ETH zürich

Requirements for CubeSats: the Astrocast CubeSat Mission

Markus Rothacher[1], Michael Meindl[1], Marcel Joss[2], Erich Styger[2]

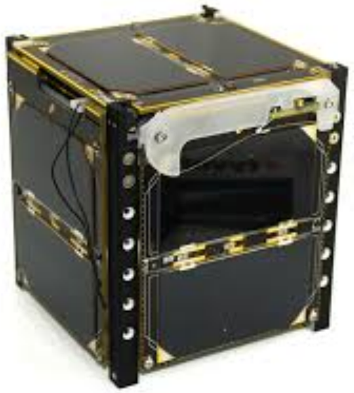
[1] ETH Zurich, Institute of Geodesy and Photogrammetry, Switzerland
[2] HSLU, Lucerne University of Applied Sciences and Arts

Overview

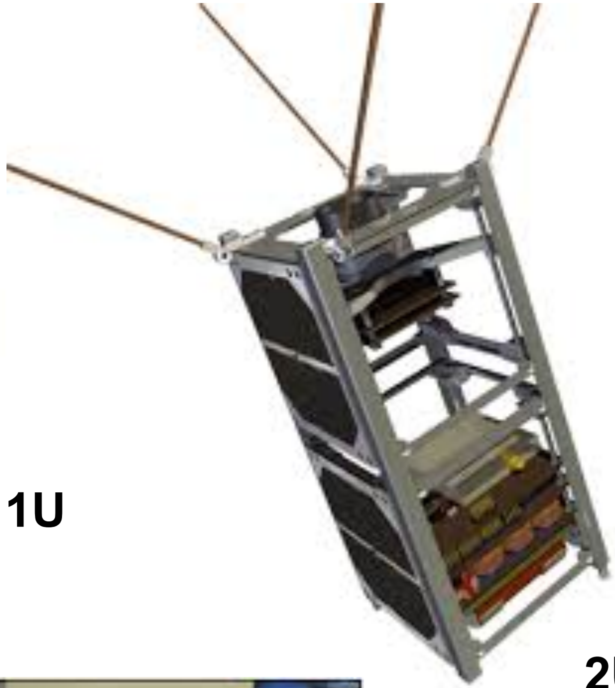
- Introduction: cube satellites
- Requirements for SLR observations and corner cubes
- Example: Astrocast Mission
- Mission Goal: Orbit Determination with low-cost GNSS
- SLR Orbit Validation
- Conclusions and Outlook

Introduction: Cube Satellites

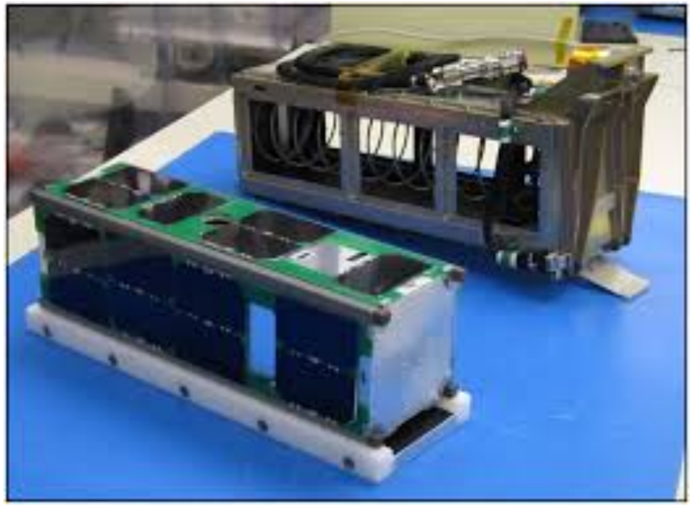
- **Standard for nano-satellites**
- Defined in 1999 by California Polytechnic State University (Cal Poly) and Stanford University
- **1 unit (1U) Cube Satellite:**
  Size: cube of 11.35 cm × 10 cm × 10 cm
  Weight: max. 1.33 kg
- **2 units (2U) Cube Satellite:**
  Size: 22.7 cm × 10 cm × 10 cm
  Weight: max. 2.66 kg
- Today cubesats may have **6, 12, 27 units**
- Usually **COTS** components are used
- Mainly used for **in-orbit demonstrations**



1U



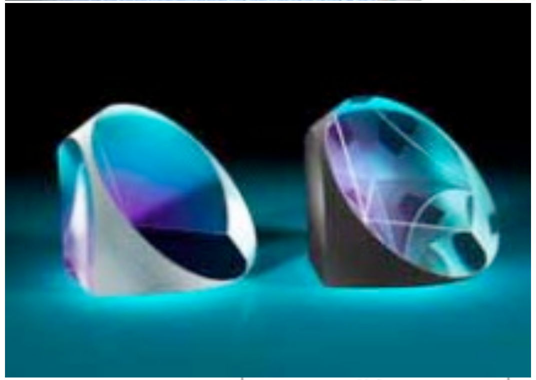
2U

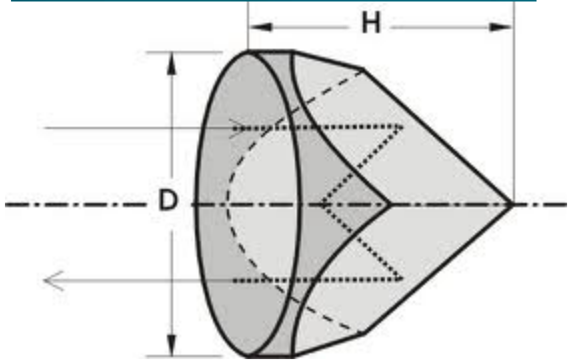


3U

SLR Requirements for CubeSats

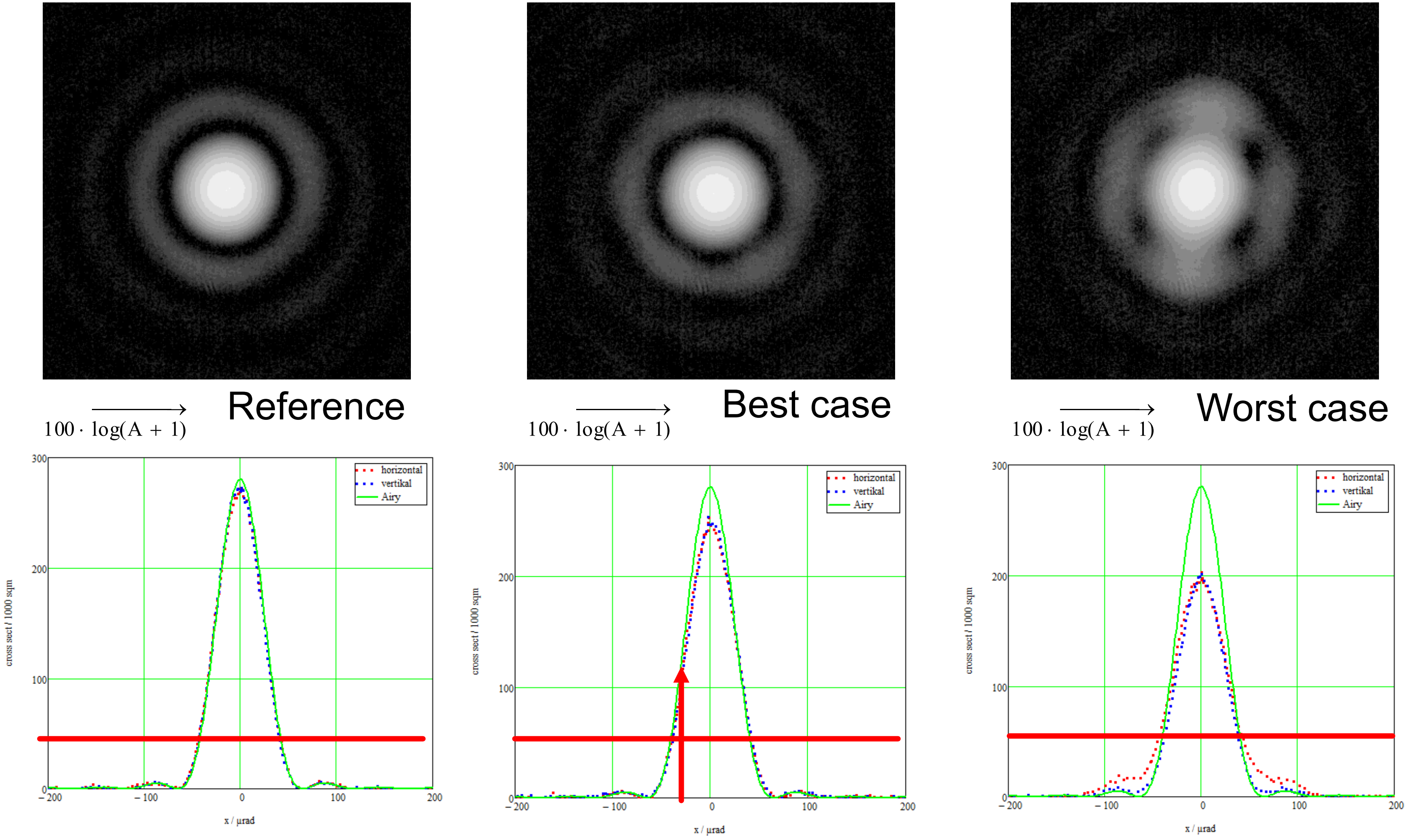
- Very **limited space** for retroreflectors, most surfaces for solar cells
- Aberration angle to be compensated **~25-50 µrad** (5"-10")
- Effective cross section should be about **50'000 m²** at aberration angle
- Use of **small 10 mm diameter prisms,** coated on the back
- Available from:
  - **Hengrun Optoelectronics Tech. Co., accuracy ±3", price € 60.-**
  - Stock Optics Ltd, UK, accuracy ±3", price €135.-
- For non-stabilized cubesats, at least one retroreflector on each surface





Retroreflector Quality Test (Ludwig Grunwaldt, GFZ)

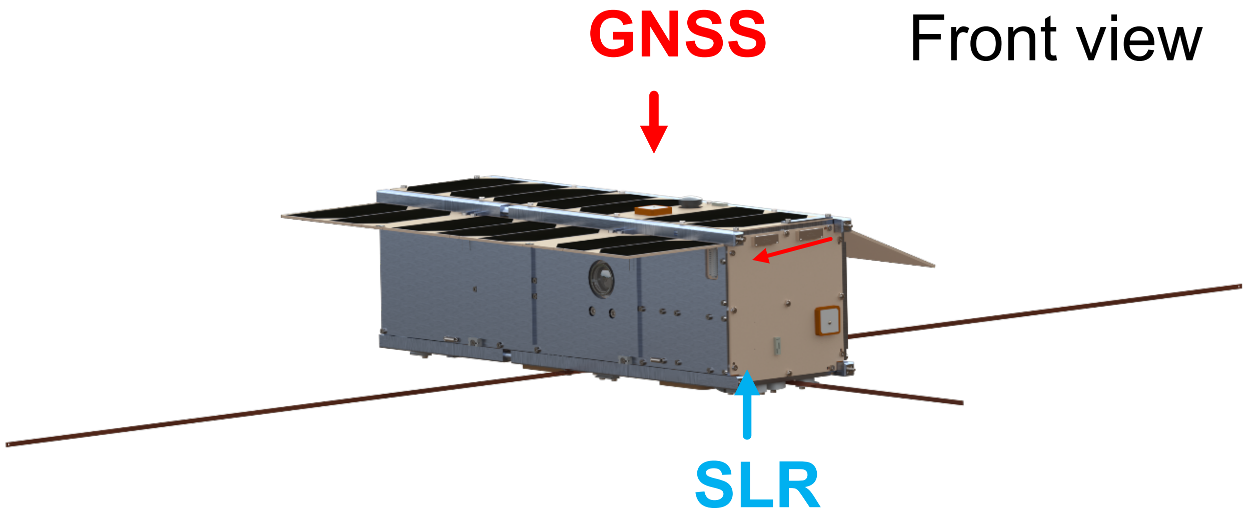
- Laboratory setup at GFZ Potsdam
- Far Field Diffraction Pattern (FFDP) images obtained
- 10 retroreflectors were tested
- Only 1 bad piece detected



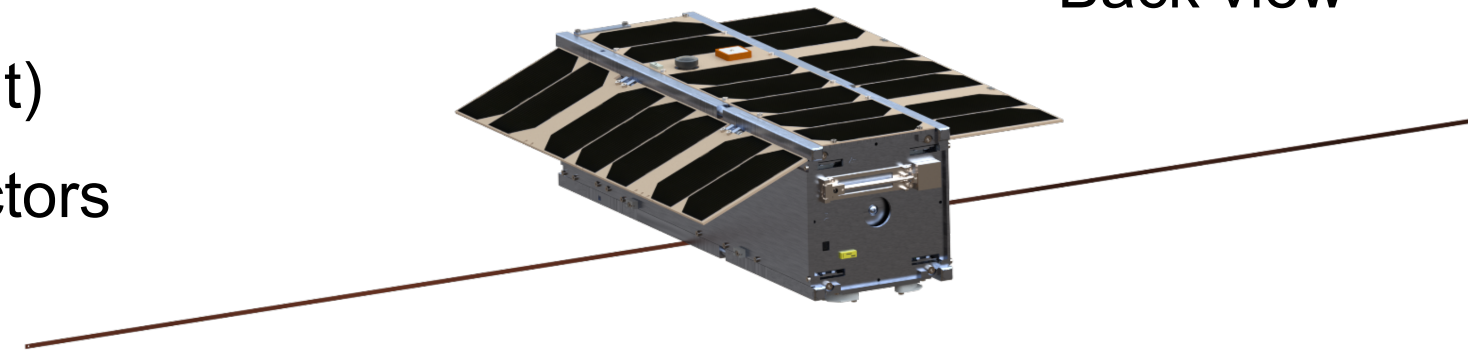
Astrocast Satellite

- 3-Unit CubeSat
- Sun-synchronous orbit at 575 km height
- Full attitude control
- Propulsion system
- S- and L-band downlink
- 2 GNSS antennas (top and front)
- Mounting with 3 SLR retroreflectors
- Launch: June 2018

Front view

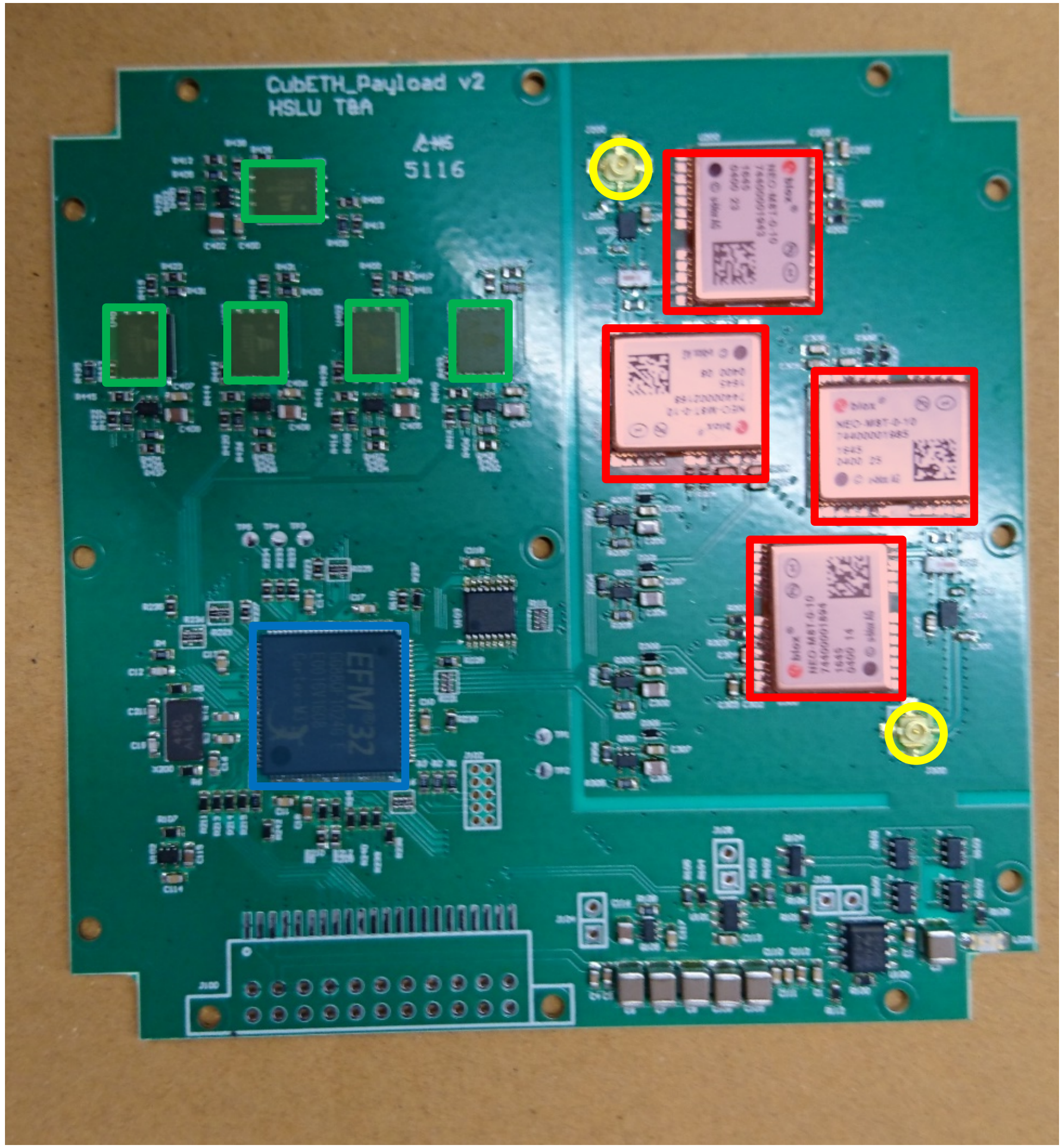


Back view



GNSS Payload Board

- 4 u-blox single-frequency multi-GNSS receivers (low-power, low-weight, inexpensive; redundancy)
- 2 antenna HF inputs (top, front antenna), two receivers per antenna
- 2.5 MB MRAM onboard memory
- ARM Cortex-M3 CPU
- Latchup protection
- Major task: space environmental tests (radiation, vacuum, temperature, …)

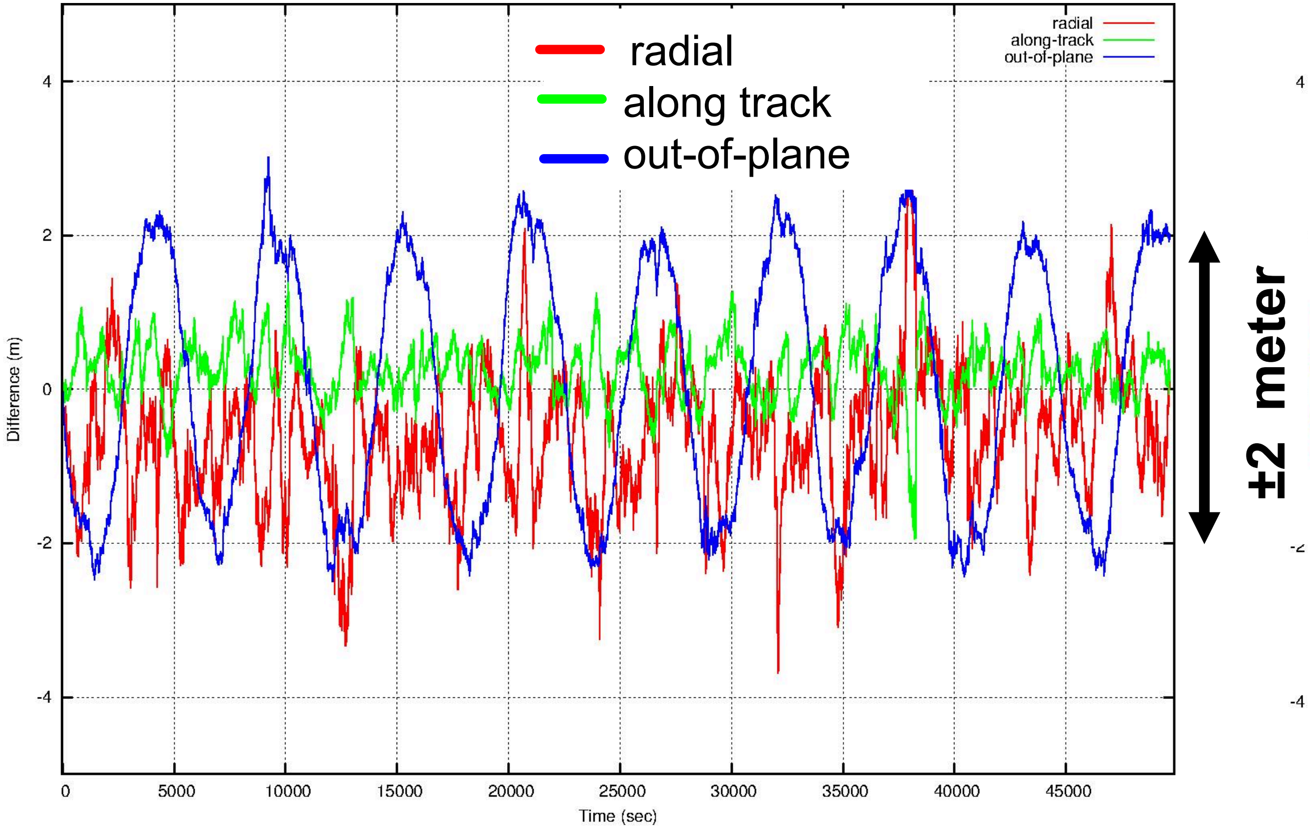


Mission Goals with GNSS Payload

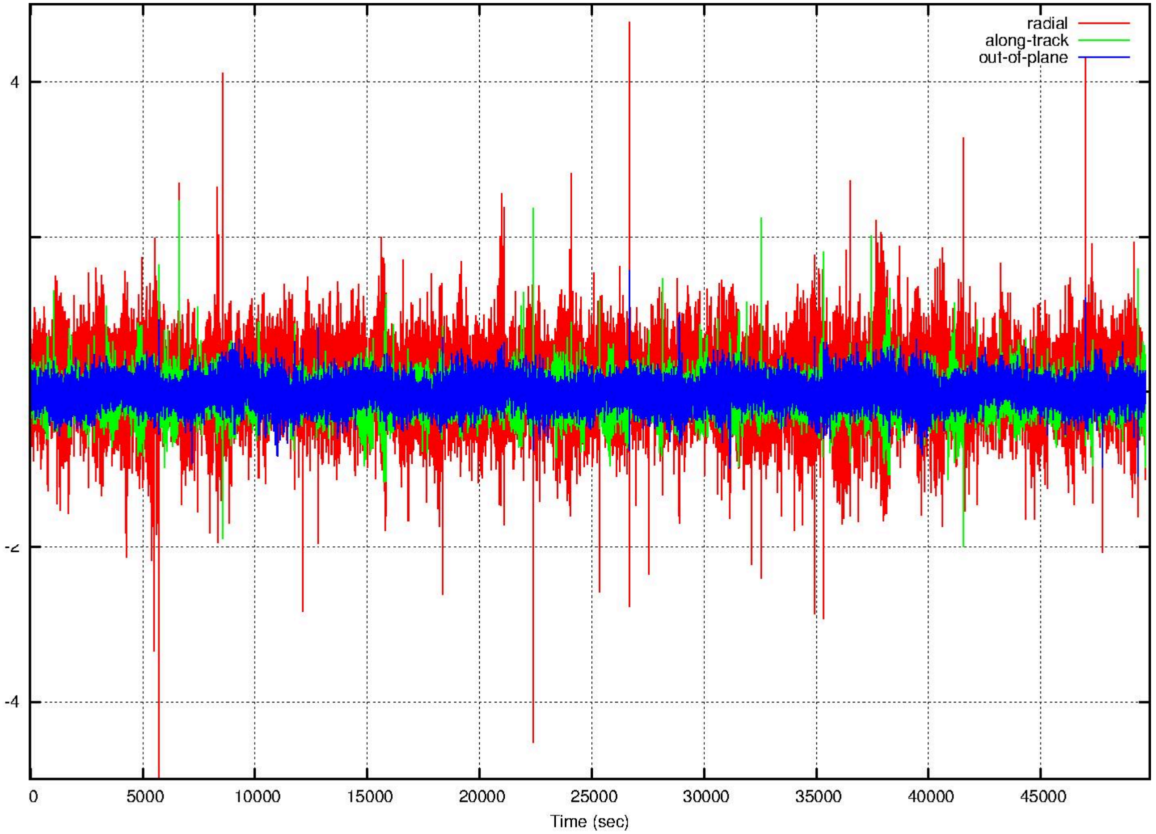
- First **multi-GNSS receiver** in space: GPS, GLONASS, Galileo, Beidou, QZSS
- **Precise orbit determination** with COTS-based **single-frequency receiver**
- **Compare the orbits** derived from different GNSS
- **Validation of the orbit accuracies with SLR**
- Validation of propulsion system
- Sidewise-looking antenna: S/N analysis at low elevations (occultation scenario)
- Short baseline in space: antenna phase center calibrations, multipath
- Keep in mind: main error sources are ionospheric refraction and broadcast satellite orbits and clocks (2-3 m)

Orbit Determination: GPS Signal Simulator Tests

u-blox navigation solution. The out-of-plane component is affected by a 1/revolution error.

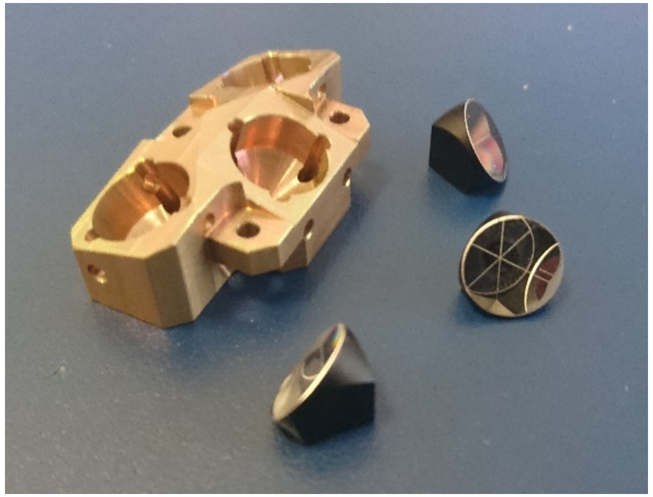


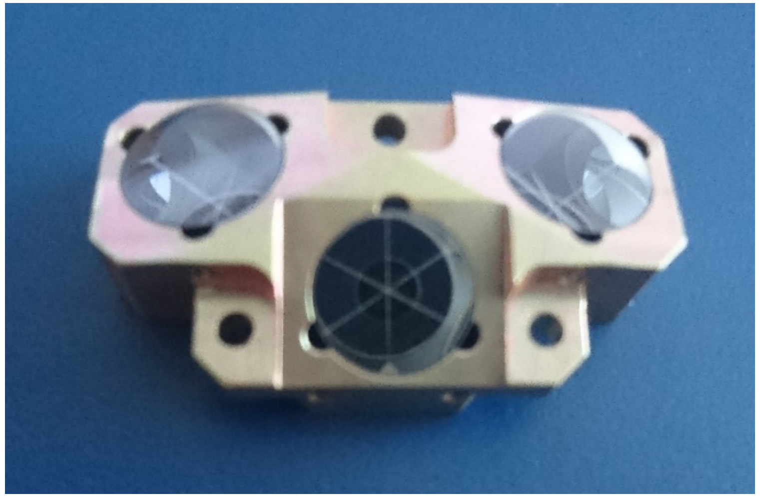
Code solution computed with Bernese out of signal simulator raw data. The RMS is 0.44 m (radial), 0.21 m (along-track) and 0.15 m (out-of-plane).

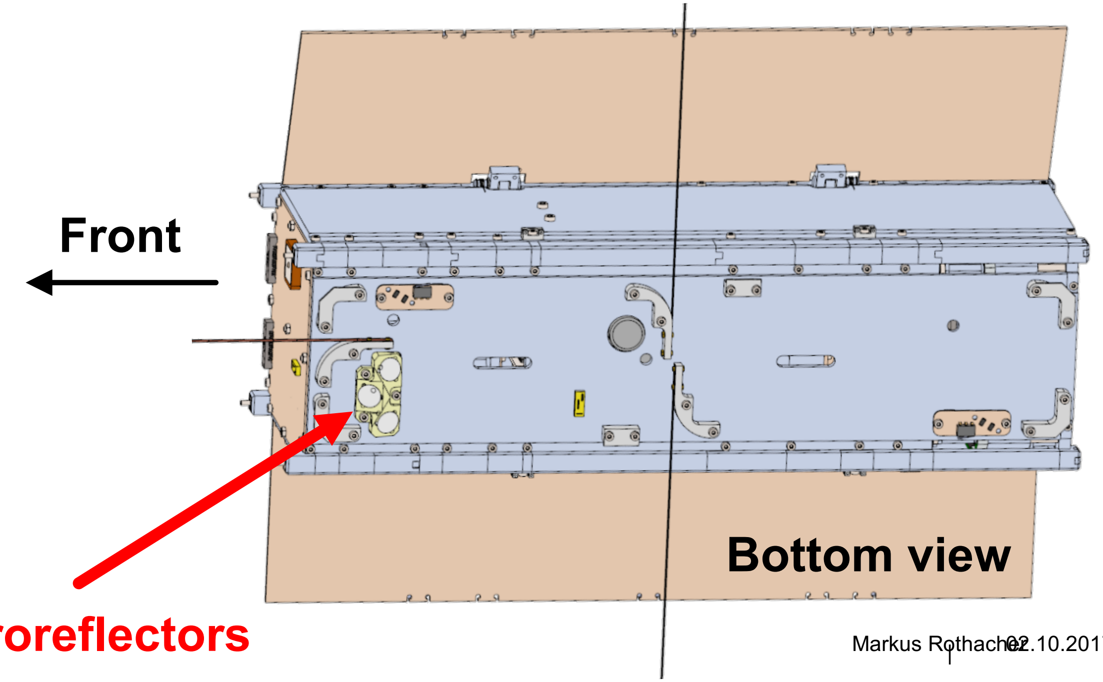


Laser Retroreflectors

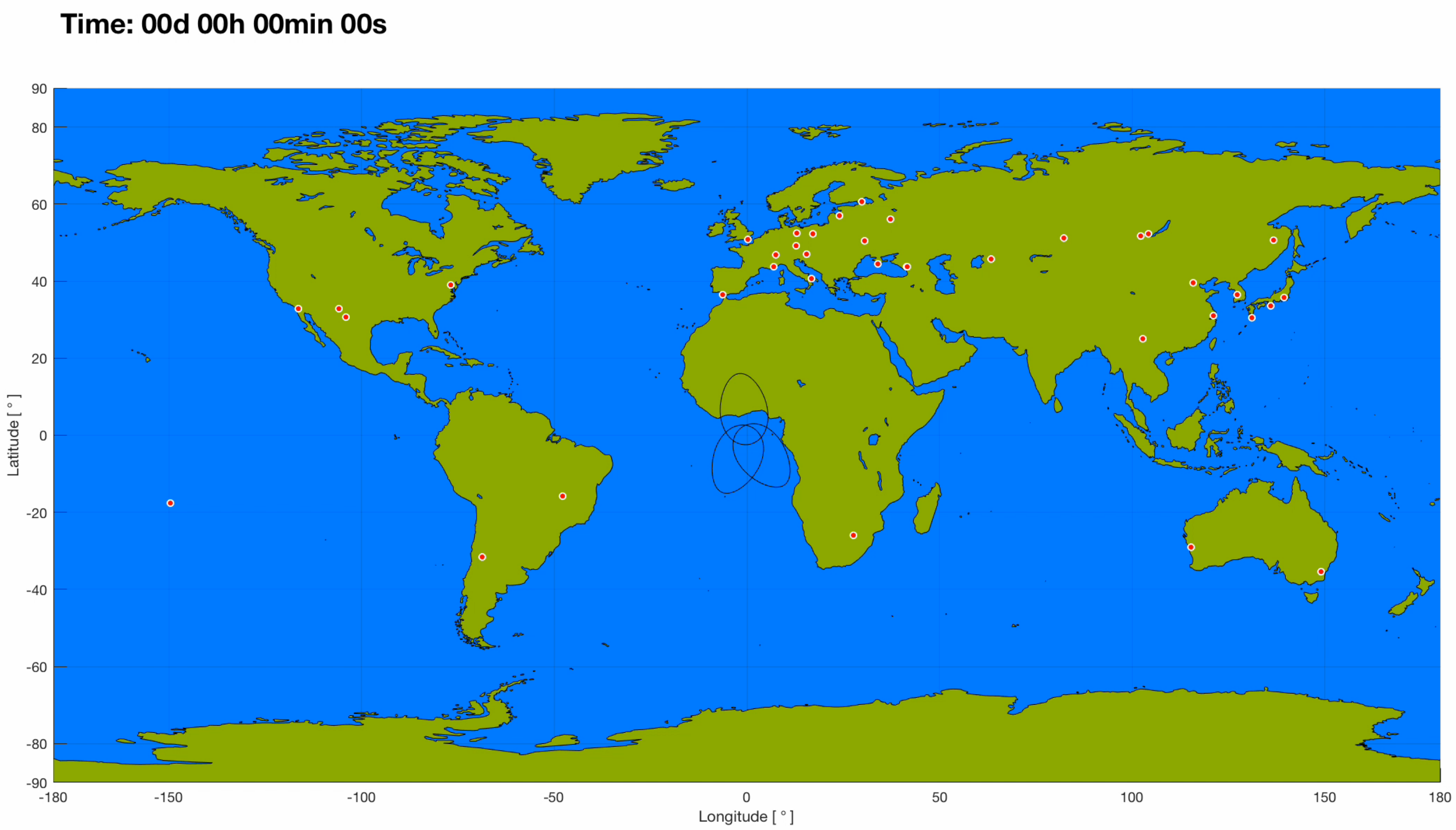
- Mounting for three corner cubes
- One front-looking reflector
- Two side-looking reflectors
- Inclination 20° w.r.t. to surface normal
- 1 cm diameter
- JGS1 optical glass







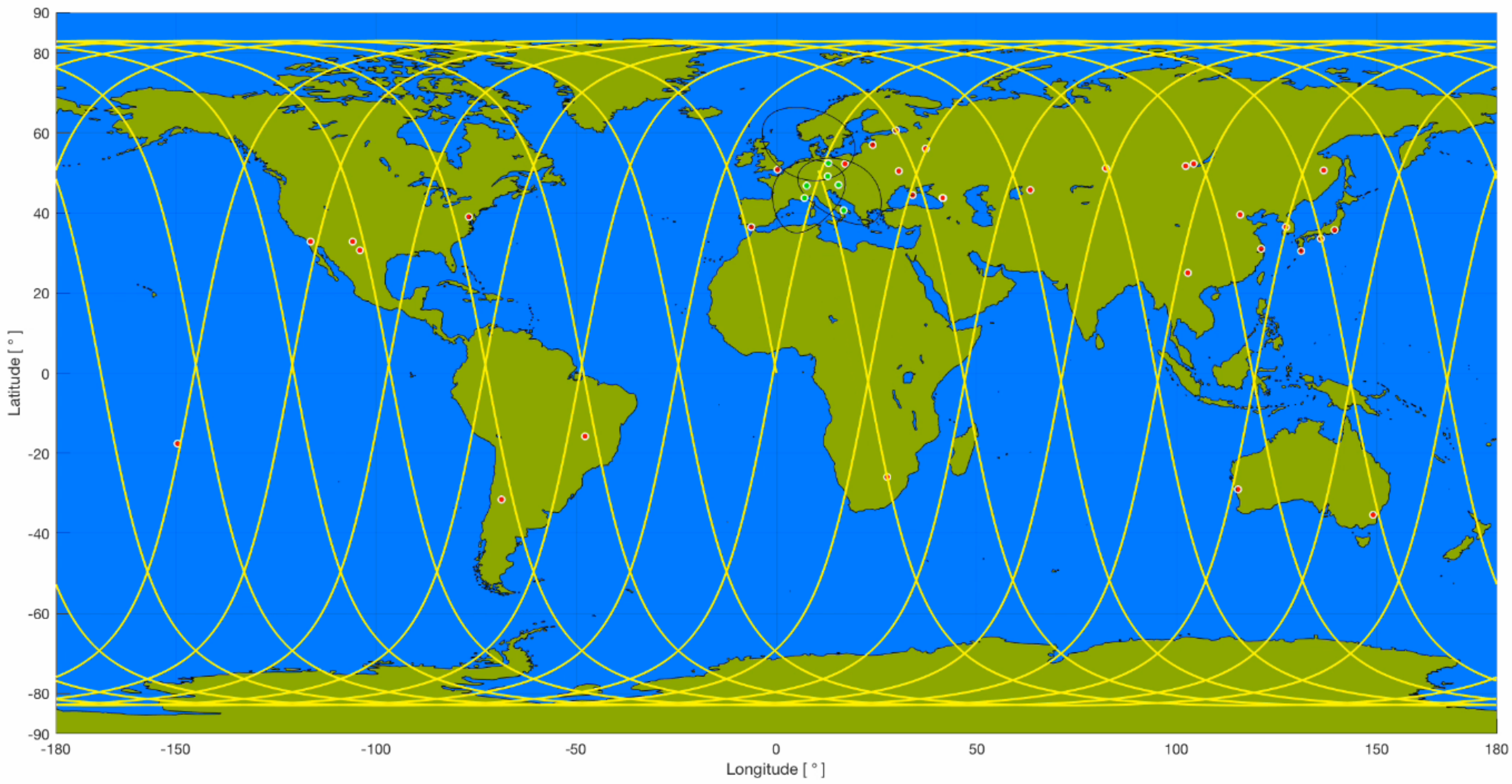
SLR Satellite Visibility Simulation



Satellite visible from:

ILRS

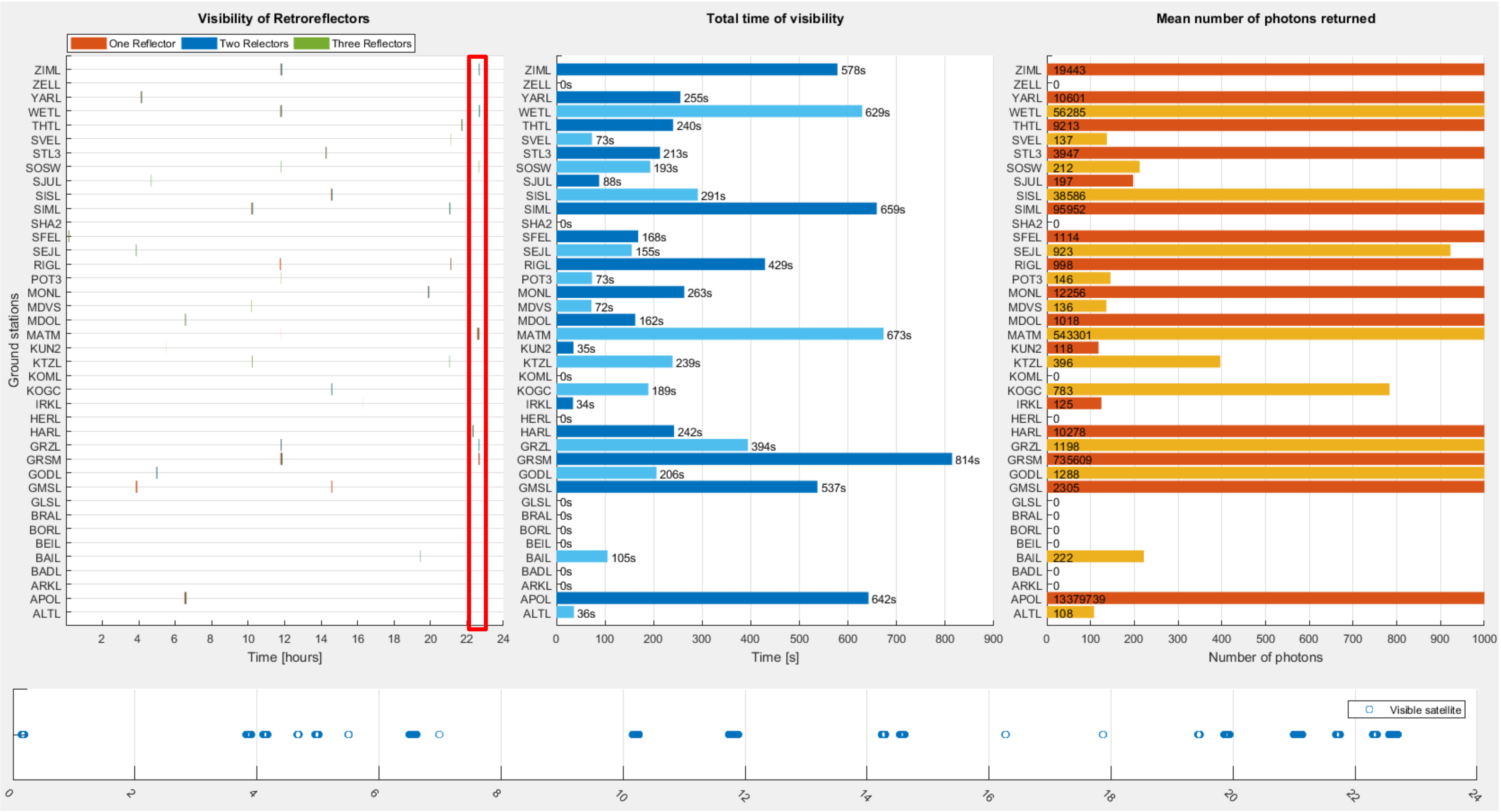
SLR Satellite Visibility Simulation: 22:40



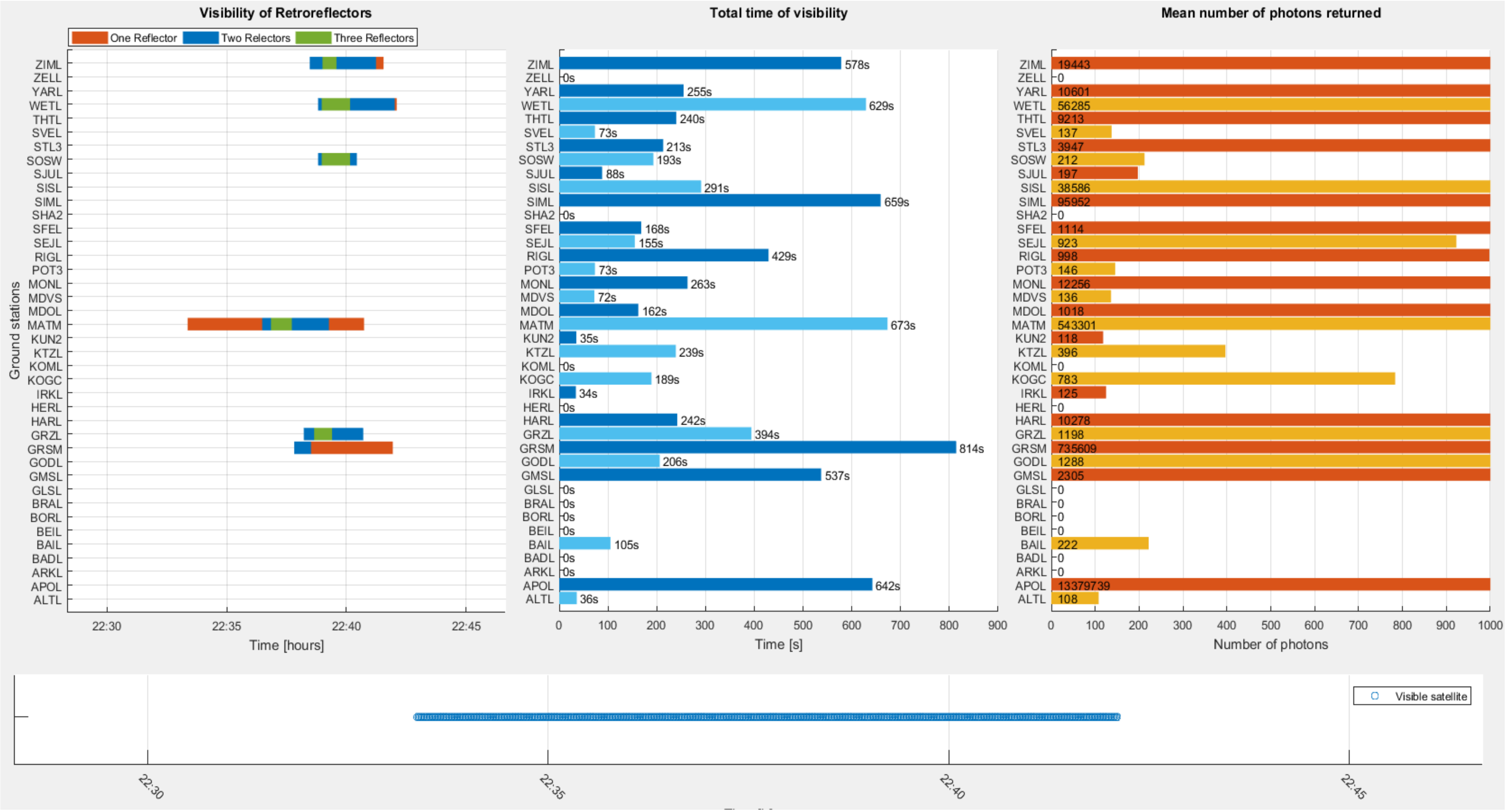
Satellite visible from:

12. GRSM
13. GRZL
21. MATM
25. POT3
33. SOSW
37. WETL
40. ZIML

SLR Satellite Visibility Simulation: 1 Day



SLR Satellite Visibility Simulation: 22:30 – 22:45



Conclusions and Outlook

Conclusions:

- CubeSats become more and more important
- Constellations with up to 4000 satellites planned; Astrocast: constellation of 40 satellites
- CubeSats can be tracked with SLR using 10 mm prisms
- **We hope that the ILRS will help to validate the Astrocast multi-GNSS satellite orbit**

Outlook:

- Present mission is only the first step

- Soon **dual-frequency COTS GNSS receivers** will become available
- **cm-level orbit determination** (post-processing) for any satellite

- Already **COTS GNSS Real-Time Kinematic (RTK) receivers** are available (e.g. from u-blox)
- **mm-level relative positioning** between satellites (formation flying, constellations)