**
  - **non-common view ground clock comparison**
- **Conduction of Fundamental Physics Tests**
  - **precise measurement of Einstein's Gravitational Red Shift**
  - **search for violation of special relativity and Standard Model Extension tests**
  - **by a search for time variations of fundamental constants.**

ACES System Architecture

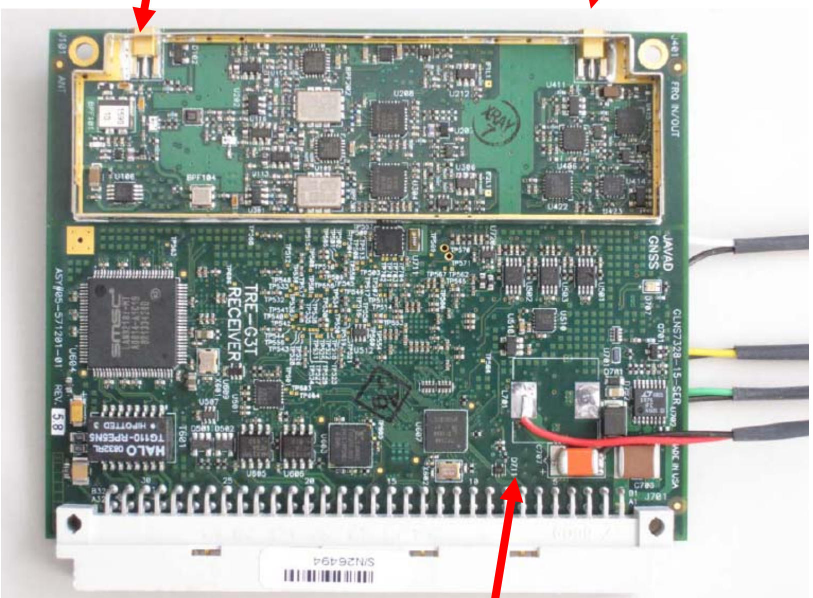




ACES Ground Segment

- **CLOCKS**
  - **PHARAO**, a Cs atomic clock
  - **SHM**, a H Maser
- **FCDP**
  - clock comparison
  - generation of ACES signal from both PHARAO and SHM
  - distribution of clock signal
- **MWL**
  - comparison of ACES with ground clocks via a dedicated microwave link
- **ELT**
  - round-trip laser ranging
  - one way time transfer
- **GNSS**
  - Orbit determination & prediction
  - Relativistic clock correction
  - **Remote Sensing**

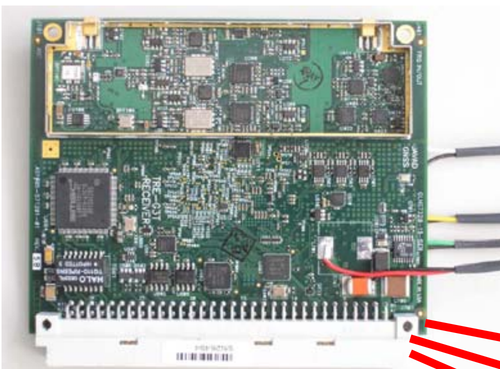
Commercial-of-the-shelf GNSS receiver JAVAD TRE-G3TH



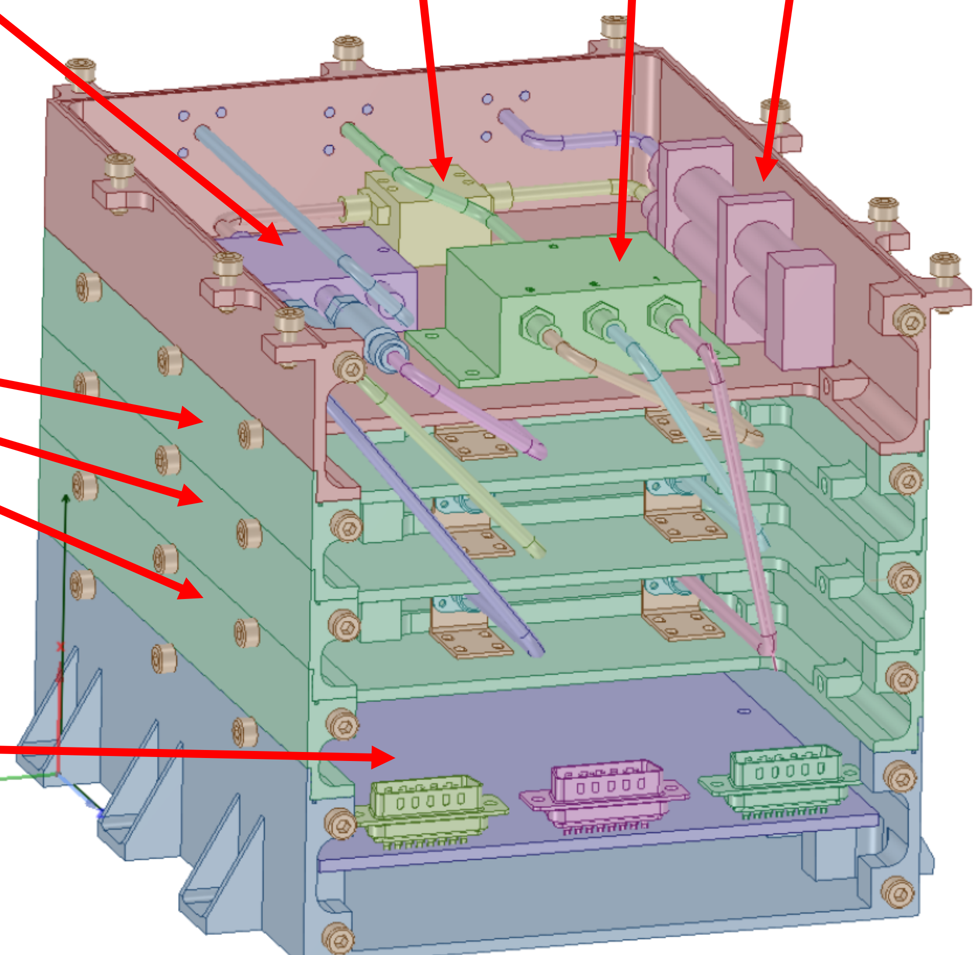
- Commercial-of-the-shelf GNSS receiver board TRE-G3TH rev. 5.8,
  - **size 100x80x14mm**
  - **mass ~90g**
  - **power ~2W**
- GNSS signal tracking
  - **216 channels**
  - **GPS L1, L2/L2C and L5**
  - **GLONASS L1 and L2**
  - **Giove/Galileo E1 and E5a**
- Modified power supply to allow for latch-up protection
  - **4 individual power line monitors and current protections**
- Modified receiver firmware
  - **suppress write processes to the boards flash memory**

ACES GNSS subsystem

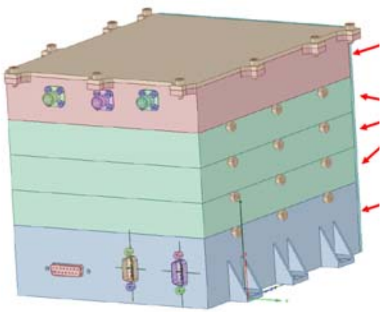
3x JAVAD GNSS modified TRE-G3TH Rev. 5.8 board

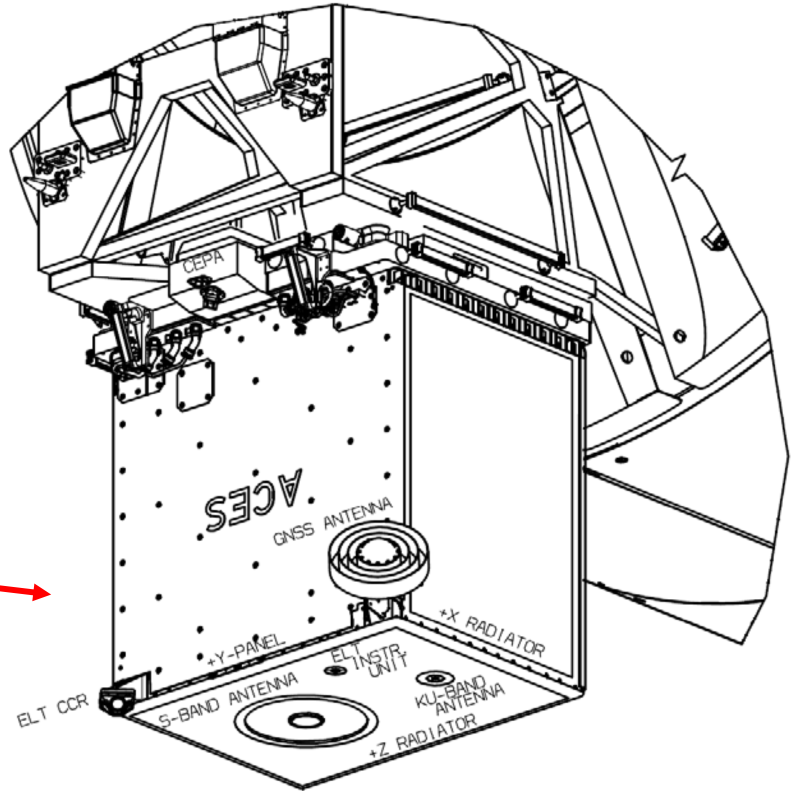


EREMS receiver interface board (here: breadboard)



ACES GNSS subsystem

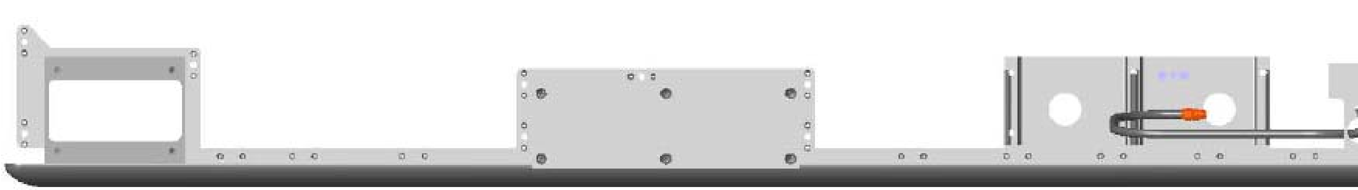


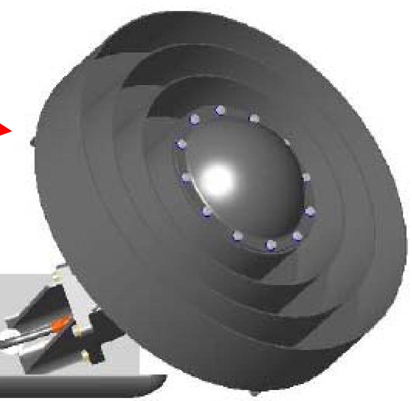


C146-24-1
L1, L2, L5 GPS, Glonass, Galileo ANTENNA

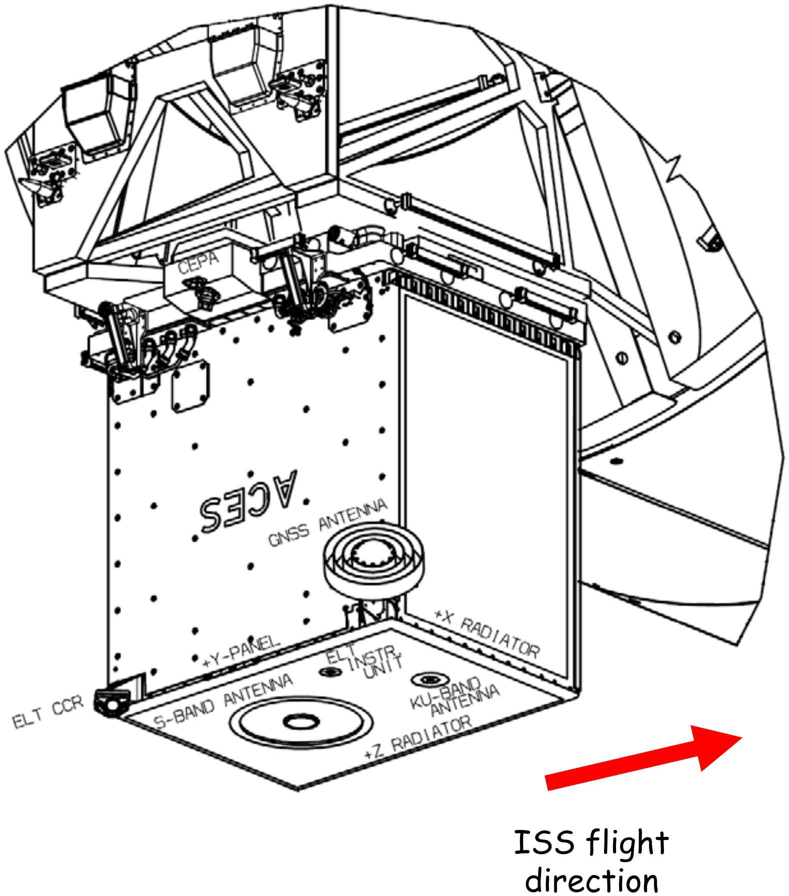
Building on the highly successful C146 Series fixed reception pattern antennas, our newest introduction covers an extended bandwidth that encompasses the entire 1176 to 1625 MHz frequency range providing coverage for GPS, Glonass and Galileo systems.

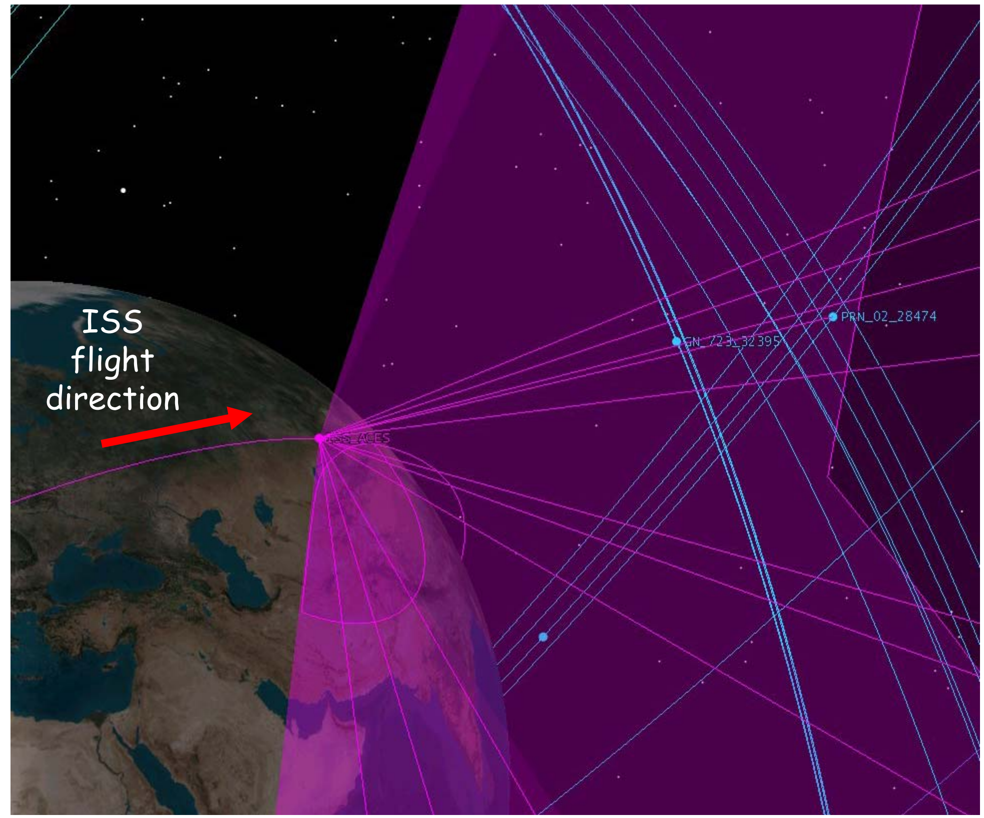
The design is suitable for both ground fixed and mobile applications and is also qualified for airborne military environments.



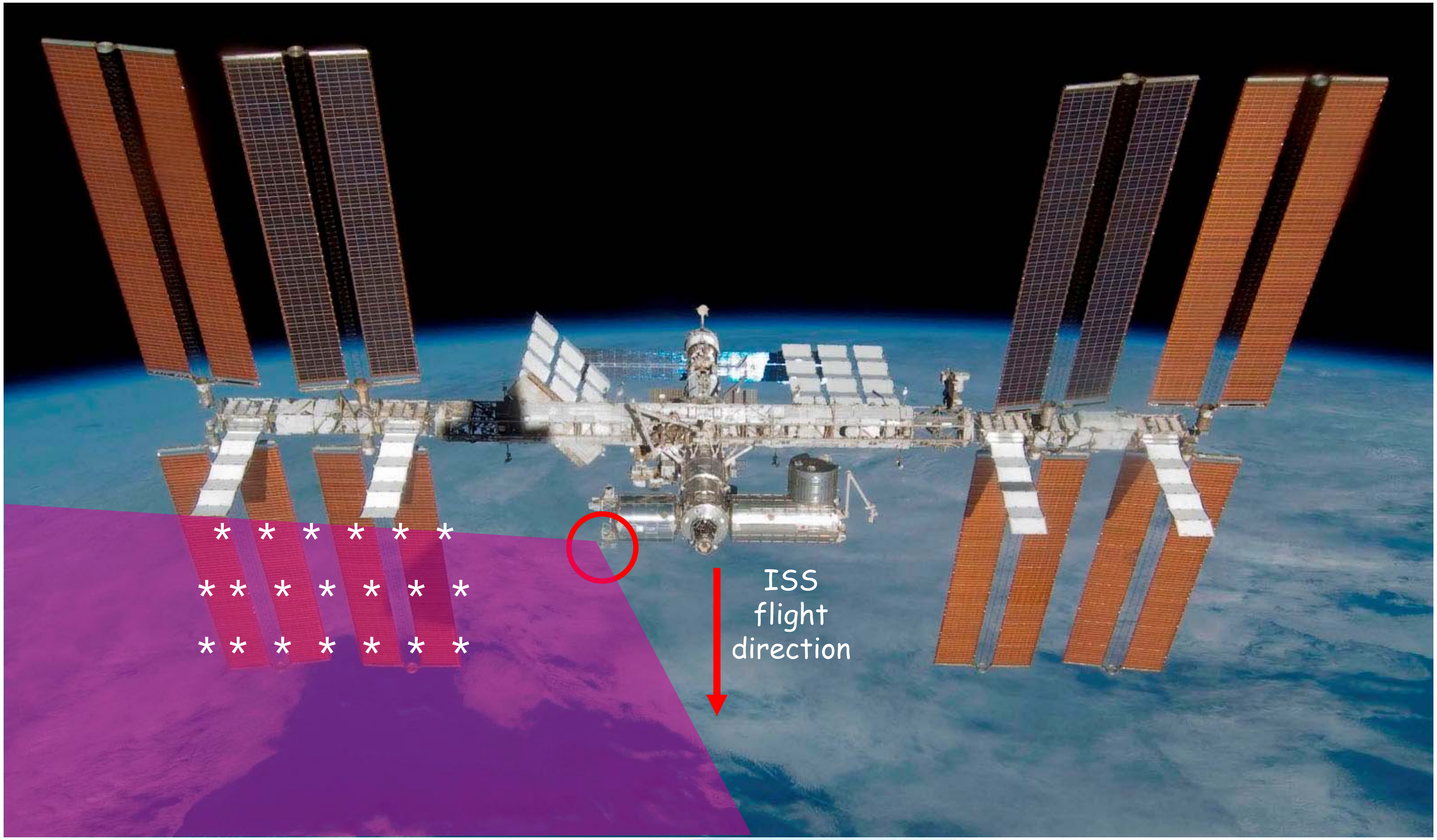


ACES GNSS antenna field of view

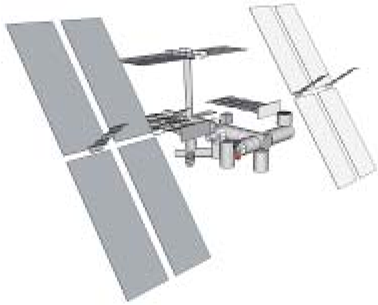


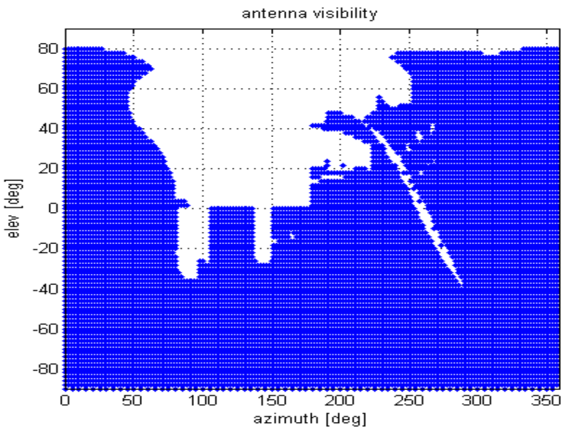


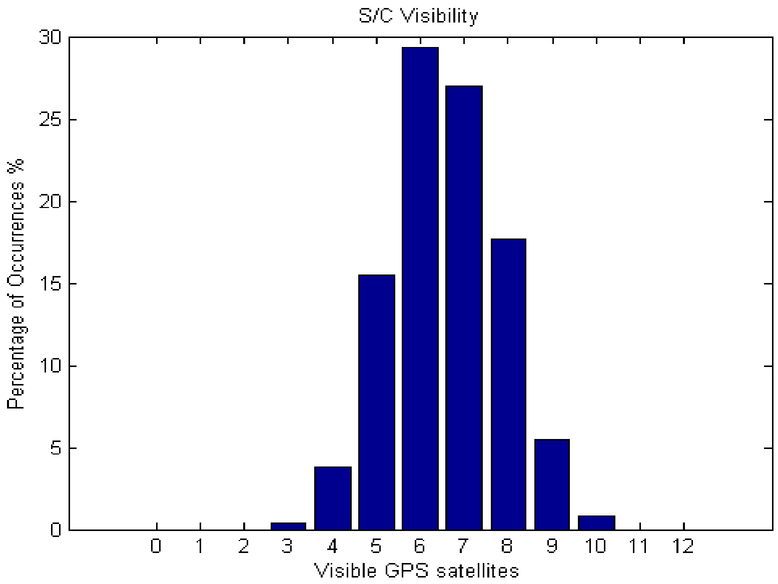
ISS structures limit field of view



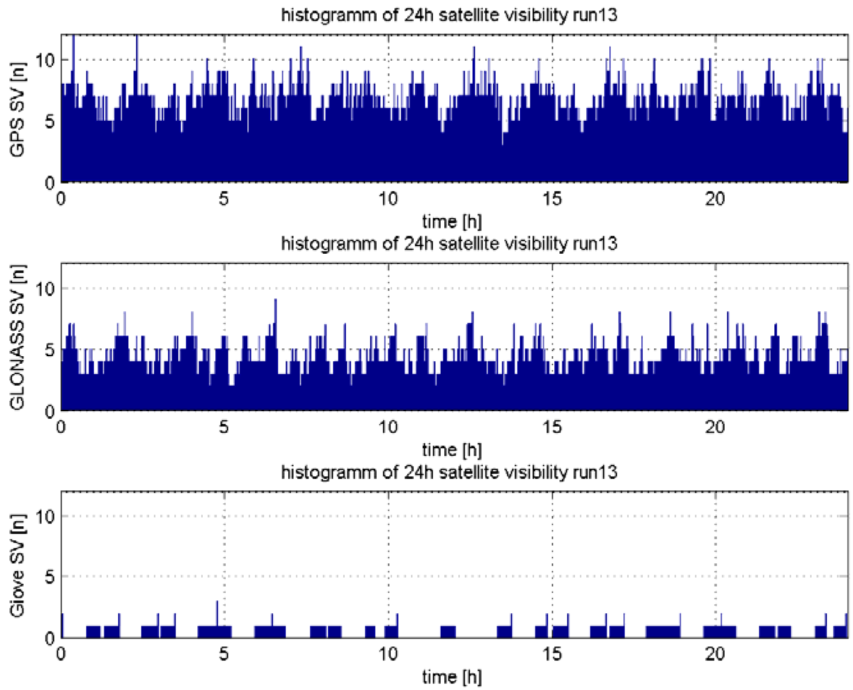
A 24h simulation using ESA's NAVLAB SW tool and orbit information of ISS and GPS satellites

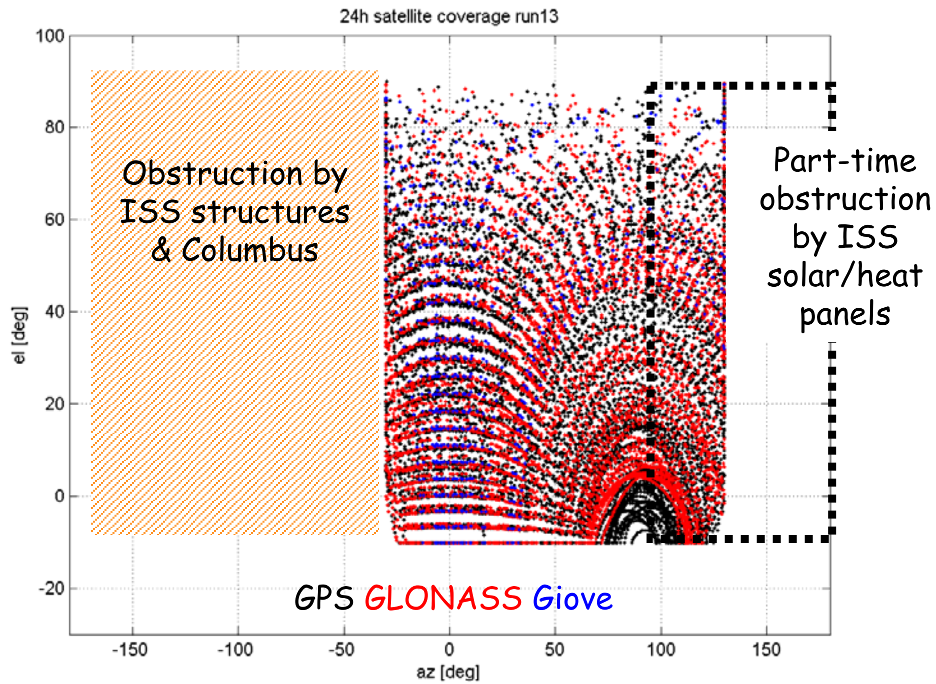




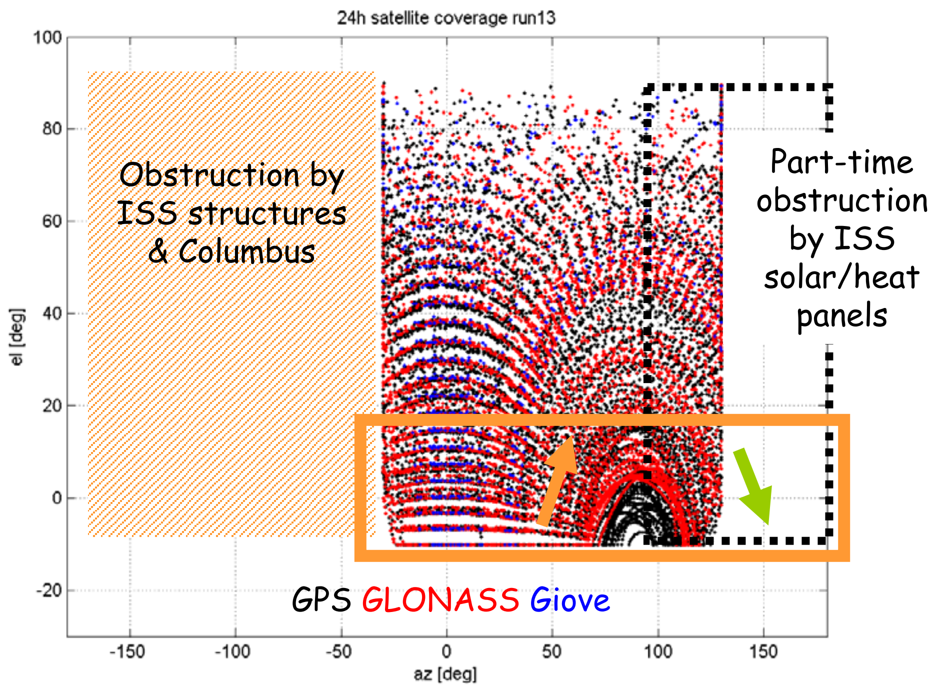


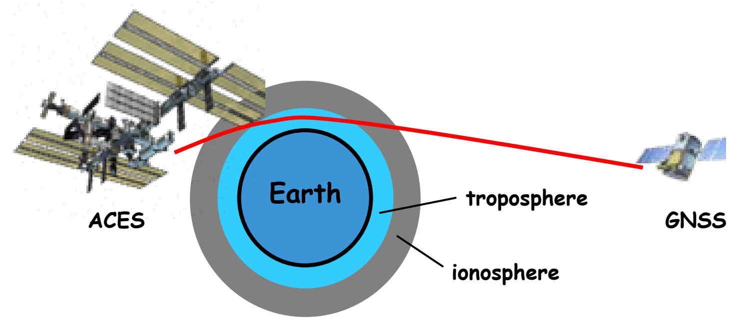
24h GNSS satellite visibility on ACES/ISS





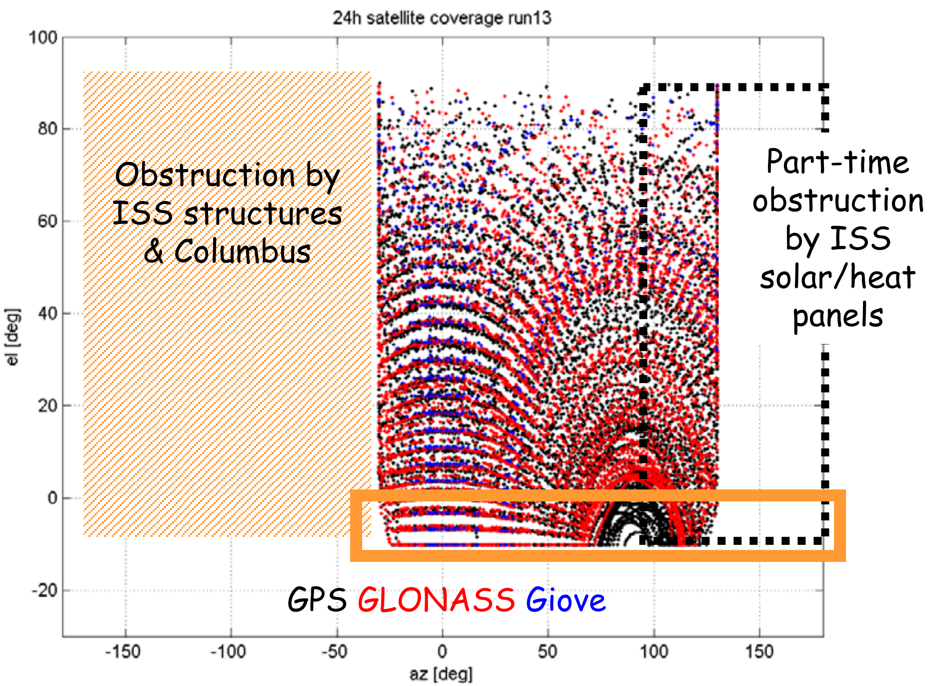
GNSS radio-occultation

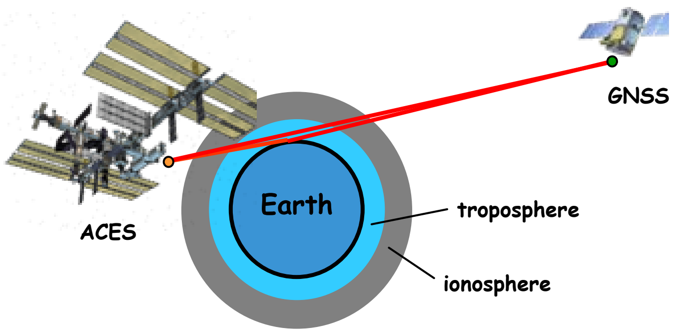




- **Rising and setting radio-occultation events at low elevations**
  - **50 Hz in-phase and quad-phase recordings**
  - **~ 80 MByte science data volume/day**
  - **Potential to implement open-loop**
- **ACES orbit at ~52°**
  - **Complementary to missions, e.g. , CHAMP Allowing observations in the tropical region**
- **Zero-differencing technique**
  - **Usage of ACES clock signal**
  - **Requirement:
known GNSS satellite and receiver clock bias**

GNSS reflectometry





- **Coherency is preserved at grazing incidence (elevations ~ < 5°)**
  - **50 Hz in-phase and quad-phase recordings**
  - **~ 80 MByte science data volume/day**
- **Phase interference can be converted to relative height variations of the reflecting surface**
  - **Relative height precision ~ some decimeter**
- **Sensitive to atmospheric and ionospheric disturbances**
  - **Usage of ACES clock signal**
  - **Requirement:**
    known GPS and receiver clock bias

Design & Implementation of reflectometry under development

Time-tagged samples at a rate of 50Hz (target 100Hz)

- Direct GNSS signal NCO carrier phase (32-bit integer) in L1/E1-band
- Direct GNSS signal In-phase (I) (16-bit integer) in L1/E1-band
- Direct GNSS signal Quad-phase (Q) (16-bit integer) in L1/E1-band

- Direct GNSS signal NCO carrier phase (32-bit integer) in L2 or L5/E5a-band
- Direct GNSS signal In-phase (I) (16-bit integer) in L2 or L5/E5a-band
- Direct GNSS signal Quad-phase (Q) (16-bit integer) in L2 or L5/E5a-band

- Reflected GNSS signal In-phase (I) (16-bit integer) in L1/E1-band
- Reflected GNSS signal Quad-phase (Q) (16-bit integer) in L1/E1-band

- Reflected GNSS signal In-phase (I) (16-bit integer) in L2 or L5/E5a-band
- Reflected GNSS signal Quad-phase (Q) (16-bit integer) in L2 or L5/E5a-band

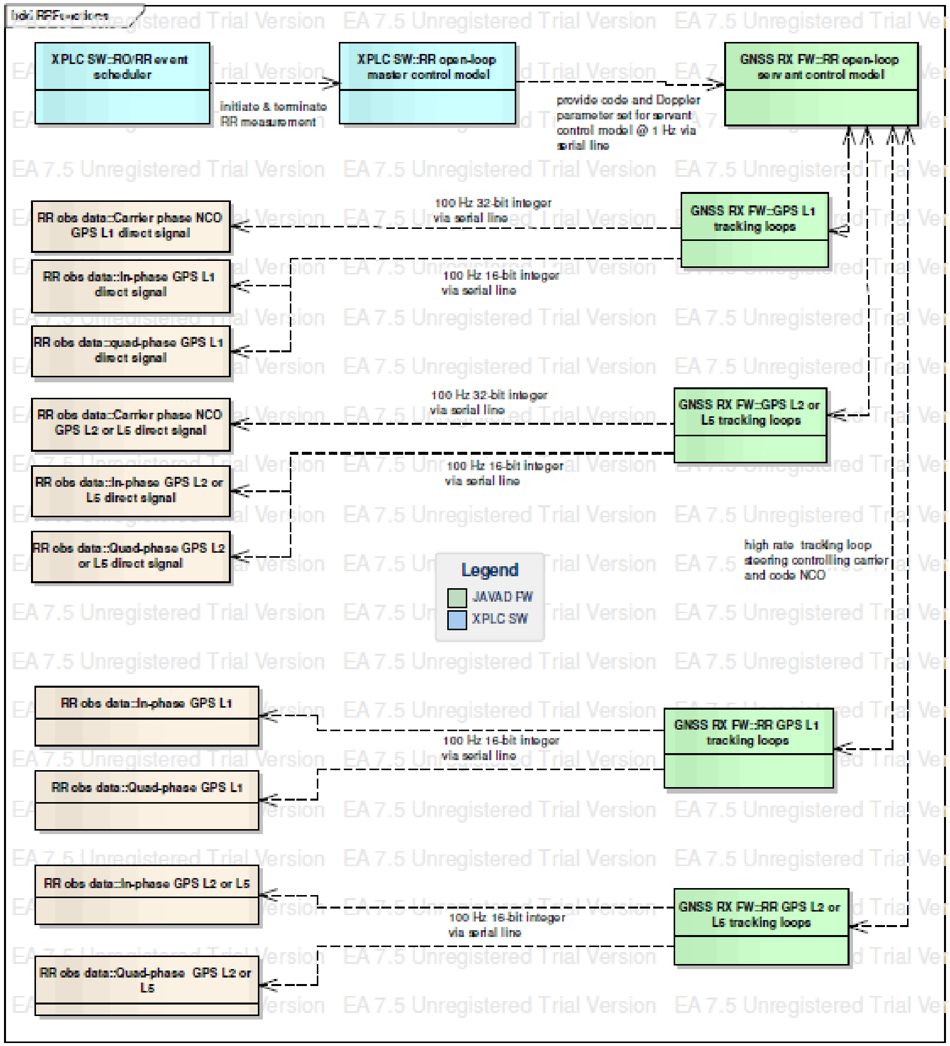


Fig. 13 Example of 2-frequency (L1-L2 or L1-L5) GPS coherent reflection open-loop measurement principle

ASTRIUM
AN EADS COMPANY

bottleneck: serial line receiver ←→ XPLC

GNSS RO/RR data type	RS422 serial line transfer load (RX)
RO with ACES clock reference L1-L2-L5 at 100Hz	58%
RO with Reference Link L1-L2 or L1-L5 at 100Hz	81%
RO with Reference Link L1-L2 or L1-L5 at 50Hz	45%
RR with L1-L2-L5 at 50Hz	52%
RR with L1-L2 or L1-L5 at 100Hz	59%

TO52

Summary

- The ACES antenna setup offers ideal conditions for reception of coherently reflected GNSS signals.
- The ISS orbit and ACES antenna positioning permits rising and setting radio-occultation observations with a focal point on tropical regions complementary to existing satellite missions.
- 2-frequency radio occultation (RO) and radio reflectometry (RR) remote sensing can be realized based on ACES Baseline design and hardware.
- Implementation of RO and RR functionality is limited to XPLC SW and JAVAD RX FW modifications.
- In parallel to ACES continuous POD measurements several daily RO and RR measurements can be scheduled
- 2-frequency phase and amplitude information of GPS or Galileo signal to capture the characteristic phase and amplitude changes are sampled at 50Hz (target 100Hz) during a scheduled RO event or RR event. Data rate is limited by serial line data transfer rate of max. 38.4 Kbit/sec.
- Open-loop functionality of ACES JAVAD RX FW grounds on GFZ developments done in GITEWS project
- working on a dedicated precalculated delay/Doppler model for RO and RR applications which controls open-loop functionality

Invitation to participate in ACES international working group (IWG)