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DOMINO – Laser Communication between SOTA, onboard SOCRATES satellite, and MEO Optical Ground Station

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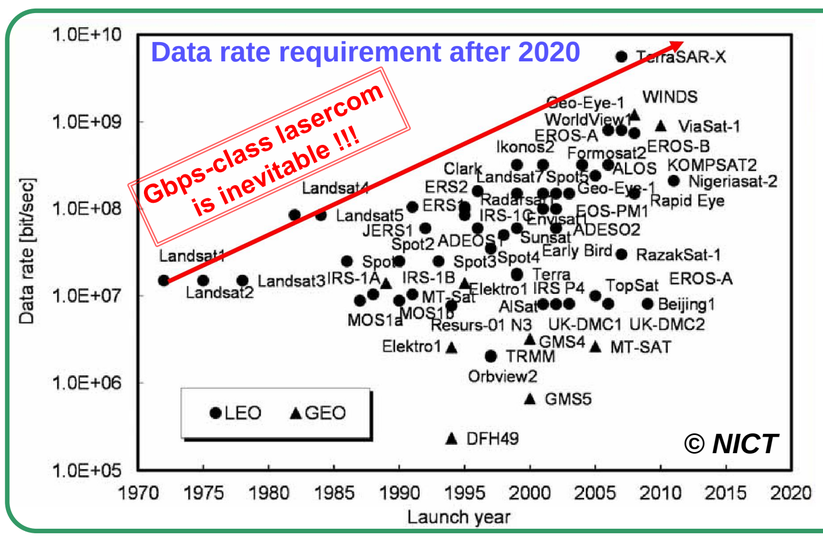
DOMINO

(**D**emonstrator for **O**ptical tele**M**etry at h**I**gh data rate i**N** low earth **O**rbit). The project is conducted in collaboration between the French national center for space studies (**CNES**), the Cote d'Azur observatory (**OCA-GeoAzur**) and the Japanese National Institute of Information and Communication Technologies (**NICT**). **GeoAzur** is the project general contractor. DOMINO project aims to demonstrate the feasibility of a communication link (the establishment of 10 Mbps) between SOTA (Small Optical Transponder) onboard SOCRATES microsatellite (Space Optical Communication Research Advanced Technology Satellite), and the MeO station located at Caussols, France. The main challenges of the project are the characterization of the turbulent atmosphere and the detection at ground of the signal coming from the satellite, for the LEO Direct To Earth scenario at 1.55 µm which interest CNES for Telemetry.



Laser communication

Advantages

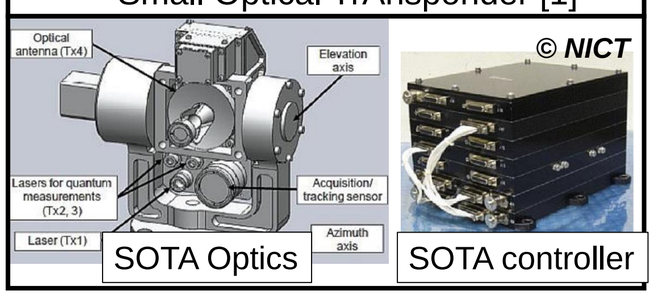
- ✓ multi - Gbps
- ✓ more compact
- ✓ low consommation
- ✓ greater security

Drawbacks

- ✓ losses & turbulences in atmosphere
- ✓ pointing & tracking

The SOCRATES microsatellite, 50-kg-classe satellite bus, engineered by AES, was launched (altitude = 628 km, inclination = 97.69 °) **on May 24, 2014**. The main objectives of SOTA, developed by NICT, are: in-orbit verification of acquisition, tracking and pointing performances; data acquisition of laser beam propagation at various wavelengths; and laser communication experiments with coding (NRZ).

Small Optical TrAnsponder [1]



Downlink from SOTA		
Issues	Tx1	Tx4
Wavelength (nm)	976	1549
Data rate (Mbps)	10 or 1	10 or 1
Intensity (MW/sr)	0.81	0.57
Divergence (µrad)	500	223

Uplink to SOTA for acquisition & tracking	
Wavelength (nm)	1064 ± 3
Required irradiance (µW/m²)	17 - 209

References:
[1] *Yoshisada K. et al., "COMPLETION OF THE SMALL OPTICAL TRANSPONDER DEVELOPMENT FOR SATELLITE-GROUND LASER COMMUNICATION DEMONSTRATIONS",ICSSC 17-2,2013.*

Space-based laser communication programs

	Asia/Japan	NASA/US	Europe
Past	- 1994: **ETS-VI** (GEO-GND) 0.8µm/0.5µm, **IMDD**, 1Mbps - 2006: **OICETS** (LEOGEO, LEO-GND) 0.8µm, **IMDD**, 50Mbps - 2011: **NeFOC** (Air-GND) 1.55µm, **QPSK**, 40Gbps	- 2000: **STRV-2** (LEO-GND, Failure) 0.8µm**, IMDD**, 1.2Gbps - 2001: **GeoLITE** (GEO-GND) - 2008: **NFIRE** (LEO-LEO) 1.06µm, **homodyne BPSK**, 5.6Gbps - 2009: DARPA **ORCA** (Air- Air-GND) TRL6	- 2001: **SILEX** (GEO-LEO, GEO-GND, GEO-Air) 0.8µm, **IMDD**, 50Mbps - 2008: **TerraSAR-X** (LEO-LEO, LEOGND) 1.06µm, **homodyne BPSK**, 5.6Gbps
Current & future Plan ⇨	- 2013: **RISESAT/ VSOTA** (LEO-GND) 0.98/1.5µm, **IMDD**, ~1kbps - 2013:**SOCRATES/ SOTA** (LEO-GND) 0.98/1.55µm, **IMDD**, 10Mbps - 2013: **ShindaiSat**, Visible	- 2013: **LLCD/LADEE** (Lunar-GND) 1.55µm, **PPM**, 622Mbps - 2013: **OPALS** (ISS-GND) 1.55µm, PPM, 50Mbps - 2016: **LCRD** 1.55µm, **DPSK/PPM**, 2.8G/622Mbps	- 2015: **OSIRIS**, 1.55µm, **IMDD**, 1Gbps - 2014: **Alphasat/ EDRS,** 1.06µm, **homodyne BPSK**, ~1.8Gbps - 2017: **OPTEL-µ**, **IMDD** 1.55µm, 2Gbps

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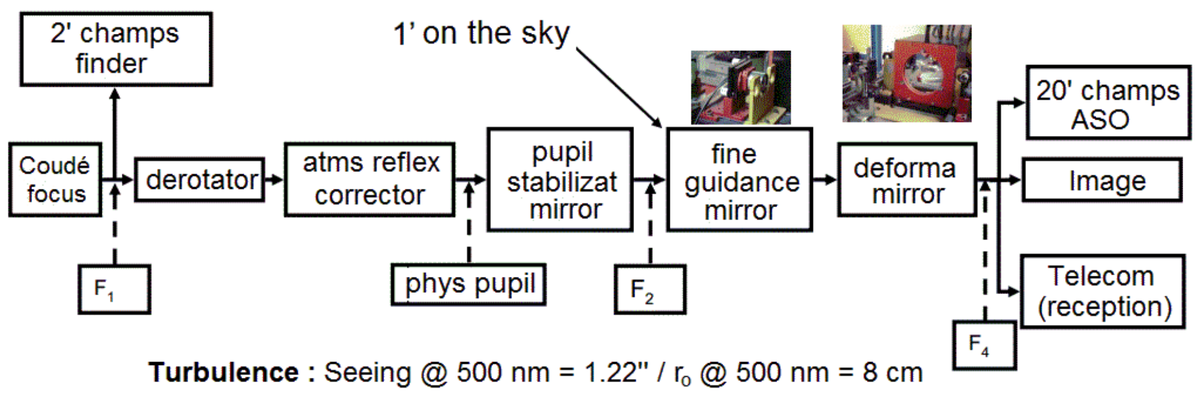
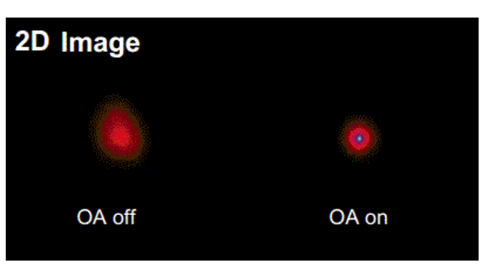
Optical Ground Station - MeO telescope

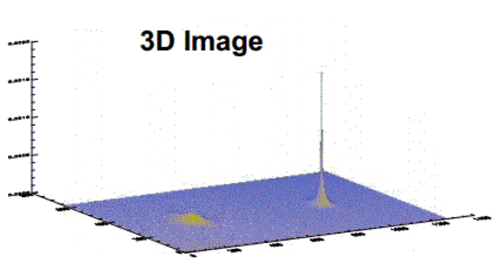
Telescope type		1.54 m Cassegrain
Weight of the mobile elements		20 tons
Diameter of the dome		9 m
Motorization – Dome	**maximum speed**	5°/s
	pointing accuracy	< 1 arcsec
	pointing precision	0.01 arcsec
	Pointing stabilization	0.2 arcsec at 1000 s
Coudé : M4 –M7 (Laboratories)	**type & diameter**	200 mm plat fold mirror
	bandwidth	350 nm to 1200 nm
	damage threshold	10 J/cm² for ns pulse
Equivalent Focus length		32 m
Field of view		5 arcmin
Station altitude		1273 m

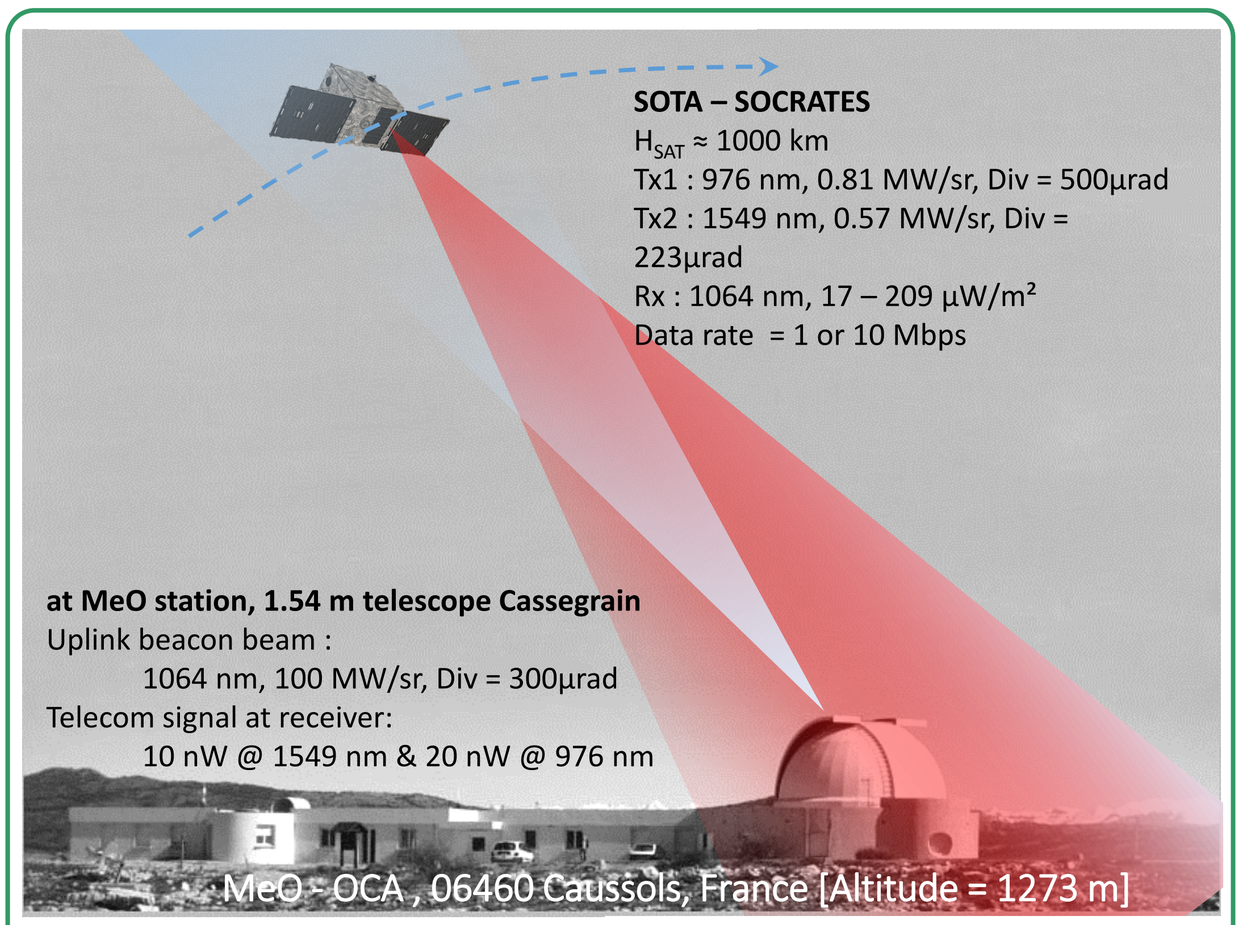
The MeO station, installed on an Alt-Az mount, is dedicated for researches on Lunar laser ranging, satellites laser ranging, time transfer, astronomy and laser communication. It comprises an important experimental setup for laser ranging and also an adaptive bench well suited to analyze the turbulent atmosphere (figure below).



Turbulence : Seeing @ 500 nm = 1.22'' / r_0 @ 500 nm = 8 cm







Configuration of the MeO station-to-SOTA laser link

For a given passage of the satellite over the MeO station, MeO points the satellite according to the predicted orbital information. As soon as the uplink is acquired, the satellite turns on the transmission laser (Tx1 or Tx4) and points back the beam in the Meo orientation. When both uplink and downlink are acquired and slaved together, the communication link is established.

Geoazur together with the industrial partners will design the demonstrator instruments. It comprises

- the uplink beacon;
- the downlink receiver;
- the equipment for atmospheric turbulence analysis
- and the software to control the whole experiment.

We also implement a closed loop system to slave the pointing of the telescope on the SOTA beacon signal. This work also includes the integration of a SOCRATES searching algorithm.