SCF_LAB: the Satellite/Lunar/GNSS laser ranging and altimetry Characterization Facilities' LABoratory

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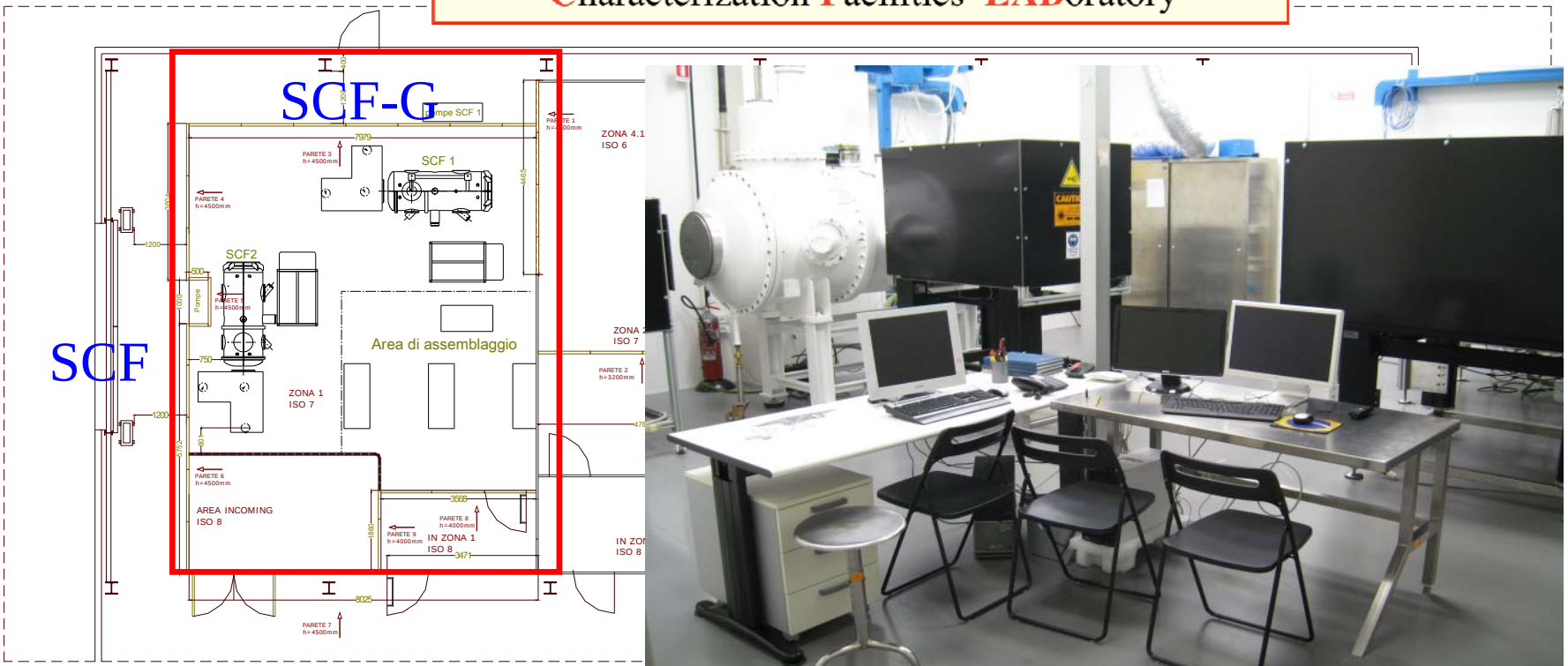
INTERNATIONAL TECHNICAL LASER WORKSHOP 2012 (ITLW-12)
NOVEMBER 5-9, 2012, INFN-LNF
Frascati (Rome), Italy

Outline

- SCF_LAB
- SCF and SCF-Test
- SCF-G
- ETRUSCO-2 and Galileo IOV
- SCF-Test Revision ETRUSCO-2
- Conclusions

SCF_LAB Clean Room

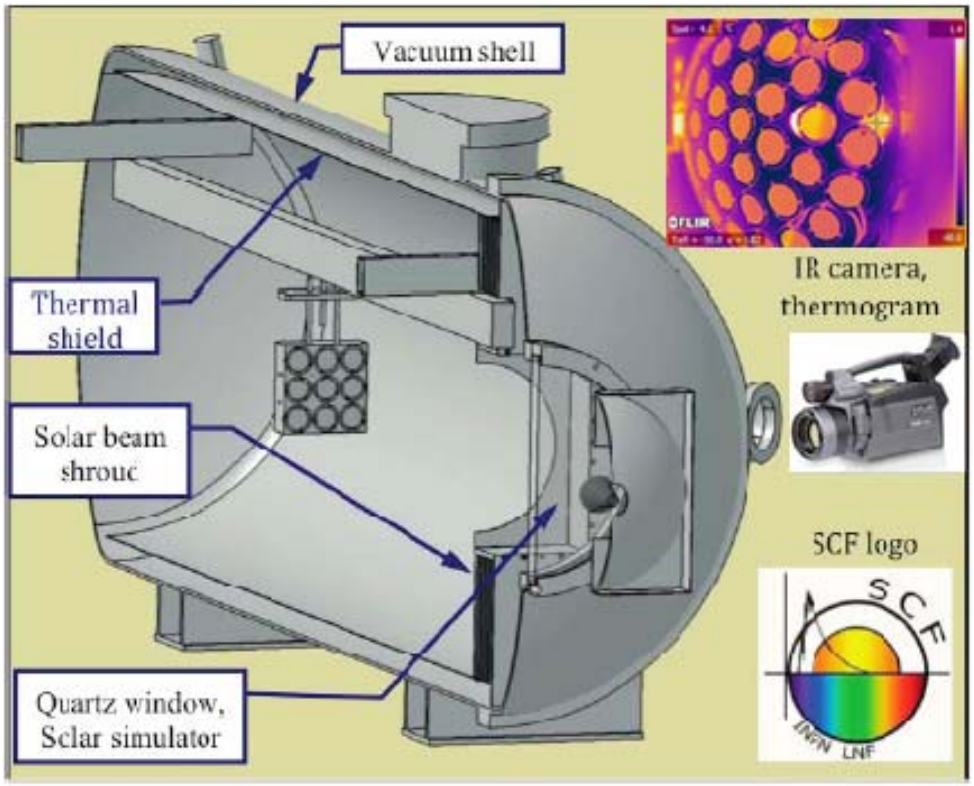
SCF_LAB
Satellite/Lunar/GNSS
laser ranging and altimetry
Characterization **F**acilities' **LAB**oratory



SCF_LAB ~ 85 m^2
cleaning class 10000
or better

SCF_LAB @INFN-LNF

Two unique OGSEs (Optical Ground Support Equipment) facilities in a clean room to characterize the space segment of laser ranging altimetry



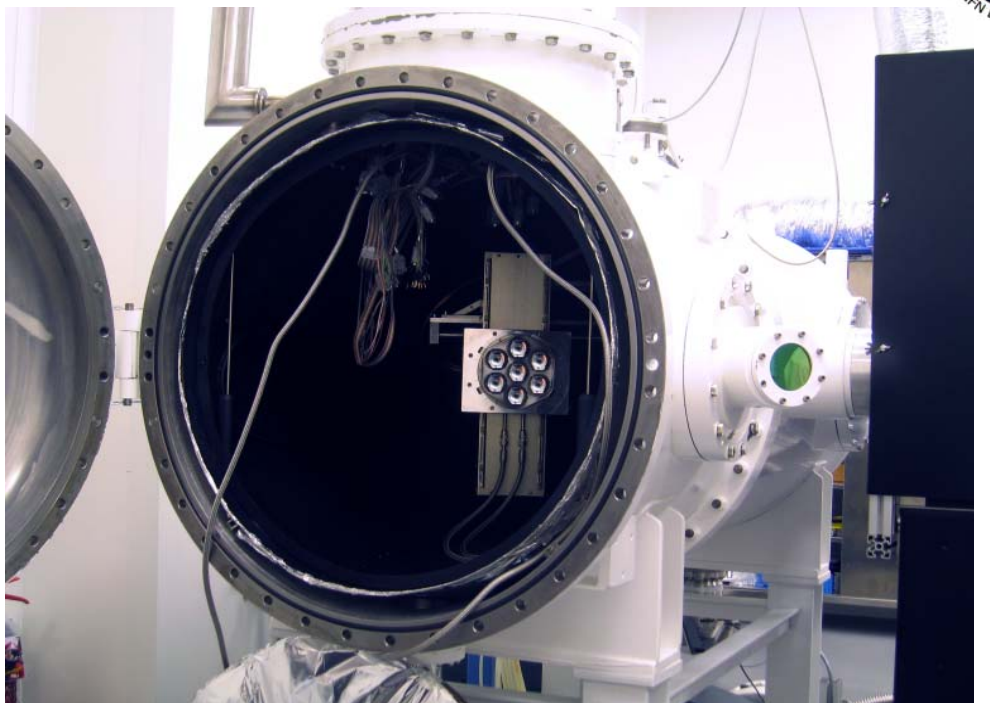
SCF for SLR/LLR/ Altimetry

SCF-G for GNSS

SCF-G

- Solar quartz window
- IR Germanium window
- Laser quartz window

SCF



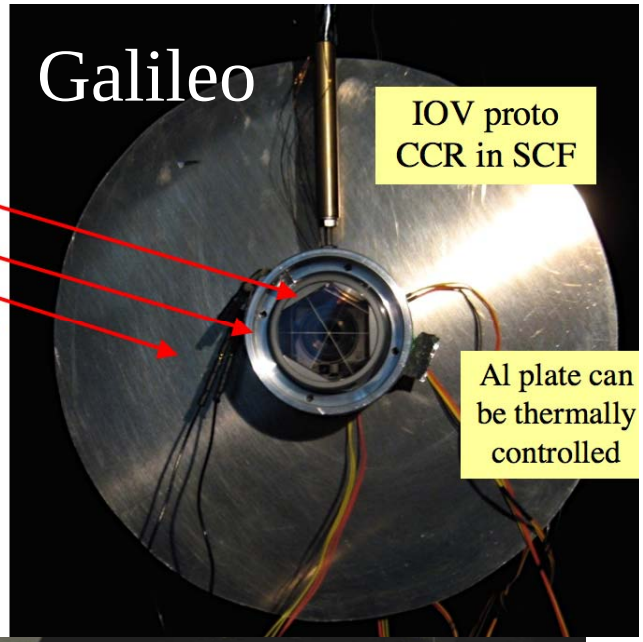
- Solar quartz window
- 2 IR Germanium windows
- Laser quartz window
- Back port

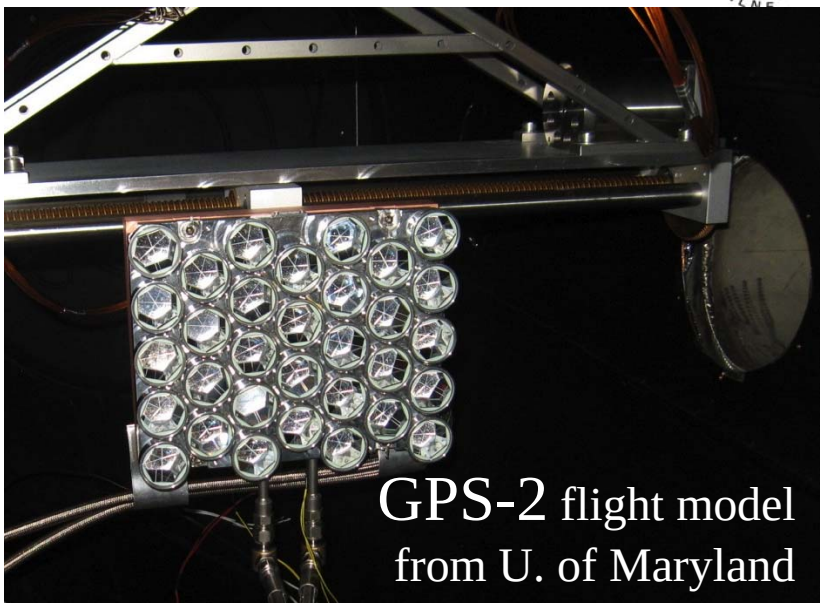
For Laser altimetry to CCRs see talk by M. Martini

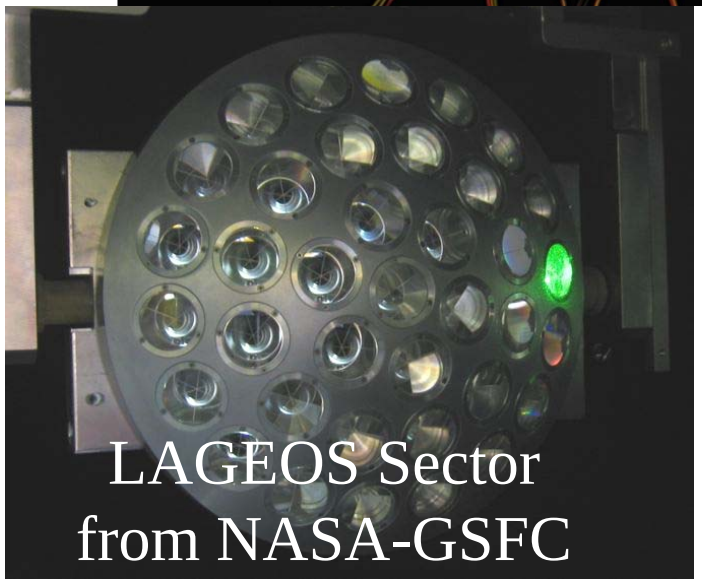
Default SCF-Test (background IP of INFN)

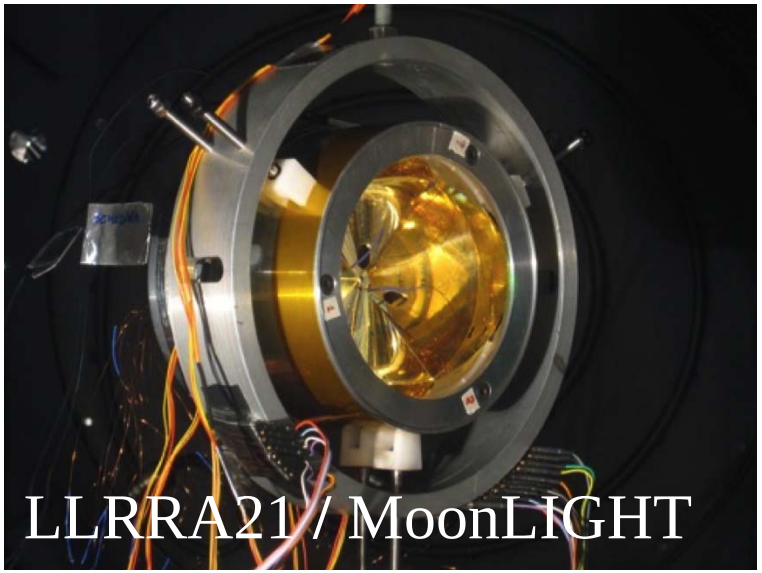
- Laboratory-simulated space conditions. Concurrent/integrated:
  - Dark/cold/vacuum
  - Sun (AM0) **simulator**
  - IR and contact **thermometry**
  - Payload **roto-translations**
  - Payload **thermal control**
  - **Laser interrogation and sun thermal perturbation at varying angles**
- Deliverables
  - **Array thermal behavior**
    - CCR thermal relaxation times (τ_{CCR})
  - **Optical response**
    - **Far Field Diffraction Pattern (FFDP)**
- Also GRA invariant Optical Cross Section (OCS) in air/isothermal conditions
- Also integrated thermal-optical simulations (upon request): see talk by A. Boni on Wednesday

World-first SCF-Tests

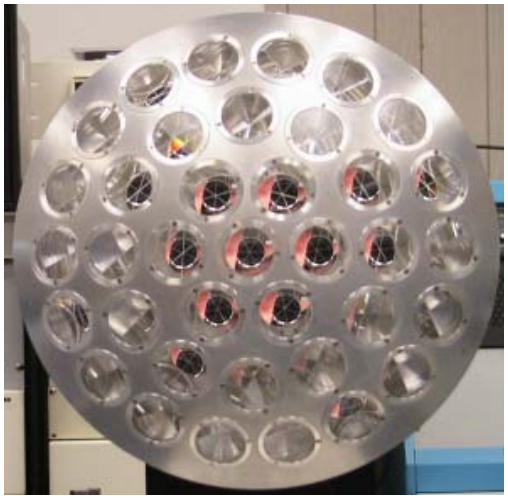


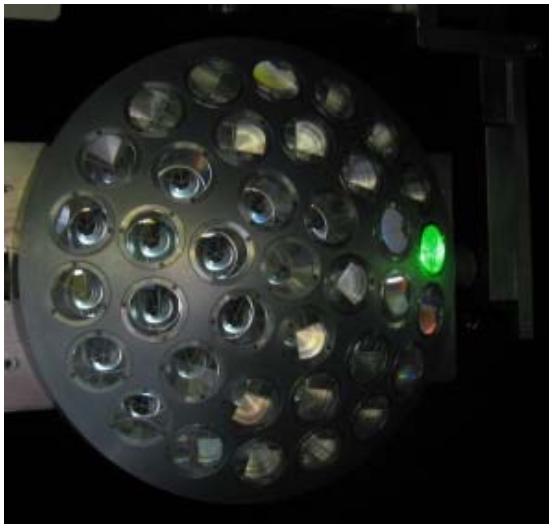


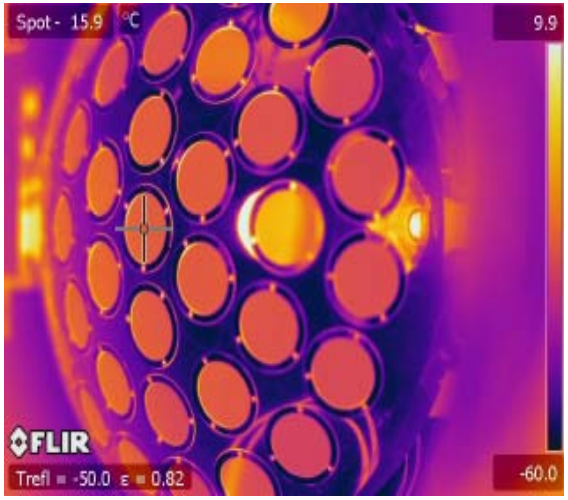


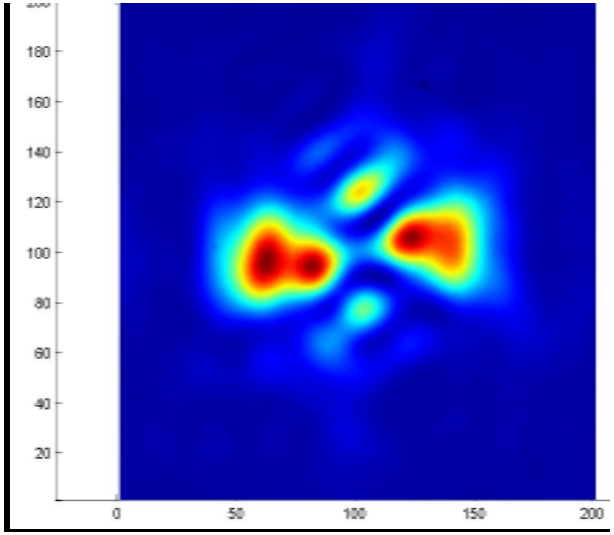


LAGEOS Sector



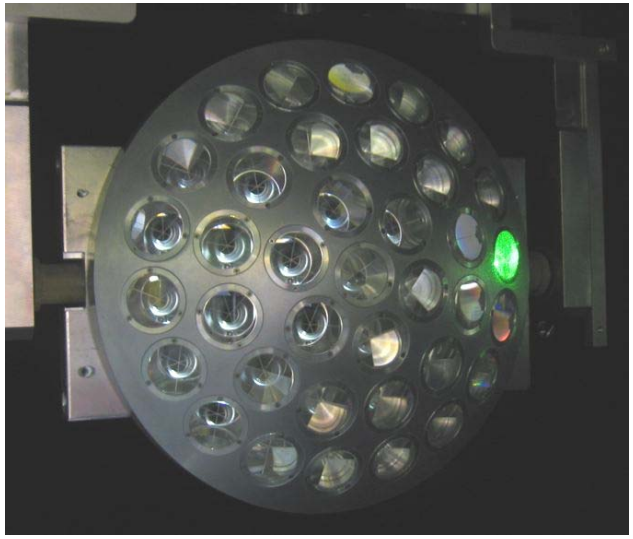






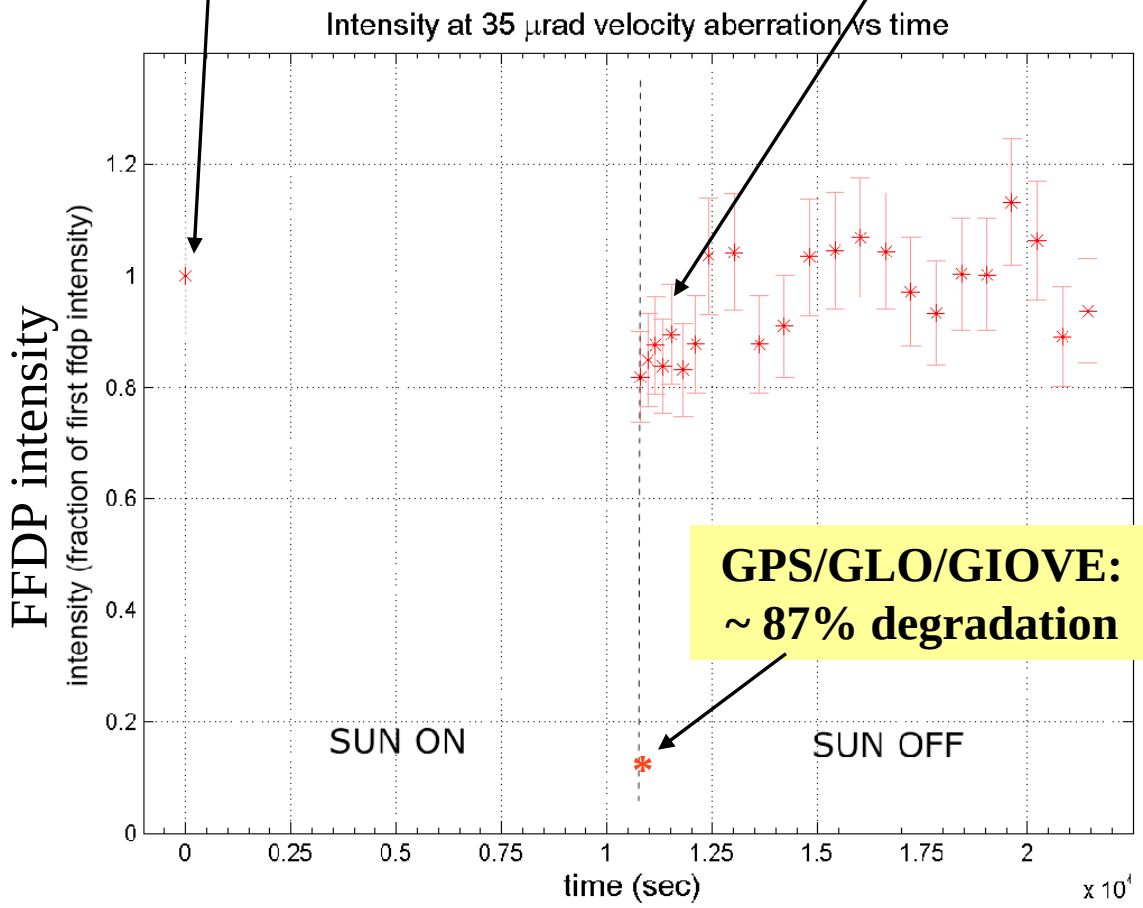
LAGEOS: uncoated SLR payload standard

LAGEOS "Sector", engineering prototype property of NASA-GSFC. Inherits from Apollo. **SCF-Tested @300K** at INFN-LNF



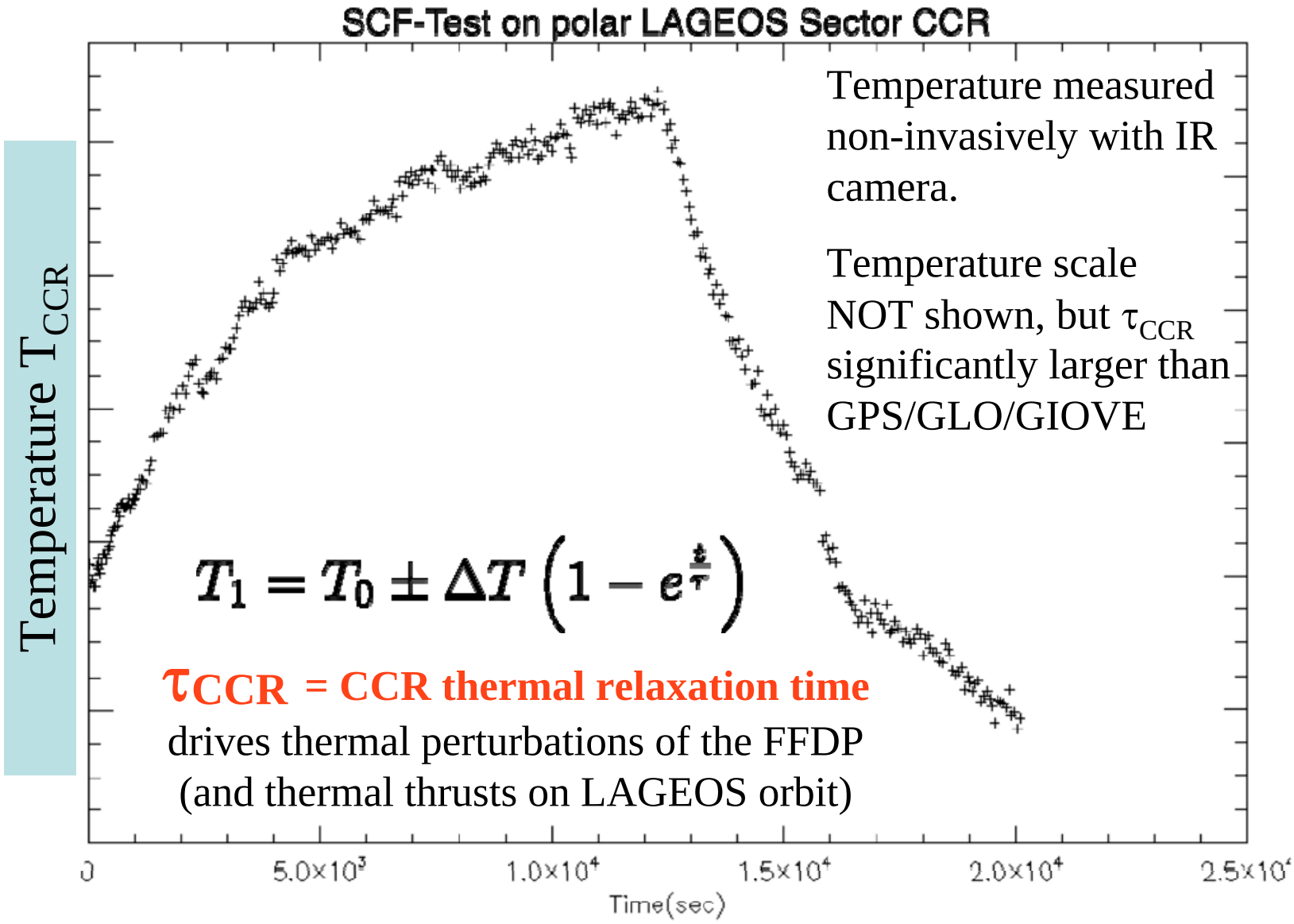
LAGEOS: laser return in space conditions not perturbed by Sun

LAGEOS: minimal degradation of laser return after 3 hr of Sun heating



GPS/GLO/GIOVE: ~ 87% degradation

LAGEOS Sector SCF-Test @300K



Temperature measured non-invasively with IR camera.

Temperature scale NOT shown, but τ_{CCR} significantly larger than GPS/GLO/GIOVE

τ_{CCR} = CCR thermal relaxation time

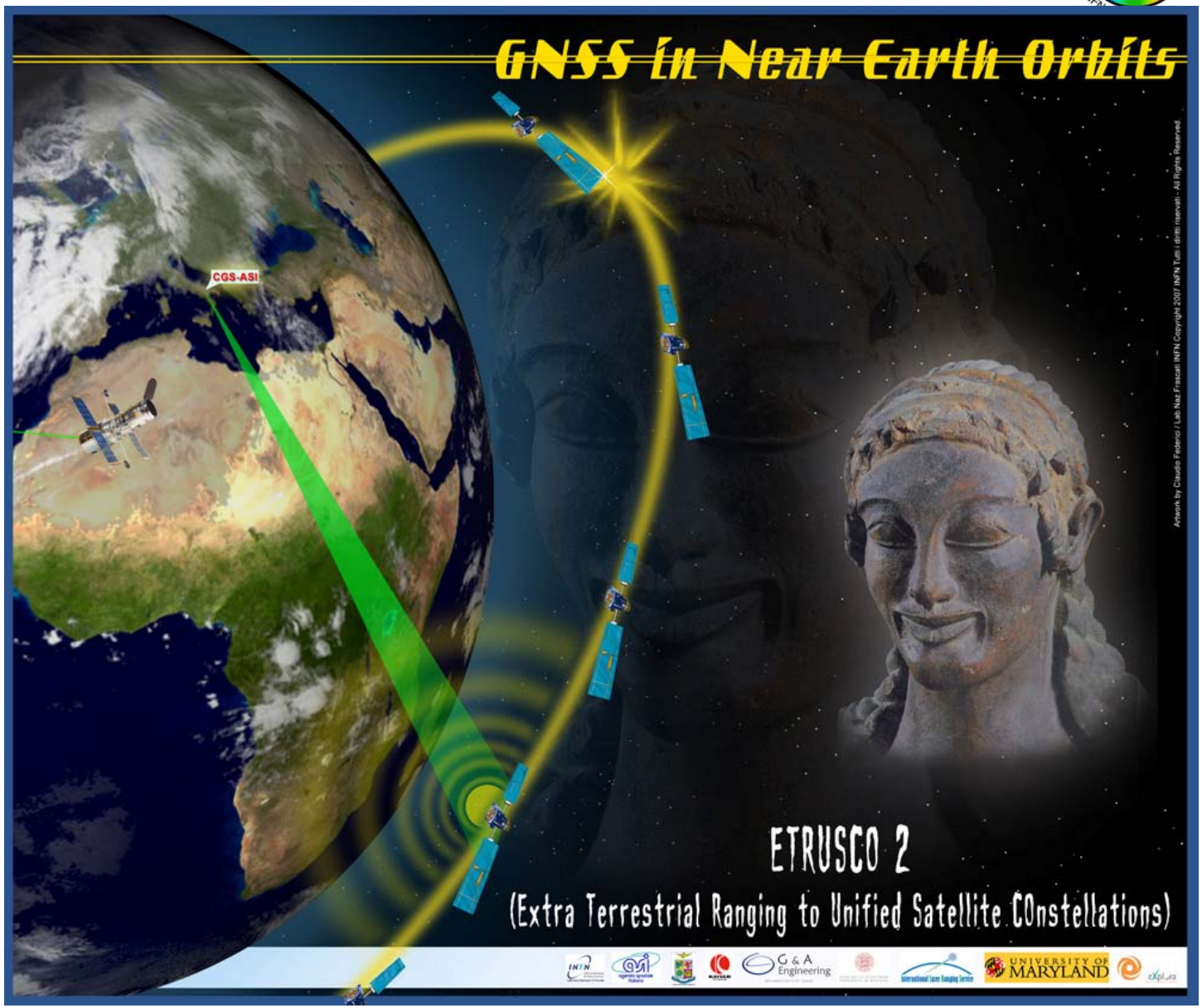
drives thermal perturbations of the FFDP (and thermal thrusts on LAGEOS orbit)

ETRUSCO-2: ASI-INFN Program for GNSS (May 2010 April 2013)

Optimized for Galileo and GPS-3

PI:
S. Dell'Agnello

Co-PIs:
R. Vittori, ESA
G. Bianco, ASI



ETRUSCO-2

- Continuation of ETRUSCO-1 INFN R&D (2006-2010) with a full-blown ASI-INFN project of technological development

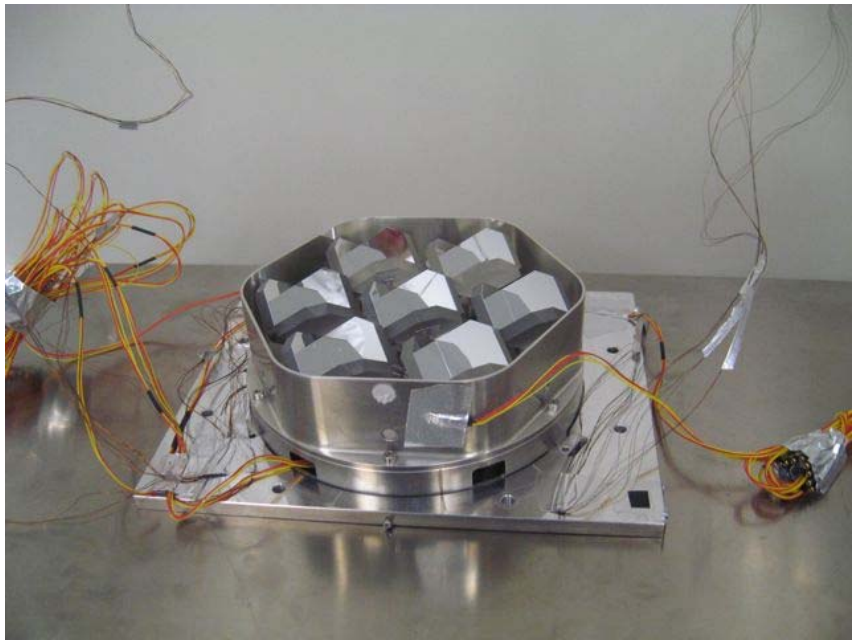
- Targeted to Galileo and GPS-3, open to other GNSS constellations
  - INFN is Prime Contractor
  - Partners:

    - ASI-CGS (G. Bianco et al), Univ. of Bologna (S. Zerbini)
    - Three Italian SMEs

ETRUSCO-2 (ASI-INFN): 2010-2013

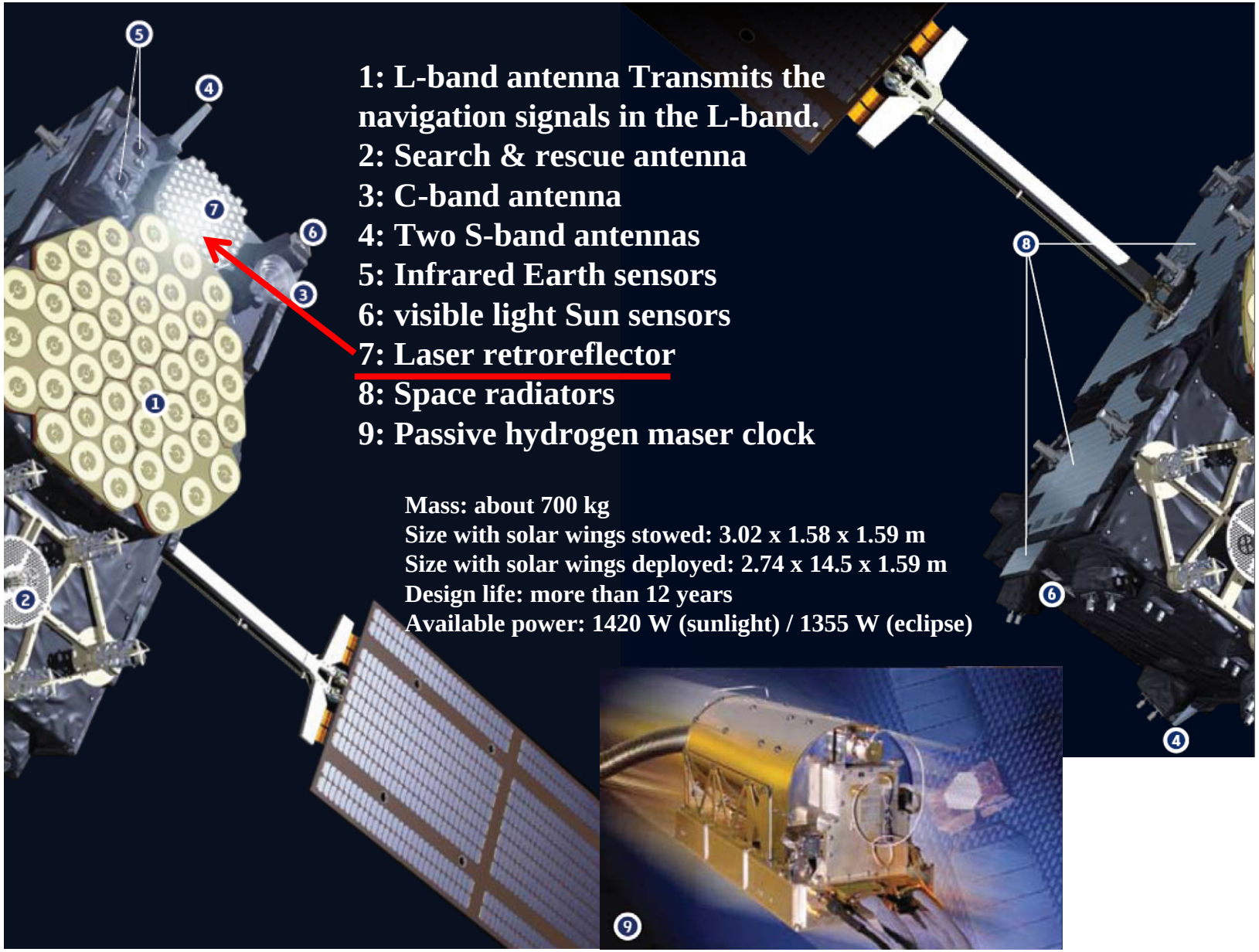
- New SCF-G, optimized for GNSS
- Two new GNSS retroreflector payloads

Small, hollow reflector prototype model, GRA-H, delivered and fully SCF-Tested with SCF in 2011



Full size model, GRA, of solid fused silica, in 2012 to be SCF-Tested with SCF-G

First 4 Galileo IOV satellites



SCF-Test/Revision-ETRUSCO-2

•Accurately laboratory-simulated space conditions

•Deliverables / Retroreflector Key Performance Indicators (KPIs)

- **GRA Thermal behavior:** thermal relaxation time of retroreflector (τ_{CCR}) and its mounting elements starting from hot/cold case (typical span of 100 K for GNSS)
- **GRA Optical response along the GCO**
  - **Far Field Diffraction Pattern** (FFDP) => laser return to ground
  - **Wavefront Fizeau Interferogram** (WFI) => retroreflected laser wavefront onboard (WFI to be delivered by end 2012, the true novelty of ETRUSCO-2); vibration and air turbulence insensitive

Note: the GCO is a very powerful, sensitive KPI. Instead, reduced, partial, incomplete tests (compared to the full space environment) are randomly misleading (either optimistic or pessimistic)

•GRA invariant Optical Cross Section (OCS) in air/isothermal conditions

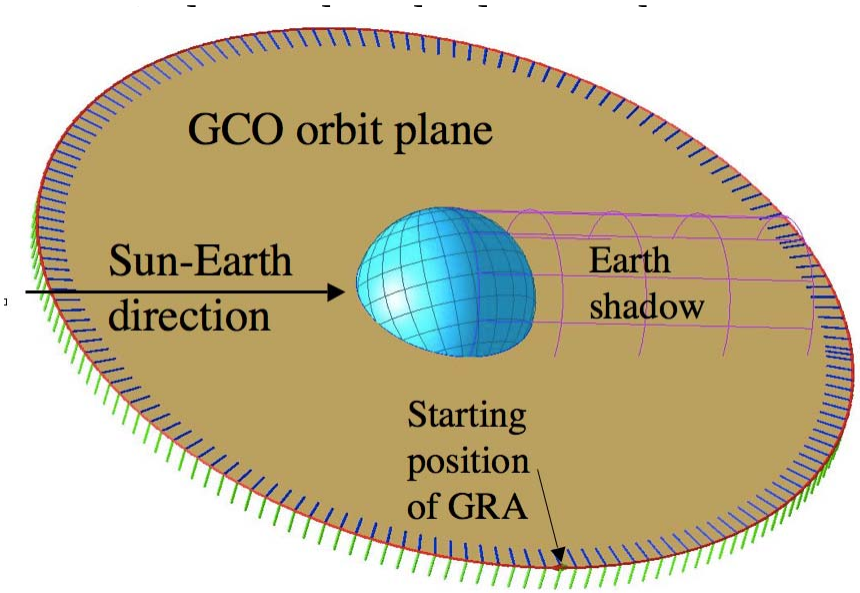
SCF-Test of Galileo Critical half-Orbit (GCO)

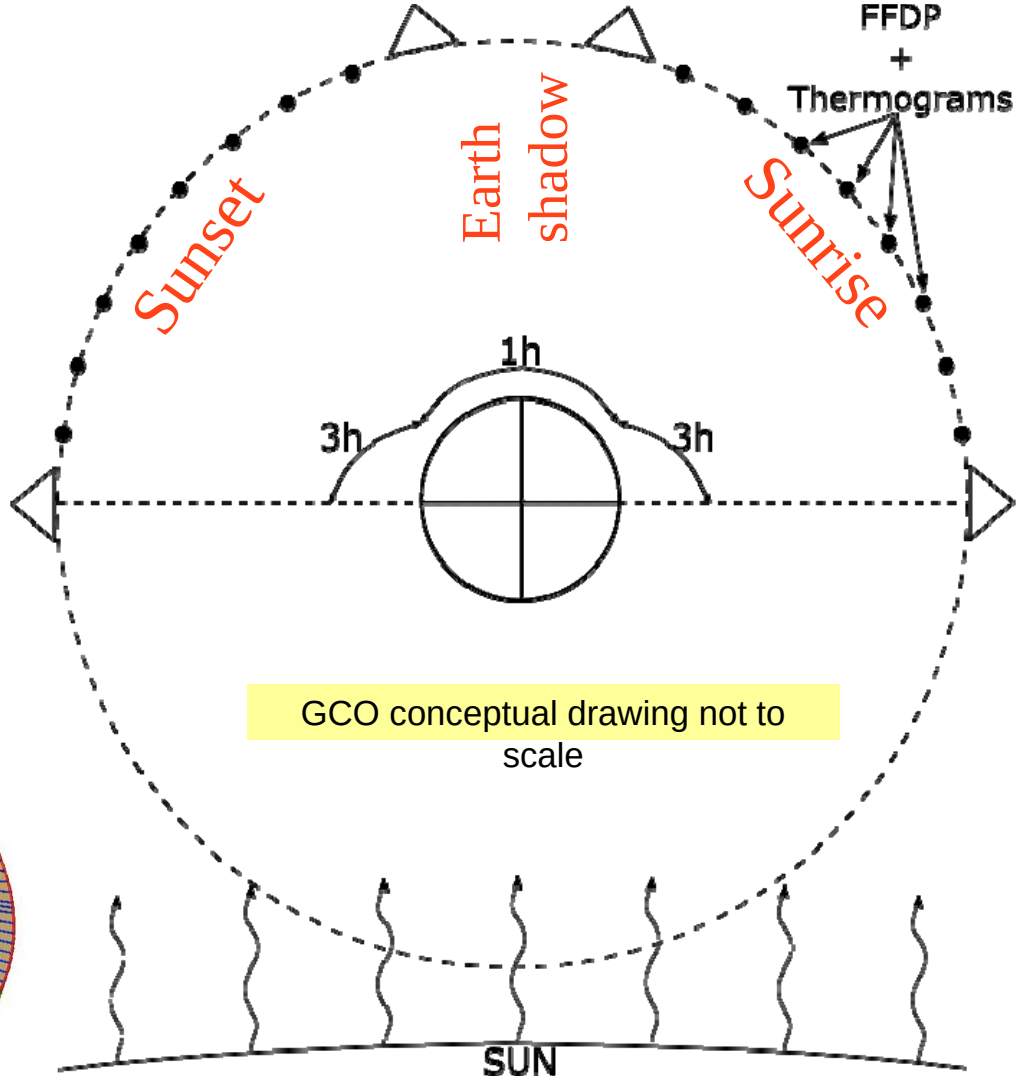
GCO: angular momentum normal to Sun-Earth direction.

Sunrise-Eclipse-Sunset probes critical features of the thermal and optical behavior of the CCR

Galileo orbit:

- Altitude = 23222 km

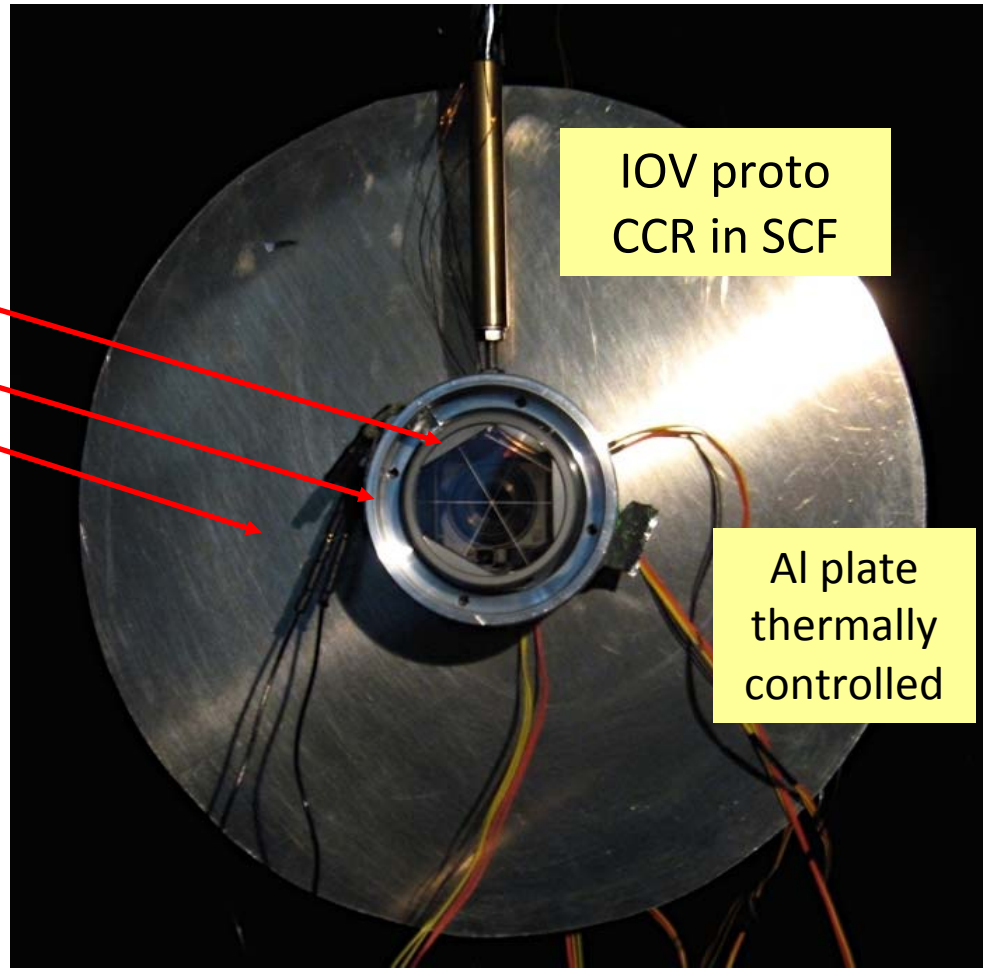


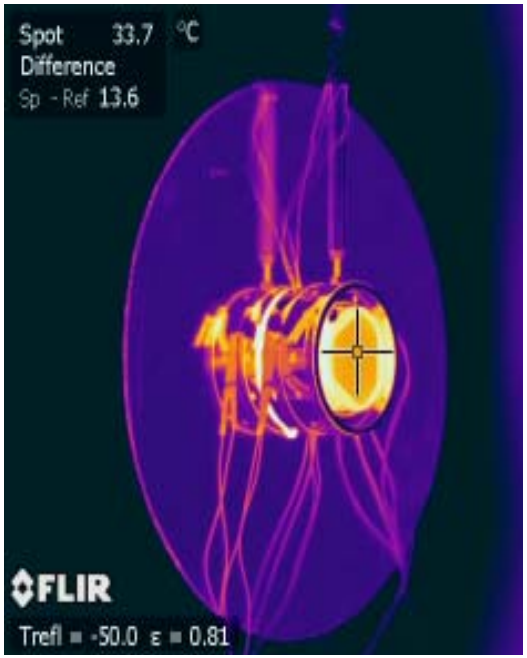


GCO conceptual drawing not to scale

GALILEO IOV CCR SCF-Test configuration

CCR housing
Al housing
Al back-plate
inside the SCF

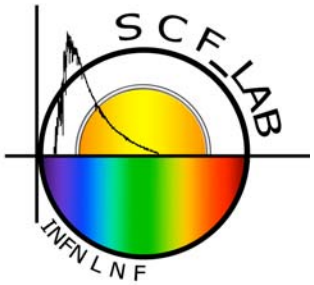




Results will be presented in Wednesday special session on GNSS and ETRUSCO-2

Conclusions and prospects

- New infrastructure SCF_LAB with two unique OGSEs
- SCF: Satellite/Lunar/GNSS laser ranging/altimetry
- SCF-G: optimized for GNSS
- SCF-Test of: GPS/GLONASS/GIOVE, LAGEOS, Galileo IOV
- New SCF-Test/Revision-ETRUSCO-2 (except for the WI) applied to a prototype Galileo IOV CCR



Thank you for your attention

Main Reference Documents

- [RD-1] Dell'Agnello, S., et al, **Creation of the new industry-standard space test of laser retroreflectors for the GNSS and LAGEOS**, J. Adv. Space Res. **47** (2011) 822–842.
- [RD-2] P. Willis, Preface, Scientific applications of Galileo and other Global Navigation Satellite Systems (II), J. Adv. Space Res., **47** (2011) 769.
- [RD-3] D. Currie, S. Dell'Agnello, G. Delle Monache, **A Lunar Laser Ranging Array for the 21st Century**, Acta Astron. **68** (2011) 667-680.
- [RD-4] Dell'Agnello, S., et al, Fundamental physics and absolute positioning metrology with the MAGIA lunar orbiter, Exp Astron, October 2011, Volume 32, Issue 1, pp 19-35 ASI Phase A study.
- [RD-5] Dell'Agnello, S. et al, **A Lunar Laser Ranging Retro-Reflector Array for NASA's Manned Landings, the International Lunar Network and the Proposed ASI Lunar Mission MAGIA**, Proceedings of the 16th International Workshop on Laser Ranging, Space Research Centre, Polish Academy of Sciences Warsaw, Poland, 2008.
- [RD-6] International Lunar Network (http://iln.arc.nasa.gov/), Core Instrument and Communications Working Group Final Reports.
- [RD-7] Yi Mao, Max Tegmark, Alan H. Guth, and Serkan Cabi, Constraining torsion with Gravity Probe B, Physical Review D **76,** 104029 (2007).
- [RD-8] March, R., Bellettini, G., Tauraso, R., Dell'Agnello, S., **Constraining spacetime torsion with the Moon and Mercury**, Physical Review D **83**, 104008 (2011).
- [RD-9] March, R., Bellettini, G., Tauraso, R., Dell'Agnello, S., **Constraining spacetime torsion with LAGEOS**, Gen Relativ Gravit (2011) 43:3099–3126.
- [RD-10] **ETRUSCO-2: An ASI-INFN project of technological development and "SCF-Test" of GNSS LASER Retroreflector Arrays**, S, Dell'Agnello, 3rd International Colloquium on on Scientific and Fundamental Aspects of the Galileo Programme, Copenhagen, Denmark, August 2011