FPGA Implementation for Time Transfer and Ranging in the COMPASSO Mission – In-Orbit Validation for Next Generation GNSS

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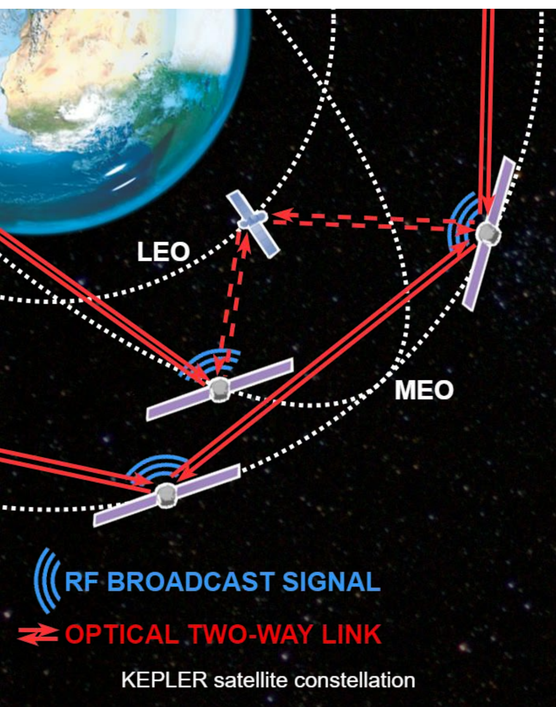


KEPLER satellite constellation

KEPLER - Next Generation Global Navigation Satellite System (GNSS)

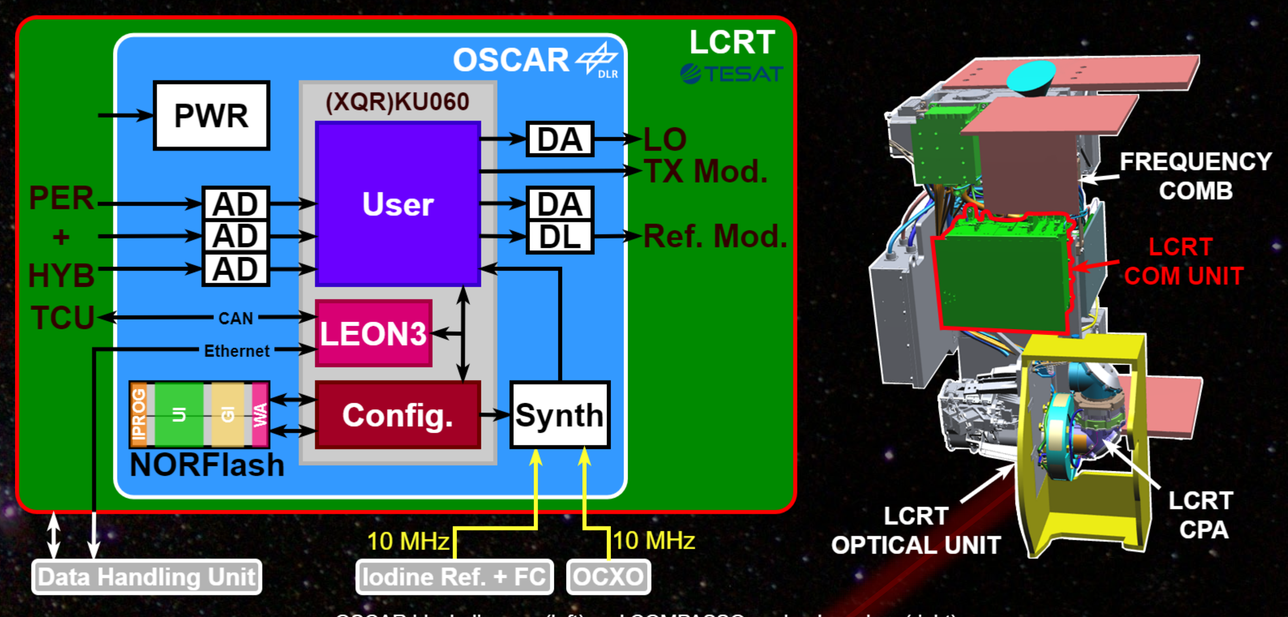
DLR proposed the KEPLER concept to address the increasing demand for precise and reliable global positioning. The system incorporates optical inter-satellite links (OISL) and in-orbit optical clocks to enhance the performance, robustness and resilience of the Galileo GNSS.

- ► Constellation of 24 MEO satellites, 6 LEO satellites and at least one ground station
- ► Bi-directional optical links implement sub cm-level range measurements
- ► Picosecond-level time synchronization establishing composite system time base
- ► Data channel for information exchange within the constellation
- ► Quasi immunity to interference, spoofing, jamming and eavesdropping
- ► Improved resilience by means of autonomous on-board operation
- ► End-user benefits by faster convergence to a cm-level solution globally

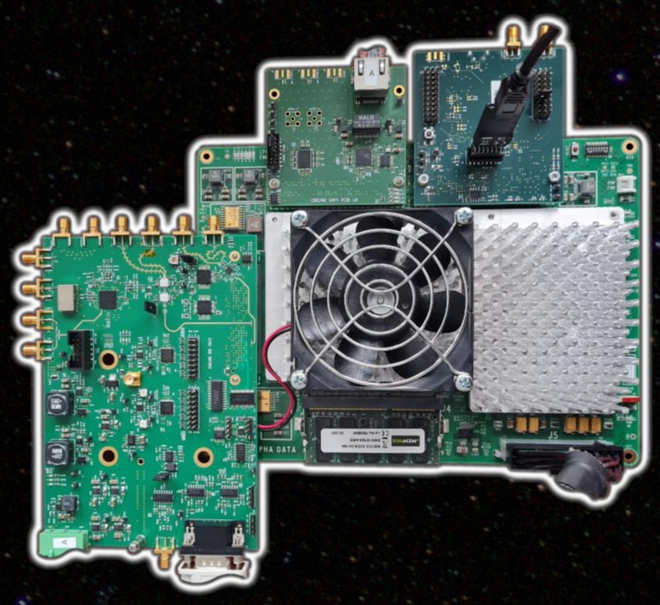
COMPASSO – In-orbit Validation

The DLR COMPASSO mission is an in-orbit validation of KEPLER key technologies. Demonstrating novel optical clocks in space as well as performing two-way time transfer and ranging (TT&R), frequency and data transfer between the ISS Bartolomeo platform and the DLR optical ground station in Oberpfaffenhofen.

- ► 2x Optical Iodine reference + optical frequency comb
- ► Laser communication and ranging terminal (LCRT)
- ► Mission duration 1.5 years with launch in 2027
- ► Status: Q2 2025 System CDR



OSCAR block diagram (left) and COMPASSO payload mockup (right)


OSCAR breadboard (ADA-DEV-KIT + custom frontend)

OSCAR – DSP unit for TT&R, frequency and data transfer

OSCAR implements TT&R, frequency and data transfer capabilities as part of the laser communication and ranging terminal (LCRT) , based on the Tesat SmartLCT. Core of the add-in unit developed by DLR is the Xilinx Kintex Ultrascale (XQR)KU060 FPGA implementing the following features:

- ► 9.6 GCps pseudo random noise based ranging sequence generation
- ► Digital signal processing referenced on highly stable clock source (Iodine + FC, OCXO)
- ► Sub-chip ranging sequence synchronization via delay locked loop and analog delay line
- ► TT&R enabled by deterministic time stamping and 75 Mbps data channel
- ► Radiation mitigation by means of multi-boot configuration, scrubbing and DTMR
- ► System control and TM/TC via LEON3(FT) SoC

Challenges and lessons learned

The scientific validation mission COMPASSO poses unique challenges for the OSCAR team, tackling their first complete vertical integration at such scale in a space project.

- ► Design decisions: mission specific vs. reusable
- ► Scheduling accounting for dynamic project conditions
- ► *"Not a product"* development: compliance vs. mission needs
  - Documentation
  - Verification and validation approach and coverage
  - ECSS (tailoring) vs. best effort

The Future

OpSTAR – Optical Synchronized Time And Ranging

Development and operation of an in-orbit testbed comprised of two satellites and co-located optical ground stations. The objective is to perform verification of PNT function performance for OISL and optical satellite to ground links as well as system synchronization for GNSS.

- ► Consortium: 33 companies of 12 ESA nations (ESA, OHB, DLR,…)
- ► Status: March 2025 Kick-off Phase A/B1

CHRONOS – OSCAR next generation with optimized functionality

You want to know more?

KEPLER

COMPASSO

OpSTAR

DLR Institute for Communication and Navigation