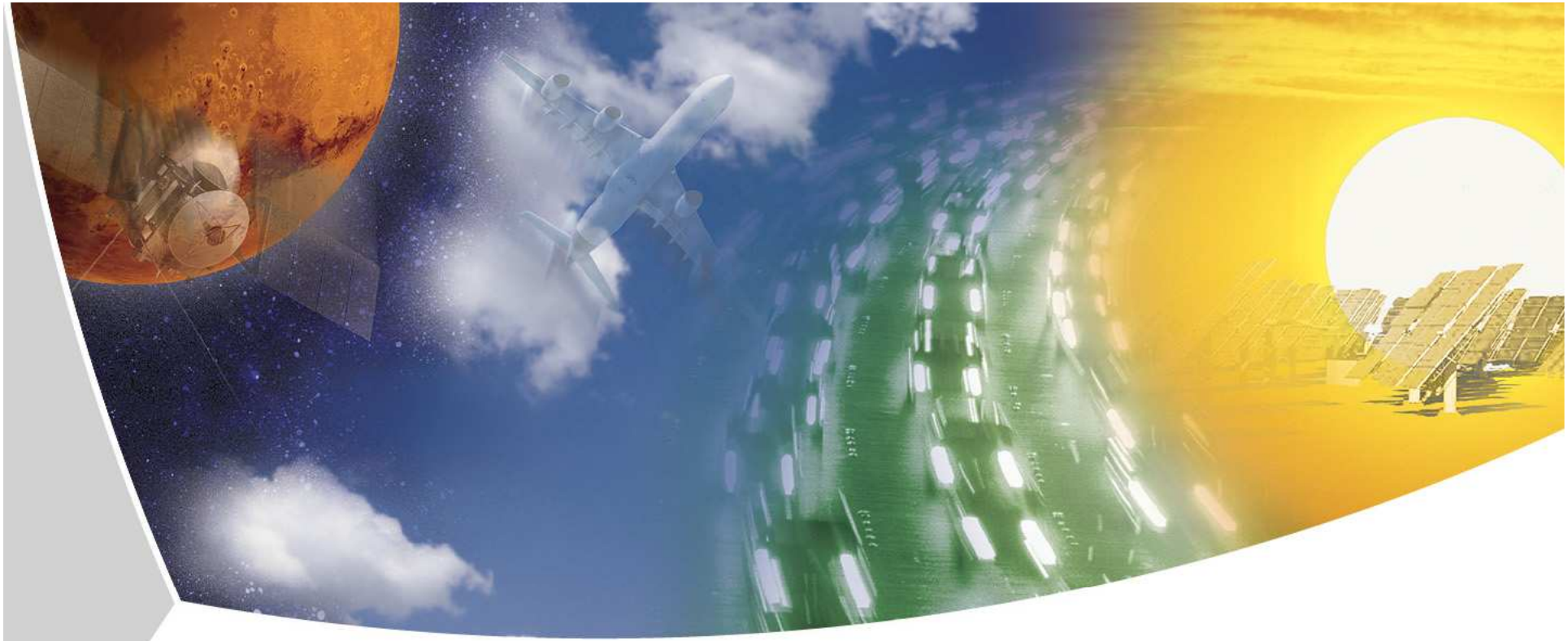


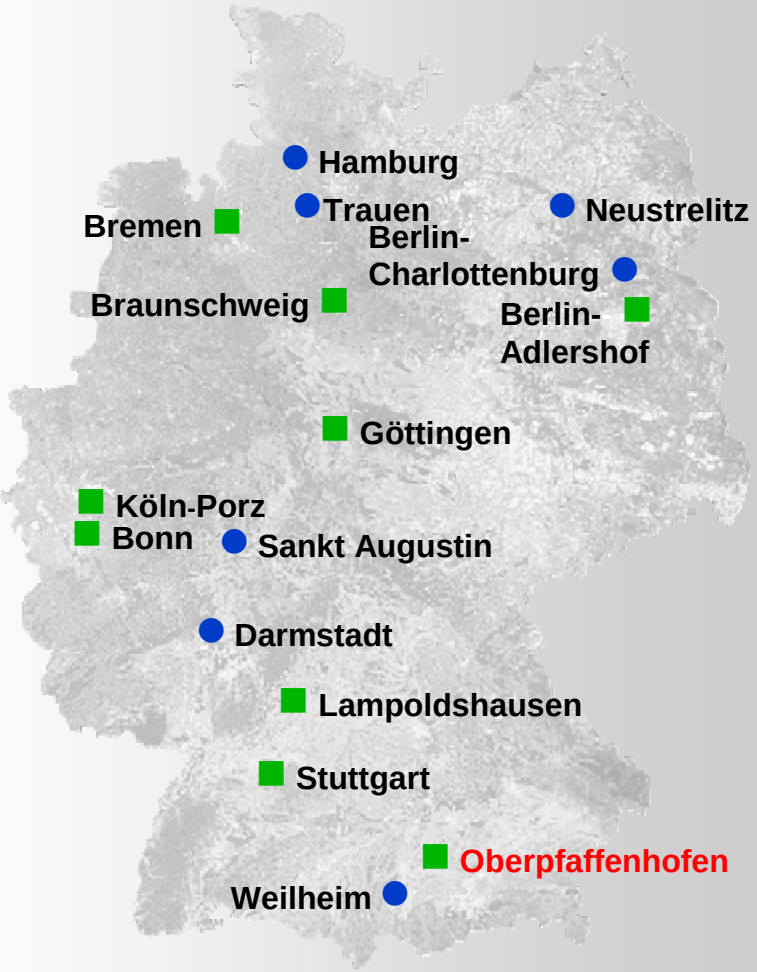
Spaceborne GNSS at DLR/GSOC

O.Montenbruck

German Space Operations Center, DLR

Organization

- DLR (German Aerospace Center)
  - Aeronautics, astronautics, energy, and transport research
  - National Space Agency
  - ~5100 employees in 28 institutes
  - 9 centers, 7 field offices
- German Space Operations Center
  - Located at Oberpfaffenhofen (25 km west of Munich)
  - Control center for unmanned and manned space missions
- GNSS Technology & Navigation
  - Spaceborne GNSS
  - Receiver design and testing
  - Autonomous navigation systems
  - Formation flying



Facilities

GSOC Oberpfaffenhofen

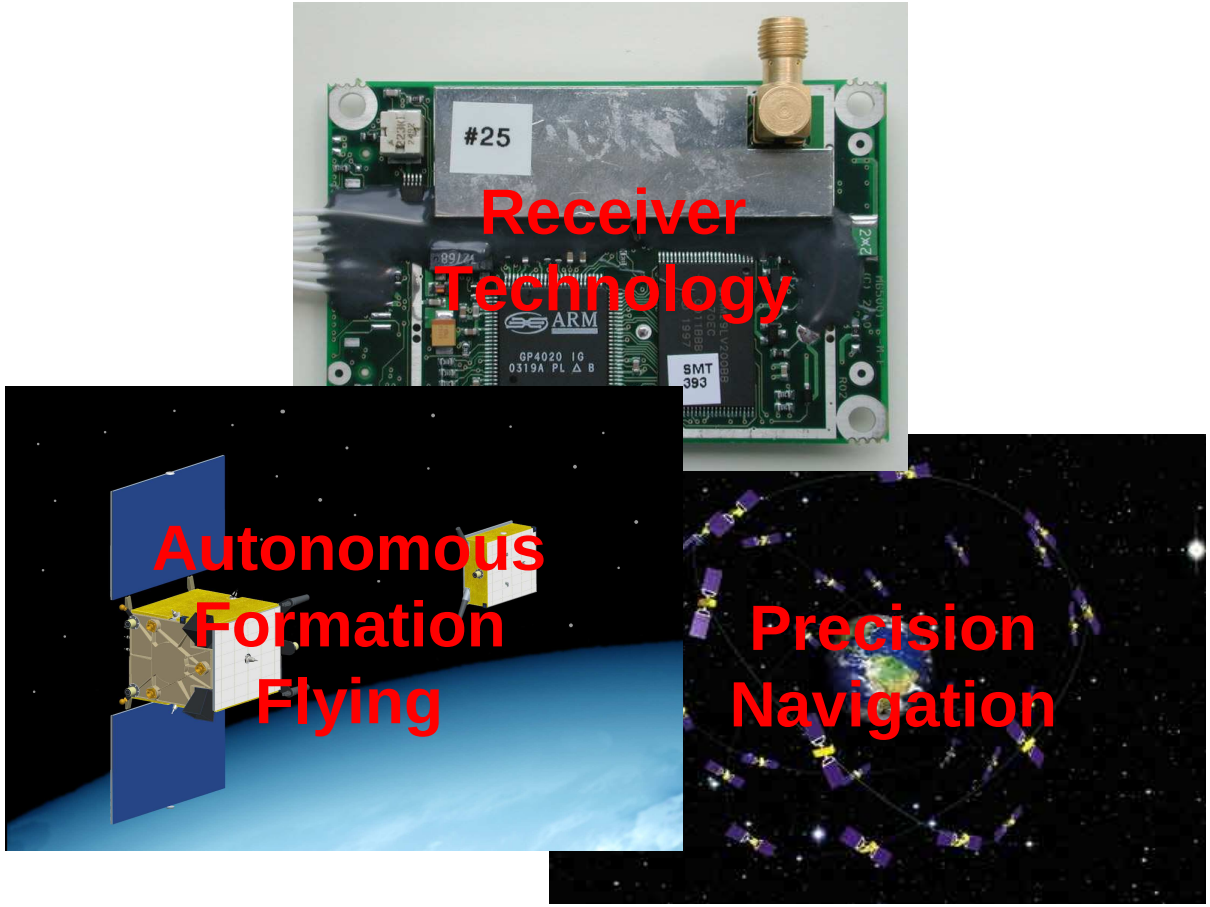
Control room
(Columbus)

Weilheim
ground station

Galileo control center

EAC, MORABA, MUSC

Research Areas

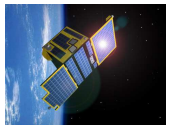


Roadmap Receiver Techology

„Affordable access to spaceborne GNSS technology“

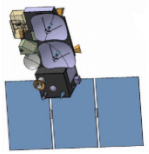
2005 | 2007 | 2009 | 2011 | 2013

Phoenix Miniature GPS



PROBA-2

Embedded Real-Time Navigation

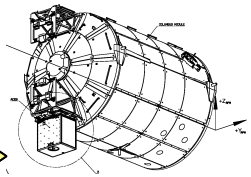


Sentinel-3
SHEFEX-2

Low Budget Science Receivers

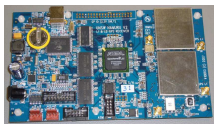
OOV On Orbit Verification

ACES



GNSS Reflectometry

Namuru



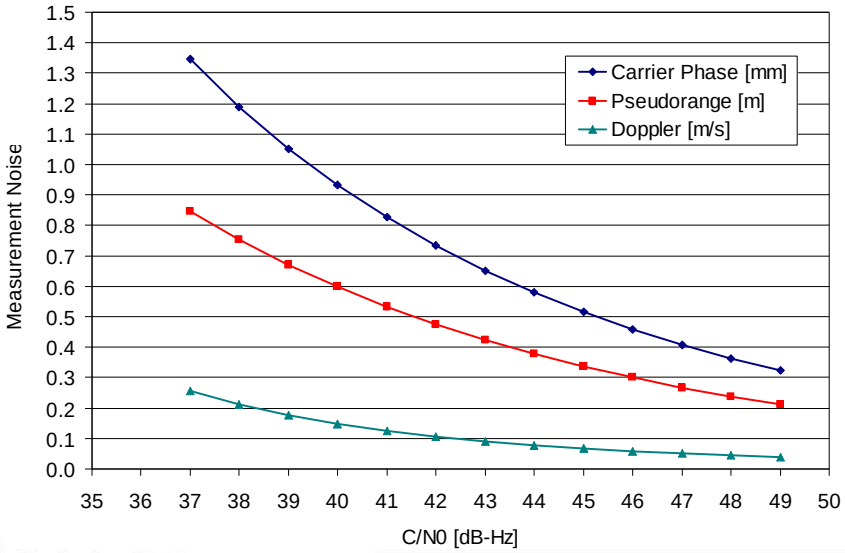
Software Defined GNSS Receiver

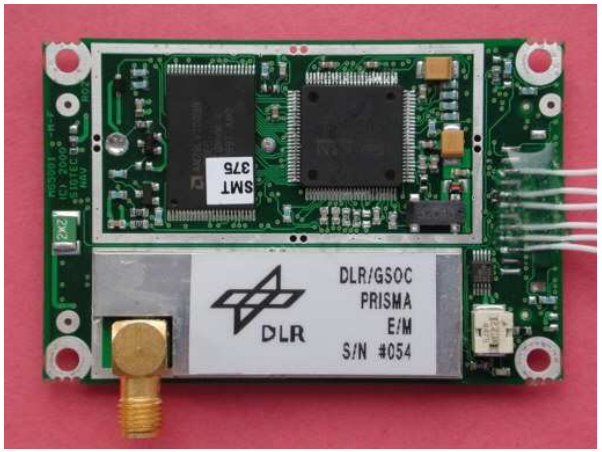
Receiver and Navigation System Support

Receiver Performance Assessment

Phoenix GPS Receiver

- SigTech MG5001 board
- 75 x 50 x15 mm
- 0.8W @ 5V regulated
- 14 krad total ionization dose
- DLR tracking s/w for LEO satellites and sounding rockets

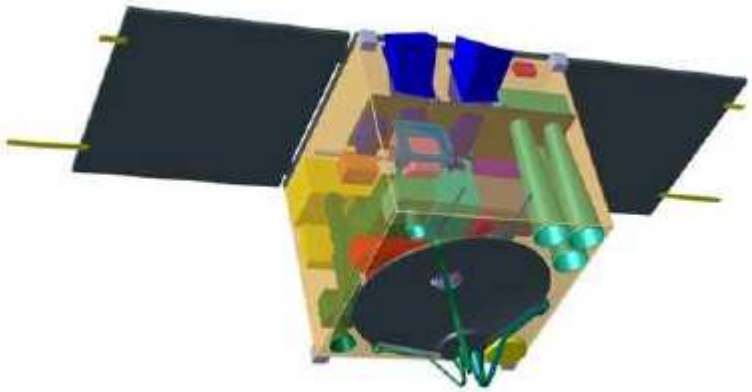




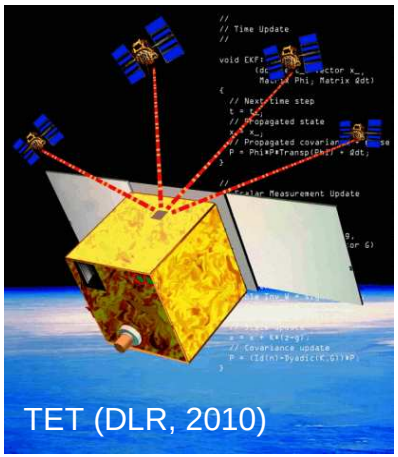
Mission Highlights

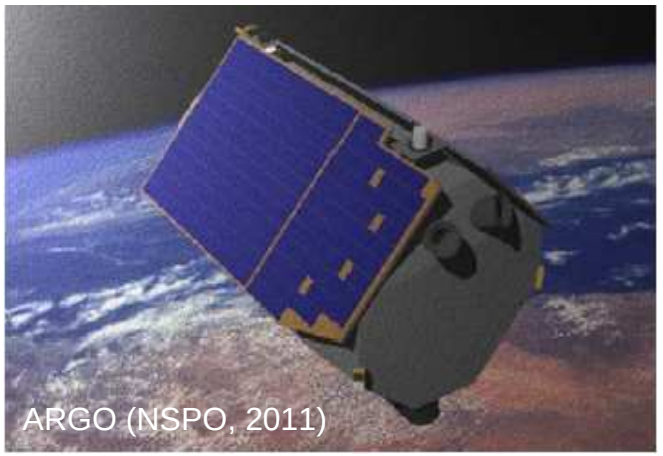

PROBA-2 (ESA, 2009)

MAST
COMPASS1

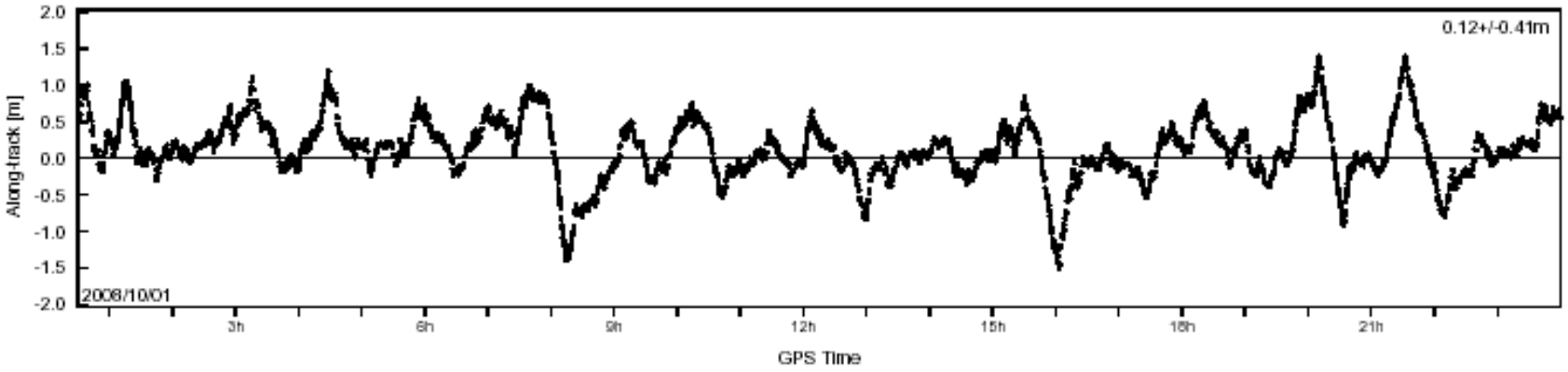

Flying Laptop
(TU Stuttgart, 2010)


X-Sat (NTU, 2009)


TET (DLR, 2010)


ARGO (NSPO, 2011)

Phoenix-XNS (eXtended Navigation System)



- Real-time Kalman filtering of GPS raw measurements
- Ionosphere-free C1+L1 combination
- Operates inside ARM7TDMI micro-processor of Phoenix receiver
- Example
  - 400 km LEO orbit, 10 TECU VTEC, 1.5m UERE ephemeris errors
  - 0.5-1 m 3D rms error

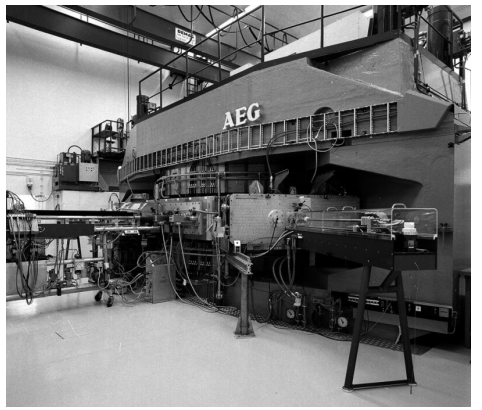
Testing of Spaceborne GNSS Receivers

Signal Simulator

Shaker

Thermal Vacuum Chamber

Co-60 Source



Proton Cyclotron

Roadmap Formation Flying & On-Orbit Servicing

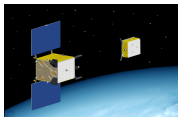
„Innovative GN&C concepts for multi-satellite missions“

2005 | 2007 | 2009 | 2011 | 2013

DGPS Navigation

Impulsive Orbit Control

PRISMA *TANDEM-X*

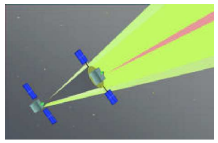


Autonomous Formation Flying

Mission Demonstrations

Self-contained Navigation Systems (RF, optical)

Optimum Distributed Orbit & Attitude Control

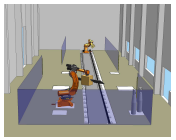


PROBA-3 ?

EPOS

ARDOS

Contact Dynamics

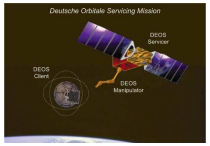


DEOS
SMART-OLEV

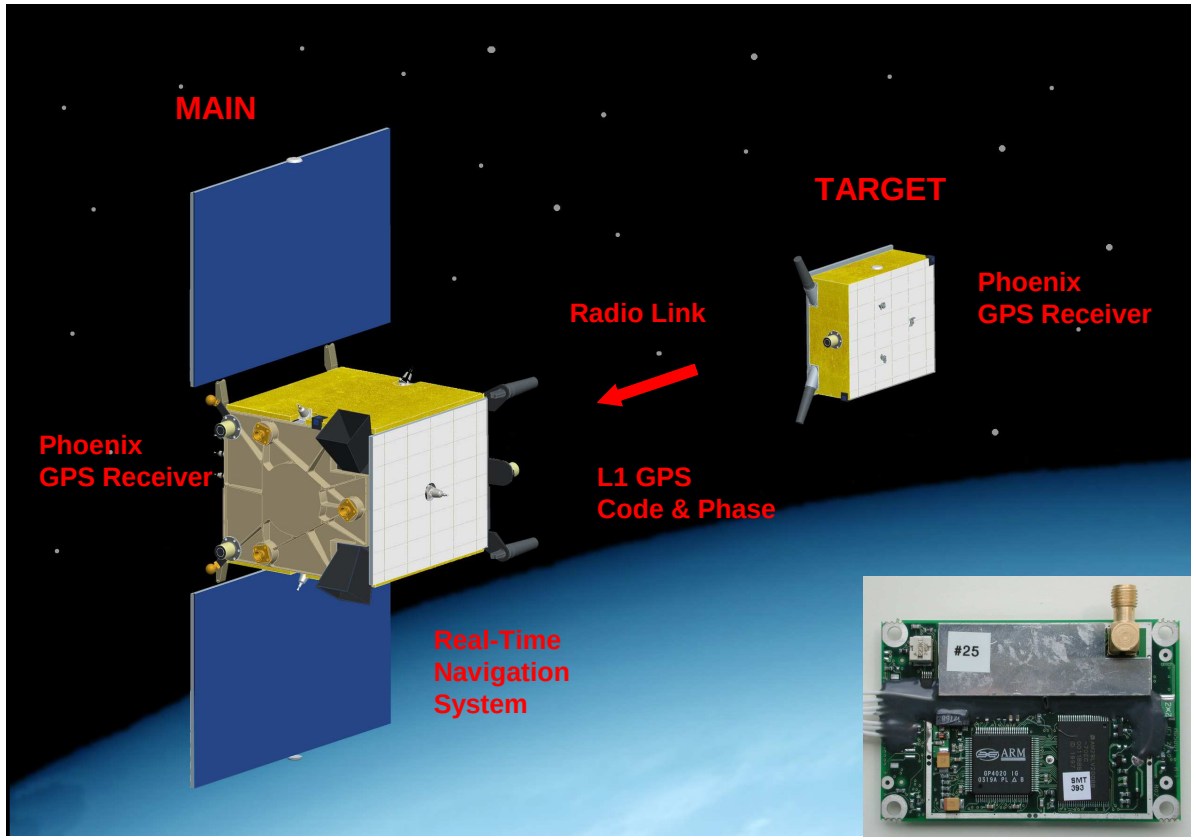
On-Orbit Servicing

Camera Based Navigation

GNC-System Support, Parameter Identifcation



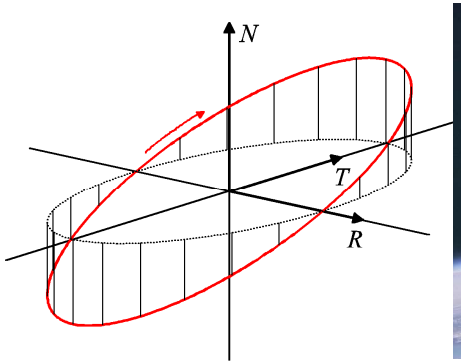
Autonomous Formation Flying – PRISMA (2009)



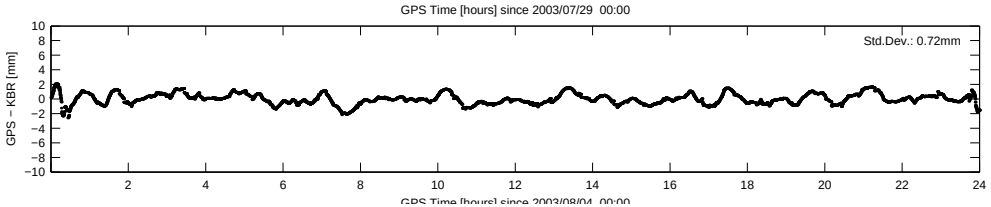
- SSC & Partners
- Demonstration RVD & Formation Flying
- Validation of Sensors, Actuators, Avionics
- Launch 2009

SAR-Interferometry –TanDEM-X (2009)

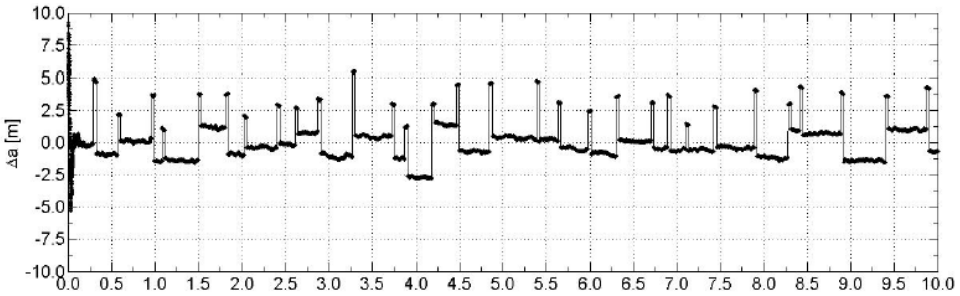
- Orbit Control
  - e/i-vector separation
  - Passive safety
  - Reproduction of TSX maneuvers



- Relative Navigation
  - IGOR GPS Receiver
  - 1 mm accuracy



- TAFF Experiment
  - Intersatellite Link
  - Real-Time Navigation
  - Autonomous Control



Roadmap Precision Navigation

„High Precision Navigation Services for Future Space Missions“

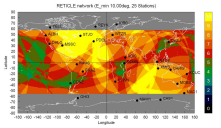
2005 — 2007 — 2009 — 2011 — 2013

Differential GPS Navigation of LEO Satellites

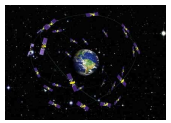
TanDEM

Prisma Satellites

Real-Time GNSS clock products

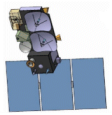


Galileo Signal Analysis & Data Processing



CONGO GNSS Receiver Network

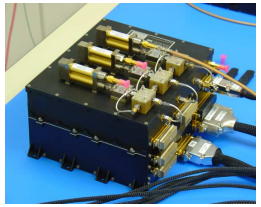
GPS based LEO POD, Near-Real-Time POD



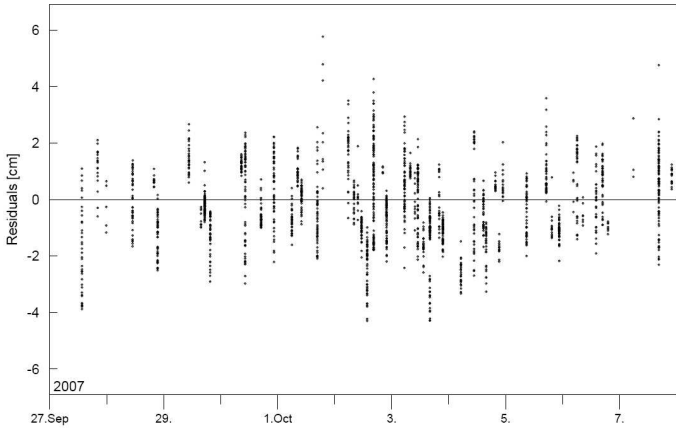
Sentinel, MetOp, SEOSAR

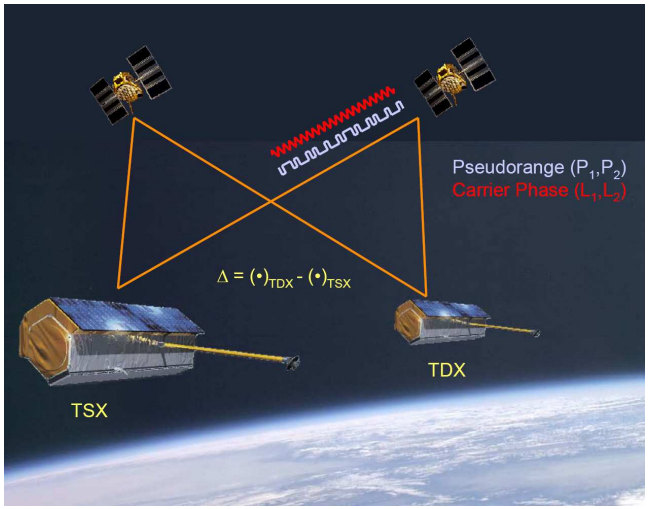
TanDEM-X Precision Baseline Reconstruction

- Identical set of IGOR GPS receivers on both s/c

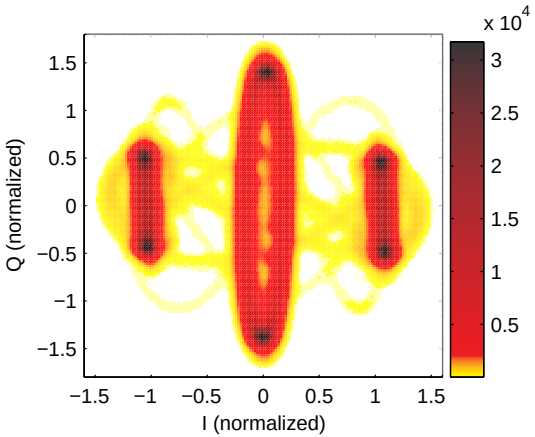


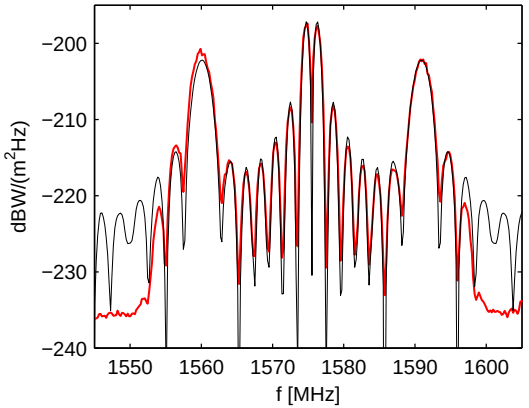
- Absolute orbits
  - ~5cm 3D rms position accuracy
  - 2.5 cm 3D rms DLR-AIUB
  - 1.5 cm SLR residuals (10° elev)
  - TDX-TSX position difference ~1-2 cm
- Relative navigation based on dual-frequency CDGPS
  - Kalman filter/smoother
  - Single differenced measurements
  - Single- or dual-frequency processing

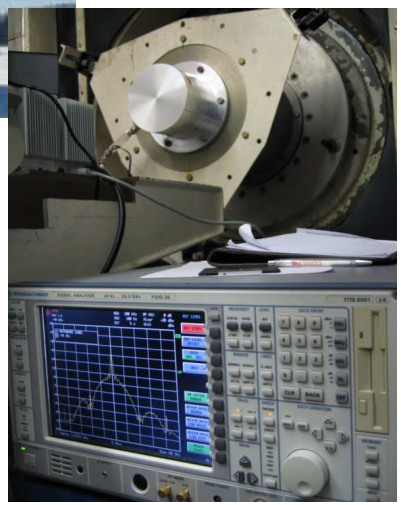


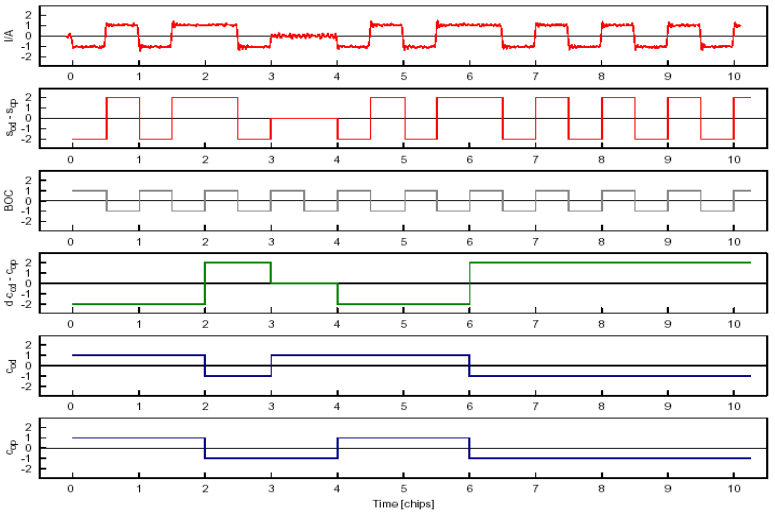


GIOVE-A Signal Analysis (2006)

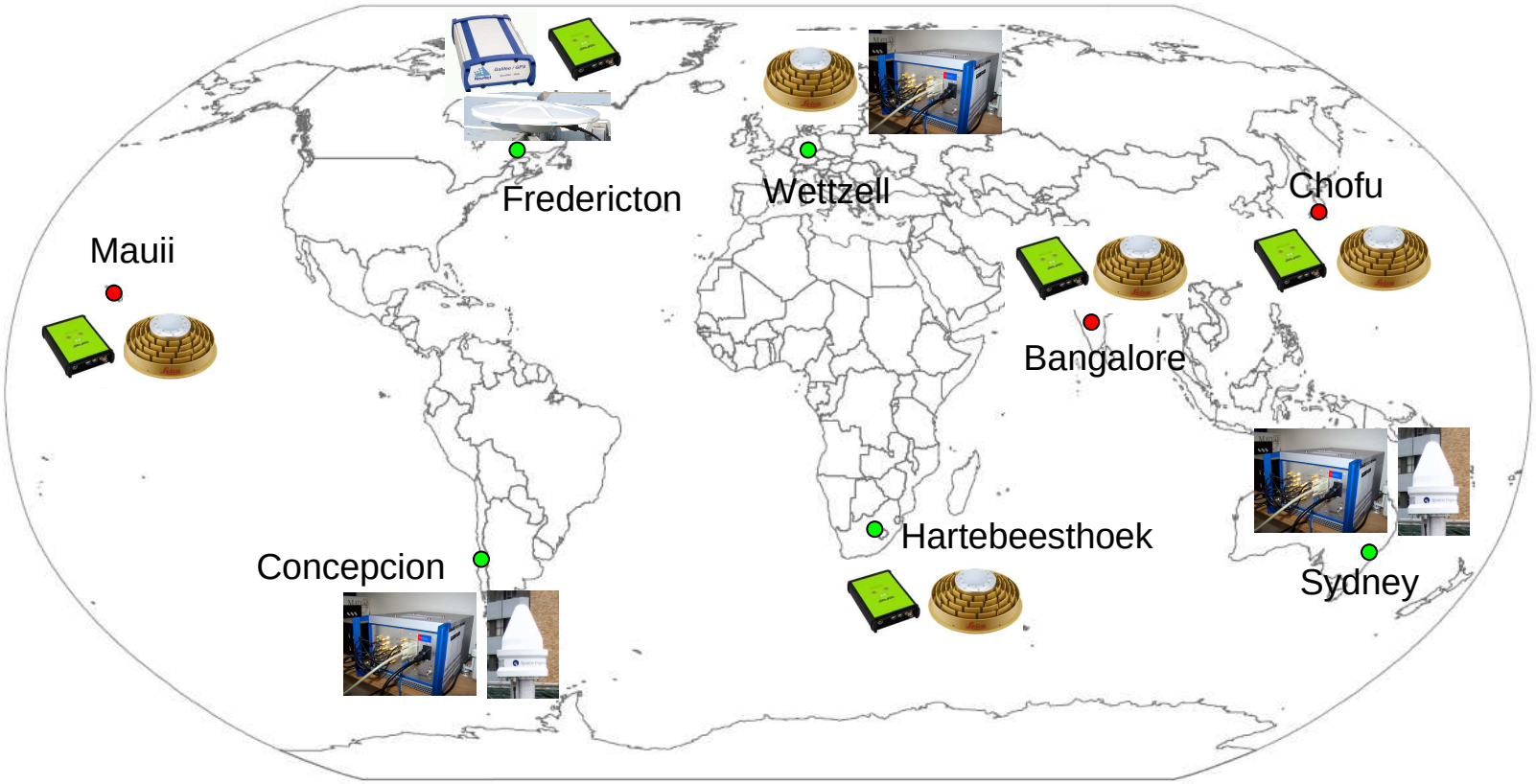








Cooperative Network for GIOVE Observation (DLR/BKG)



● operational ● under construction

Collaboration Options

- Technical
  - GNSS real-time network setup (NTRIP) and utilization (clocks, iono,integrity)
  - SLR based orbit determination of GNSS satellites
  - SLR/GNSS cross-comparison for LEO satellites
- Networking
  - Satellite Geodey at TU Munich (Urs Hugentobler) and Wettzell Station (GNSS, SLR, LRR, VLBI)
  - Zimmerwald Observatory (Werner Gurtner)
  - GALILEO project (???)