SCF_Lab @ LNF

R&D and Services on laser retroreflector-based

Geometrodynamics for Gravity, GNSS, GMES, EO, …

SCF_Lab

Satellite/Lunar/GNSS

laser ranging and altimetry

Characterization **F**acilities **Lab**oratory

Simone Dell'Agnello for the SCF_Lab Team

Italian National Institute for Nuclear Physics, Laboratori Nazionali di Frascati (INFN-LNF),
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INFN-Space/3, Frascati, September 19, 2012

SCF_Lab Team. Acknowledgments.

INFN-LNF

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G. Bianco (ASI-CGS),
D. Currie (USA, U. of Maryland)
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Students

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M. Marra, V. Maddaluno

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ASI,
ESA & Galileo,
Italian Ministry of Defense/Air Force,
ISRO

Acronyms and definitions

1. ASI: Agenzia Spaziale Italiana
2. BT: Break Through
3. CCR: Cube Corner Retroreflector
4. EO = Earth Observation
5. ESA: European Space Agency
6. ETRUSCO: Extra Terrestrial Ranging to Unified Satellite Constellation
7. FFDP: Far Field Diffraction Pattern
8. FOC: Full Orbit Capability
9. GCO: GNSS Critical half Orbit
10. GMES = Global Monitoring for Environment and Security
11. GNSS : Global Navigation Satellite System
12. GPS: Global Positioning System
13. GRA: GNSS Retroreflector Arrays
13. GTRF: Galileo Terrestrial Reference Frame
14. ILRS: International Laser Ranging Service
15. IOV: In Orbit Validation
16. IPR: Intellectual Property Rights
17. ITRF: International Terrestrial Reference Frame
18. ITRS: International Terrestrial Reference System
19. KPI: Key Performance Indicator
20. OCS: Optical Cross Section
21. LAGEOS: LAser GEOdynamics Satellite
22. SCF: Satellite/lunar/GNSS laser ranging and altimetry Characterization Facility
23. SCF-G: Satellite laser ranging Characterization Facility optimized for GNSS
24. SLR: Satellite Laser Ranging
25. TIR: Total Internal Reflection
26. WI: Wavefront Interferogram

GNSS, Gravitation, Space geodesy. **ILRS**

LEO, GNSS, GEO, Moon

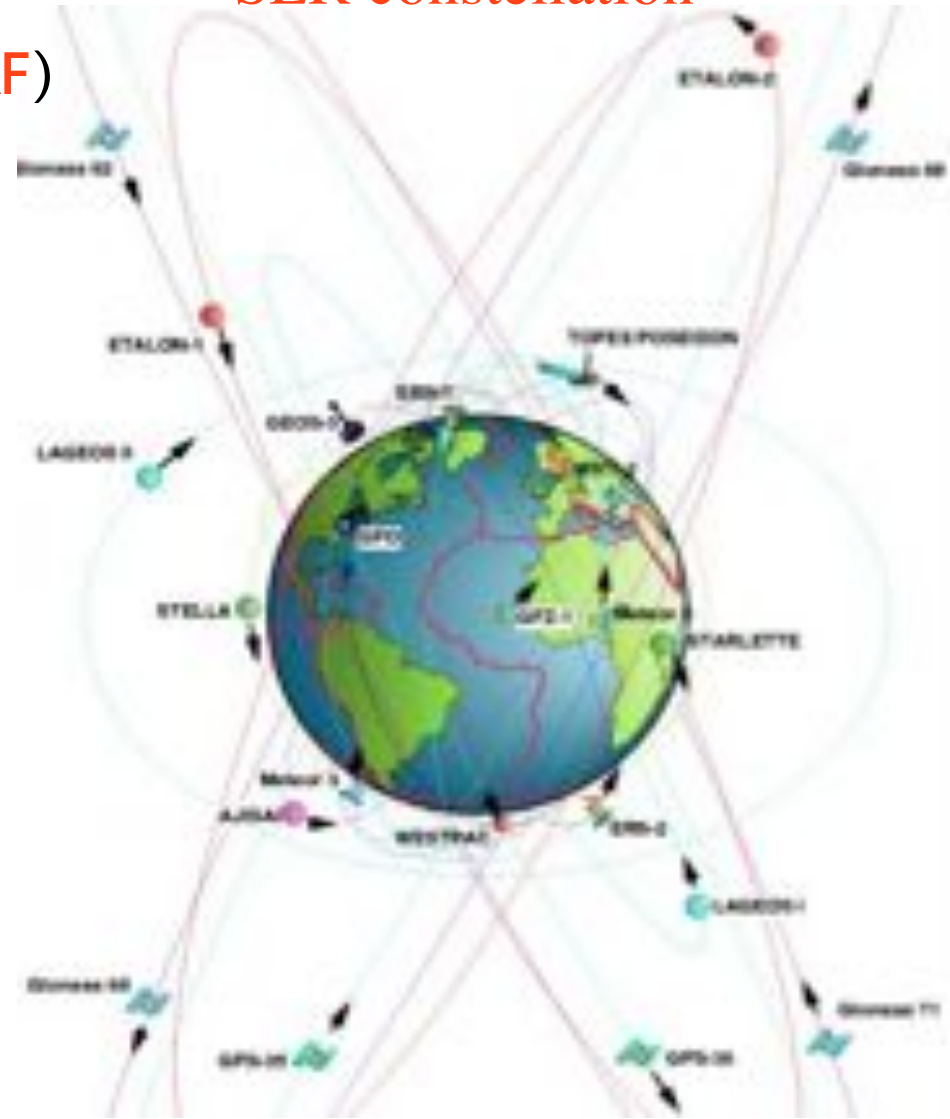
Int. Terrestrial Reference Frame (ITRF)

- Geocenter from SLR (LAGEOS)
- Scale from SLR (LAGEOS) and VLBI
- Orientation (wrt ICFR) from VLBI
- ITRF distribution w/GNSS
- DORIS, …

LAGEOS

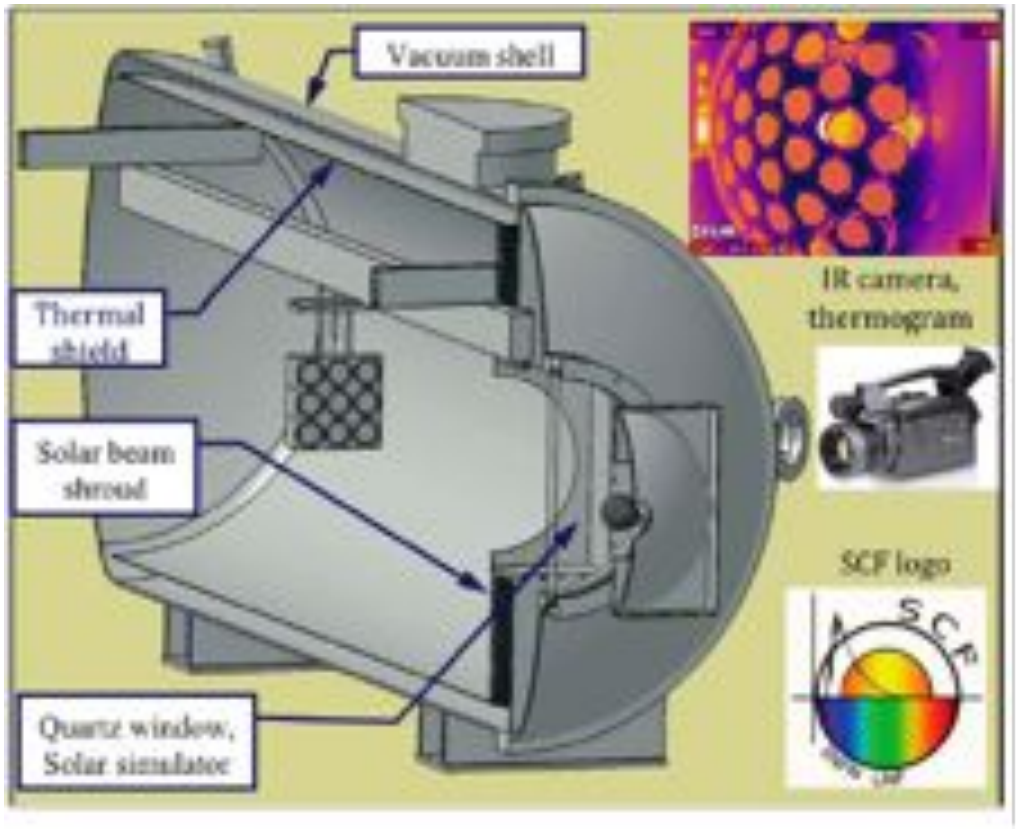
International Laser Ranging Service

SLR constellation

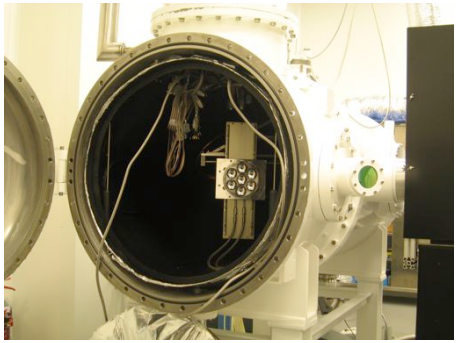


SCF_Lab @INFN-LNF

Two world-unique **OGSE** (Optical Ground Support Equipment) facilities in a clean room to characterize the space segment of laser ranging altimetry. *In 'INFN jargon': "test beam of laser retroreflector detectors"*



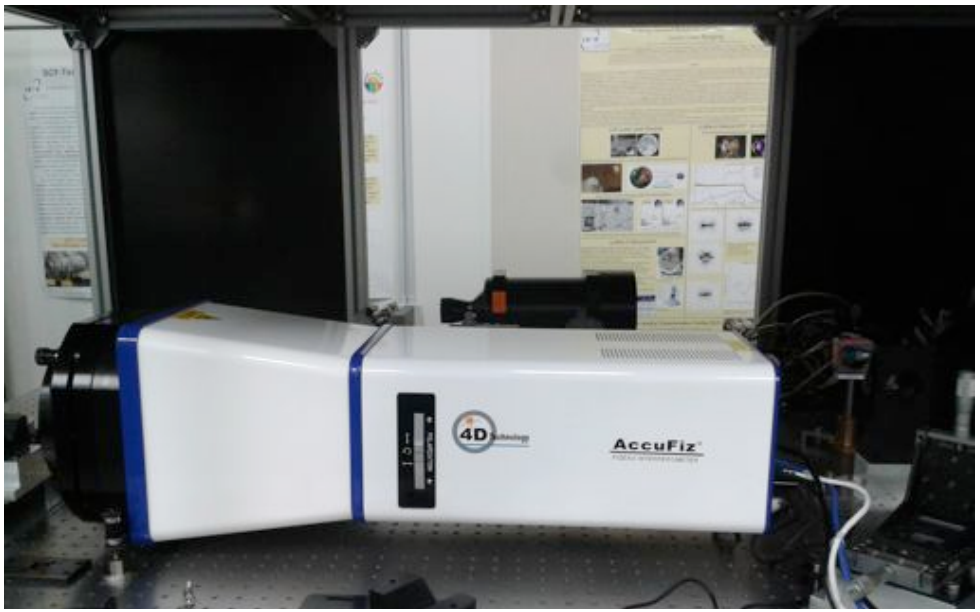
SCF for SLR/LLR/ GNSS/ Altimetry (RD-1, RD-2)



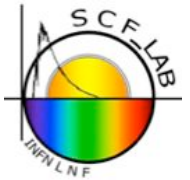
SCF-G for GNSS (RD-10)

SCF_Lab @ LNF

Two solar simulators, two optical Far Field Diffraction Pattern optical tables, one Wavefront Fizeau Interferometer (WFI, capable of linear and circular polarization), Class 10000 / ISO 7 clean room



The SCF-Test (background IP of INFN)



J. Adv. Space Res. **47** (2011) 822–842

Creation of the new industry-standard space test of laser retroreflectors for the GNSS and LAGEOS

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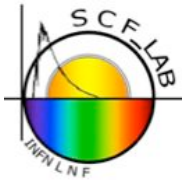
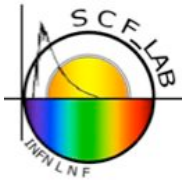
SCF-Test/Revision-ETRUSCO-2 (ASI-INFN)



- Laboratory-simulated space conditions. Concurrent/integrated:
  - Dark/cold/vacuum
  - **Sun AM0 simulators** (2) and Earth IR simulator
  - Non-invasive IR and contact **thermometry**
  - **Laser interrogation and sun perturbation at varying angles**
  - Payload **thermal control**
  - Payload **roto-translations**
- Deliverables / Retroreflector Key Performance Indicators (KPIs)
  - **Thermal behavior** (τ_{CCR}, thermal relaxation time)
  - **Optical response: Far Field Diffraction Patter, (near-field) Wavefront Fizeau Interferogram**
- Beware: reduced, partial, incomplete tests (compared to the full space environment) can be very misleading (either optimistic or pessimistic)

Space Flagships: Galileo, GMES …



- **Galileo**, ETRUSCO/ETRUSCO-2 (INFN-ASI)
  - EU Flagship Space Program n. 1
- **GMES**, Global Monitoring for Environment & Security
  - EU Flagship Space Program n. 2
- ETRUSCO-GMES (CSN5 R&D), with external contracts:
  - **ETRUSCO-IOV:** SCF-Test for Galileo IOV
  - **ETRUSCO-IRNSS** : SCF-Test for 'Indian Galileo' (GNSS)
  - **G-CALIMES**: Laser-based Unification of Galileo and Italian constellations for radar mapping of Earth surface
    - Cosmo-SkyMed (CSK) & Cosmo Second Generation (CSG)

SCF-Test GPS flight array by USSR

CCR Technology deployed on GLONASS, GPS, GIOVE. **We have de-qualified it with SCF-Testing**. It is not and will not be used anymore for GNSS, not even on GLONASS

Third and last ever made for GPS. On loan from Univ. of Maryland to SCF_Lab

~19 x 24 cm^2,~1.3 Kg,

32 CCRs

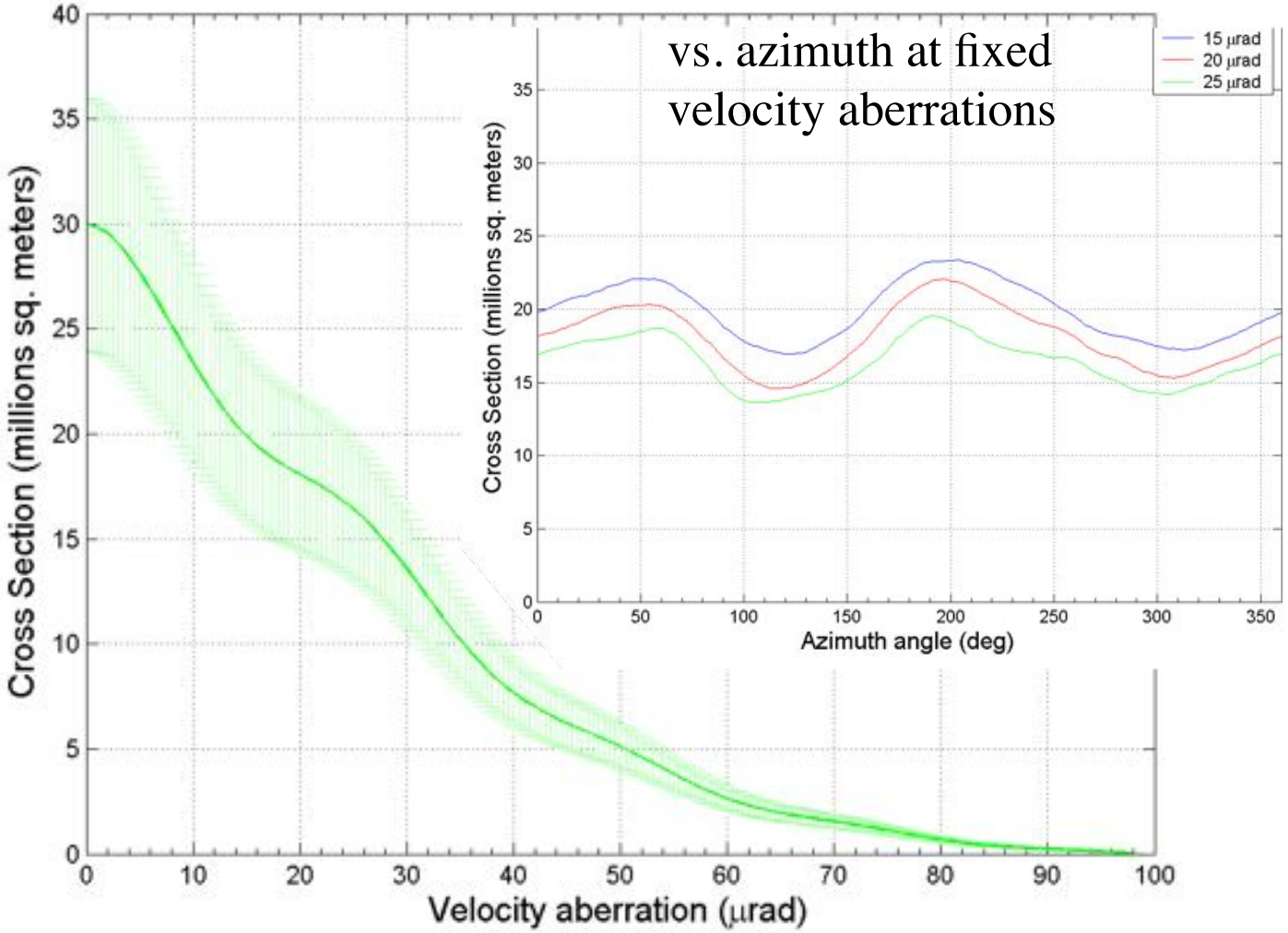
GPS flight model optical cross section at 532 nm

in air/isothermal conditions vs. velocity aberration

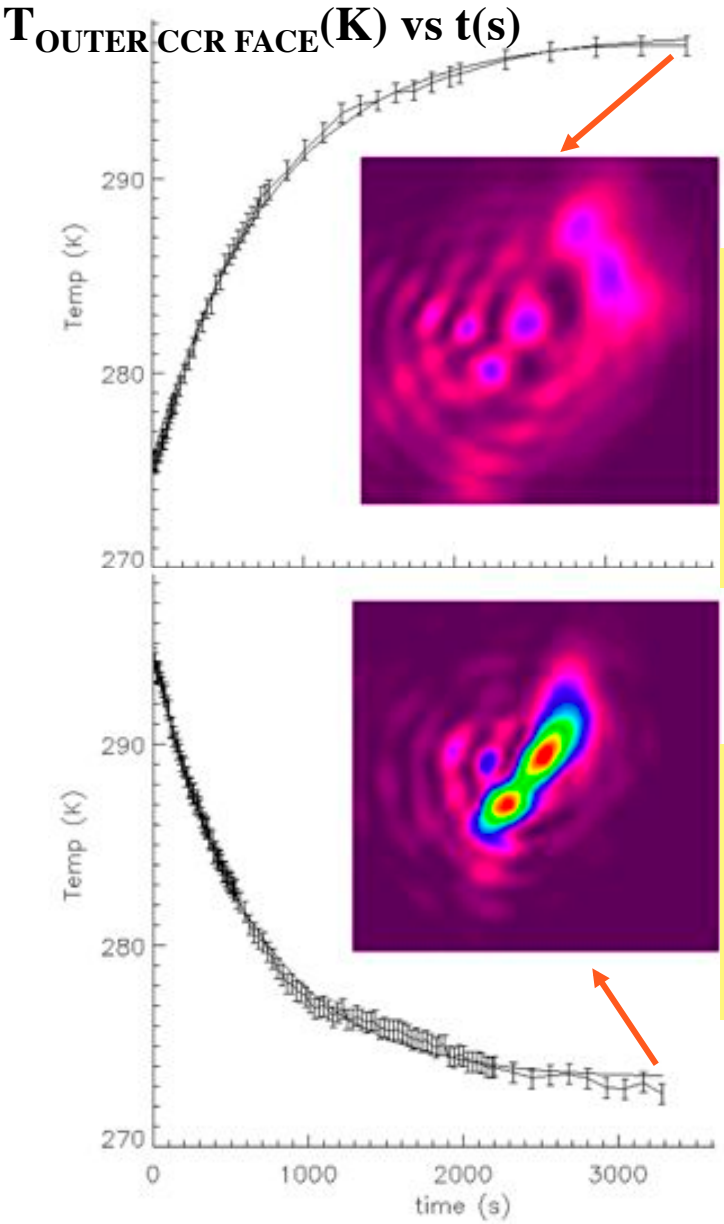
Measurement in absolute m^2, μrad units.

Below specs by factor > 5 at 20-20 μrad, because array is small and inefficient

To my knowledge this is the only measured, published optical cross section for GNSS



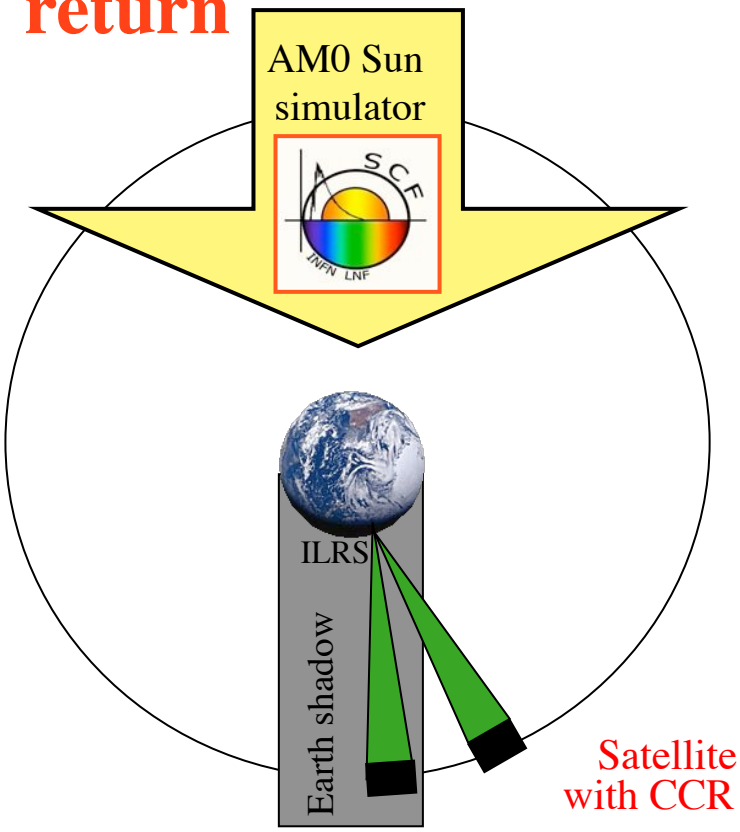
SCF-Test of GPS flight model



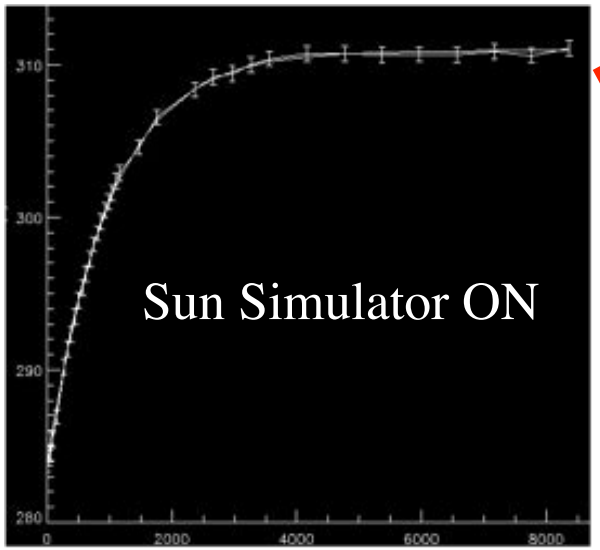
Sun on: laser return (FFDP) severely degraded

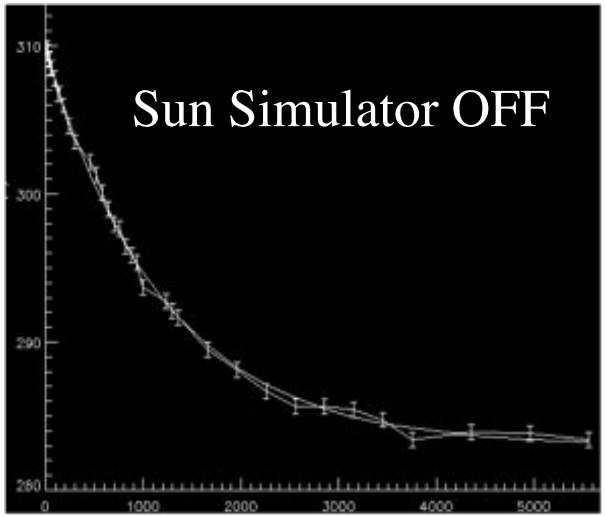
Sun off: laser return (FFDP) peaks restored

Factor ~7 reduction of laser return



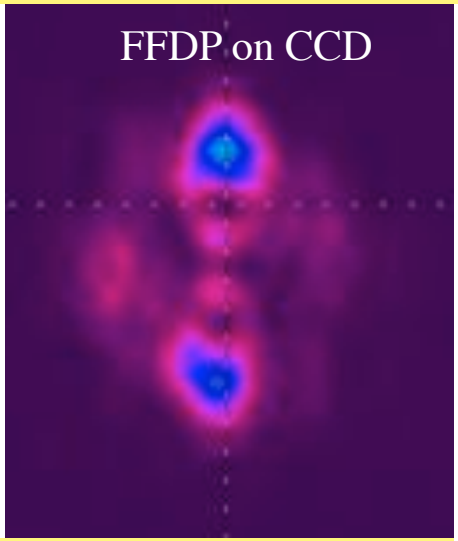
SCF-Test of GLONASS/GIOVE CCR



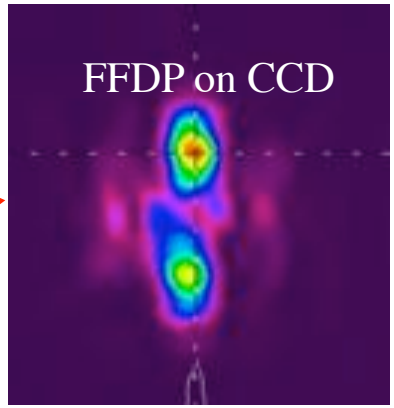


$T_{OUTER\ CCR\ FACE}$(K) vs t (sec)

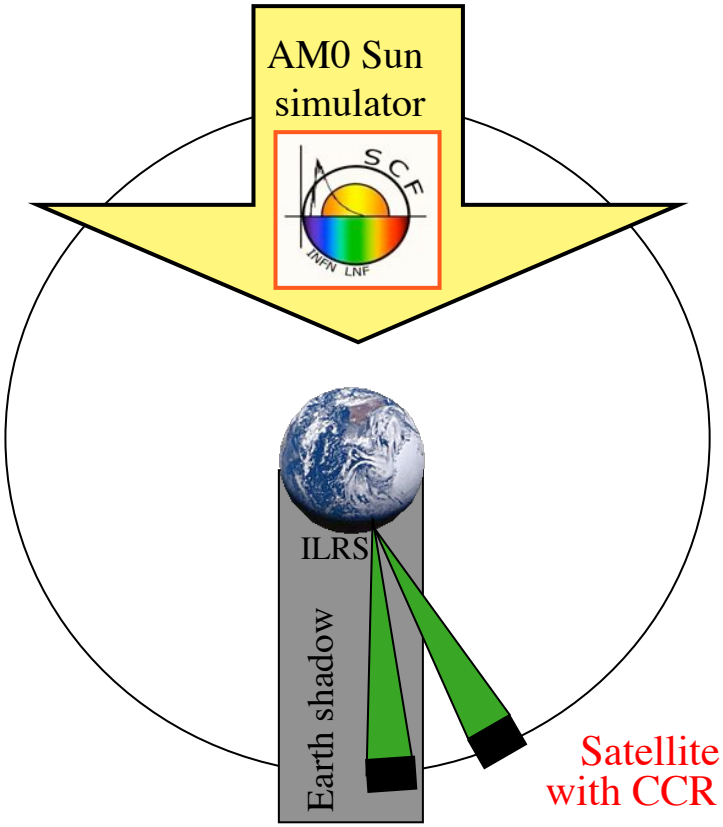
Sun on: laser return (FFDP)
Peaks severely degraded; $dist_{peaks}$~1km



Sun off: FFDP peaks restored; d_{peaks}~0.5 km



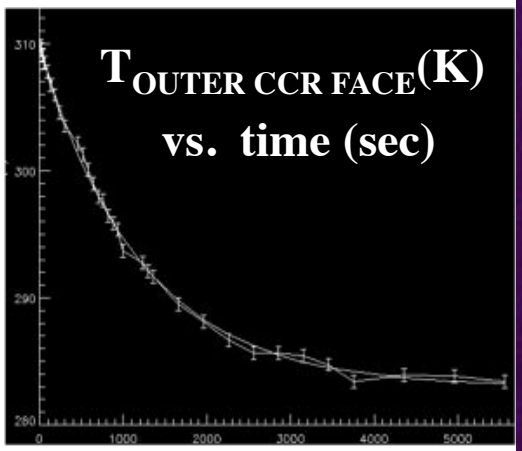
Factor ~7 reduction of FFDP

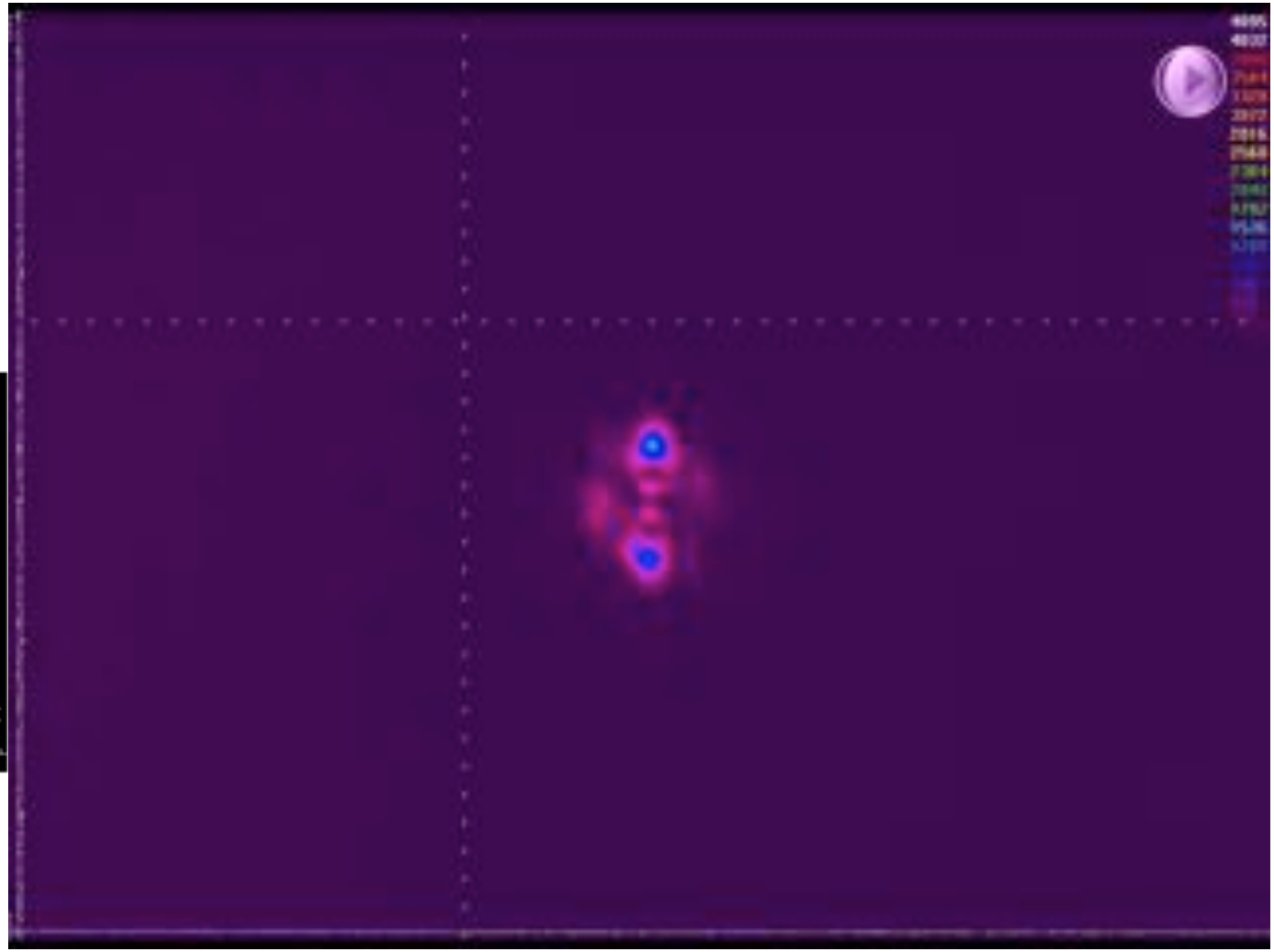


Making optical SCF movies

(of laser return)

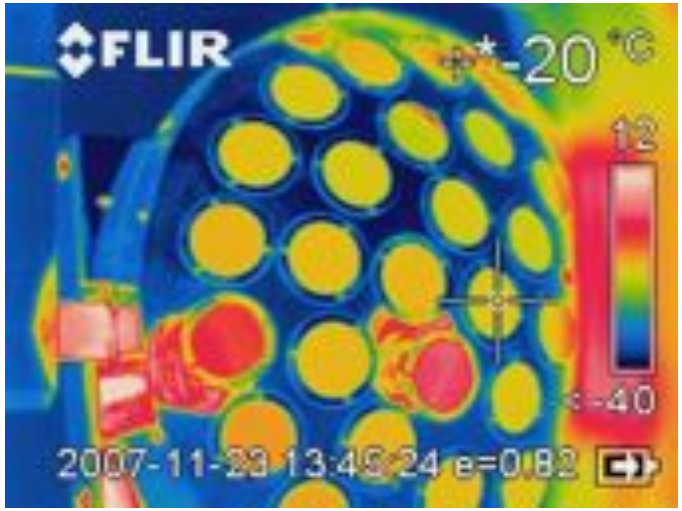
SCF-Test of GLONASS, GIOVE

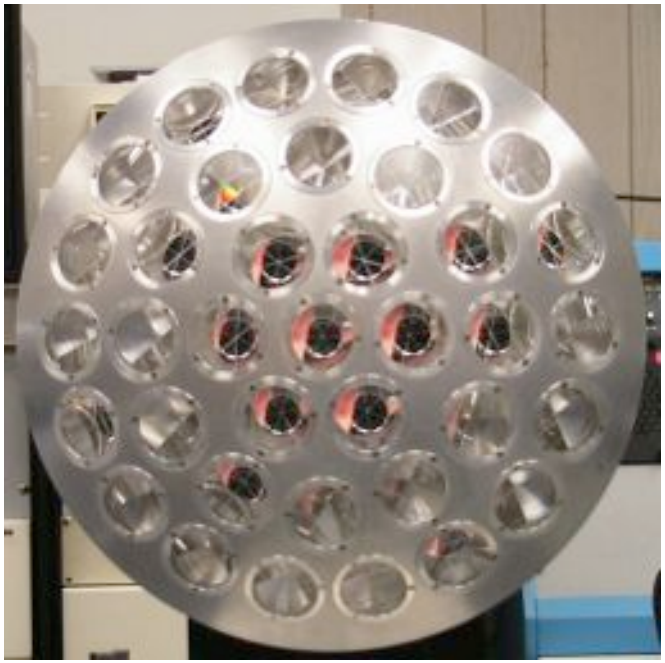




SCF-Test of LAGEOS **Sector** of NASA-GSFC

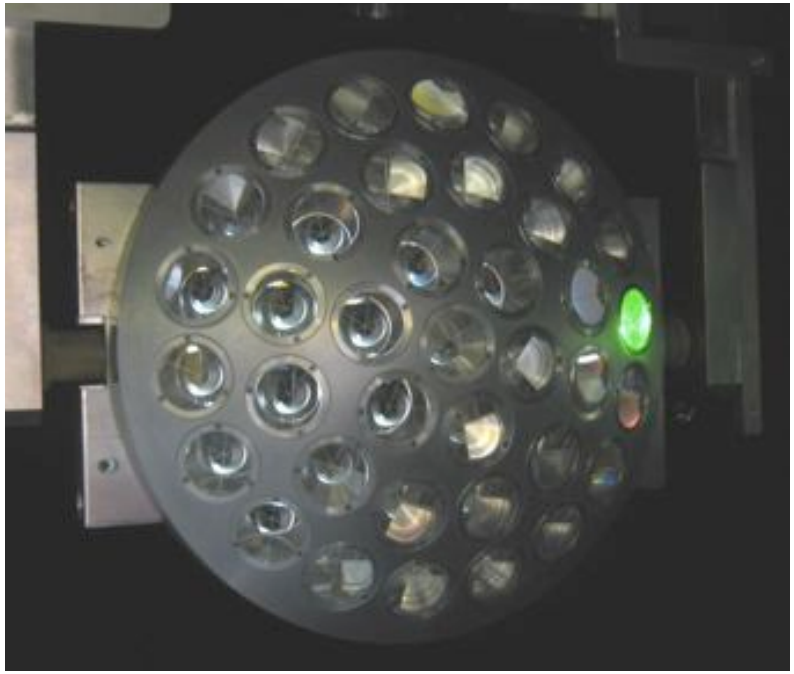
LAGEOS is the ILRS reference payload standard.





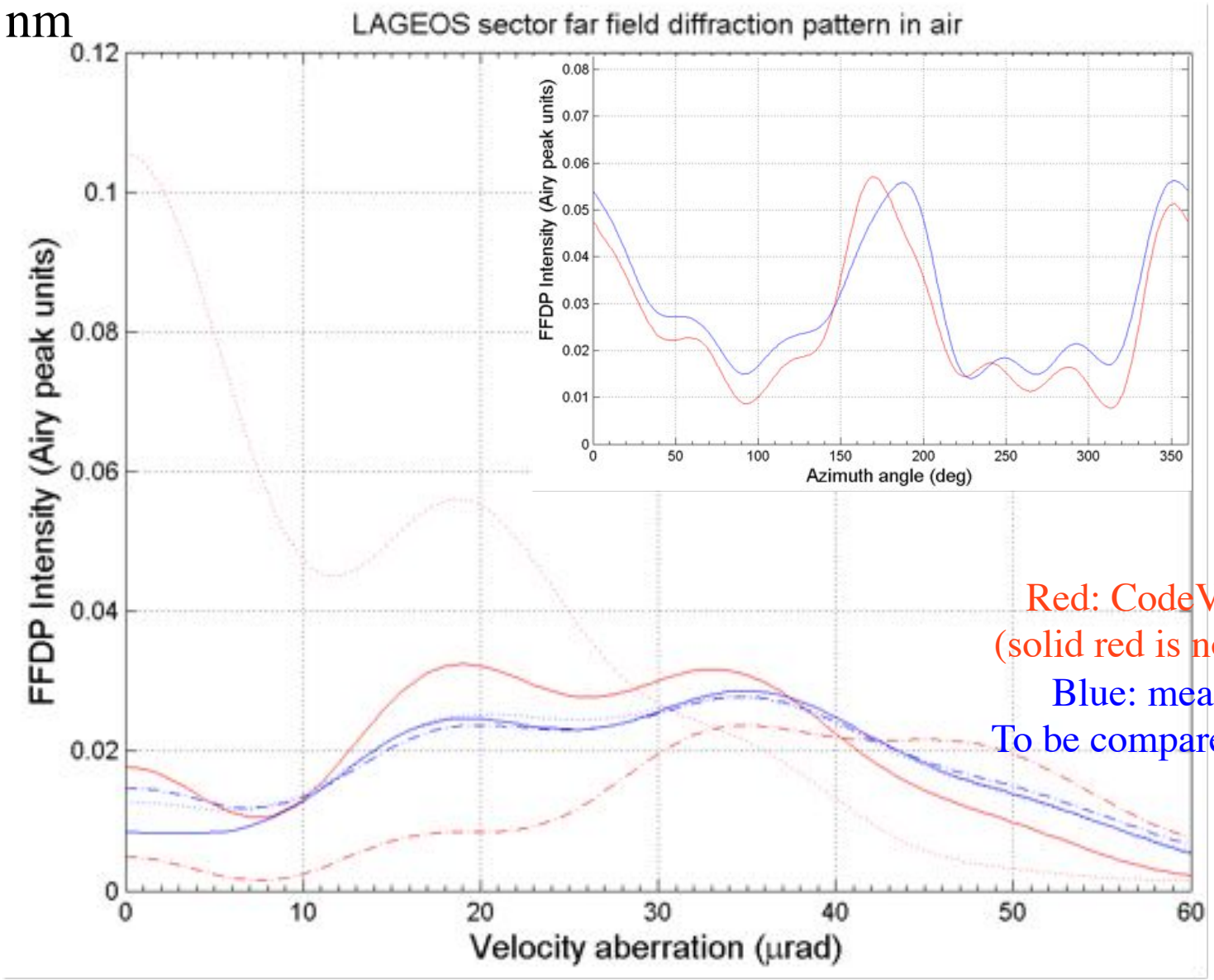
Clockwise:

SCF and its Solar, IR and Laser windows; IR photo of the Sector; laser illuminating one CCR inside the SCF; Sector at GSFC



LAGEOS optical response in air/isothermal conditions

532 nm



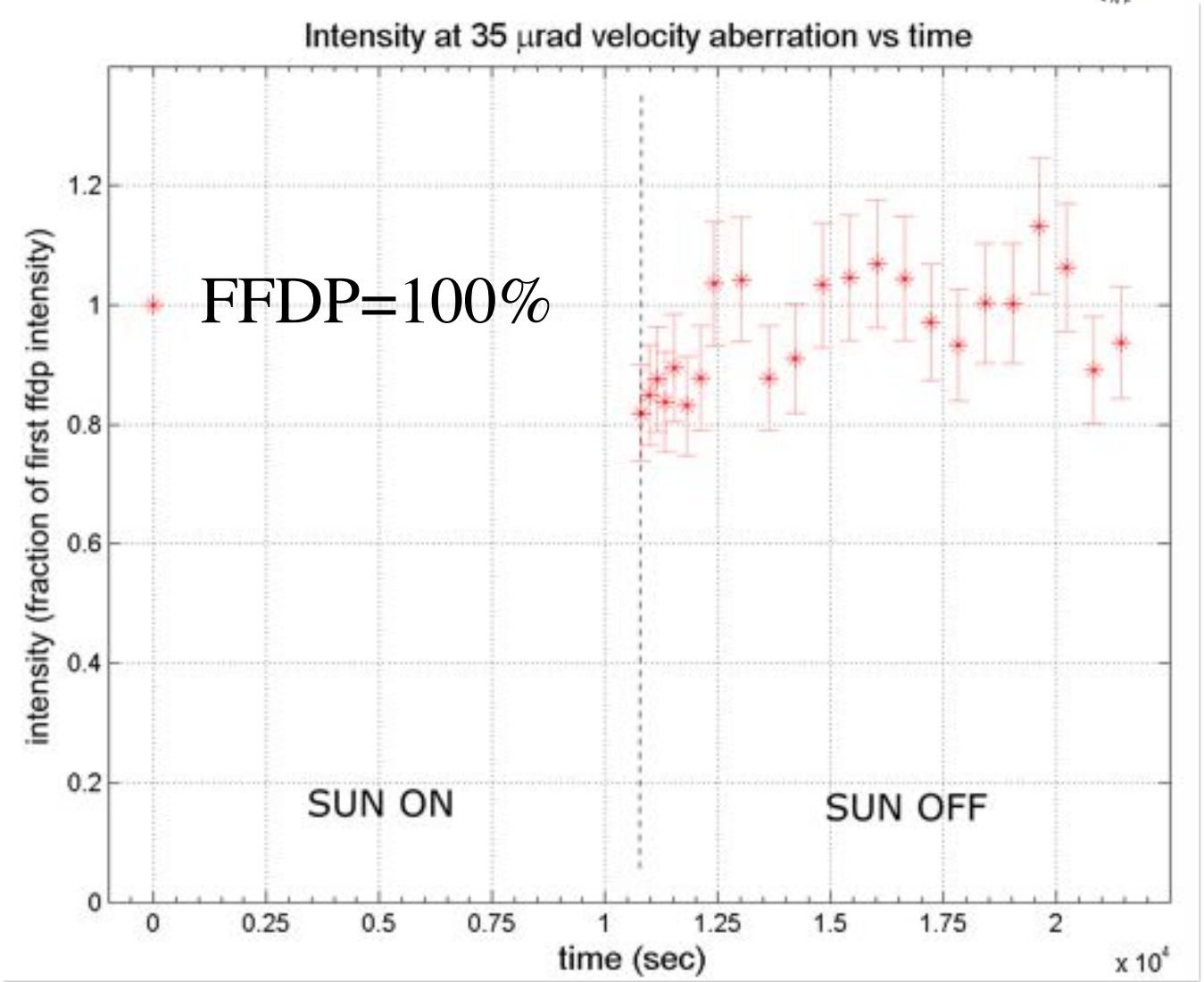
Red: CodeV simulation
(solid red is nominal curve)
Blue: measurements
To be compared to solid red

SCF-Test of LAGEOS Sector

LAGEOS is the ILRS reference payload standard:

1) **Laser response**: **modest degradation** unlike GPS, GLO, GIOVE

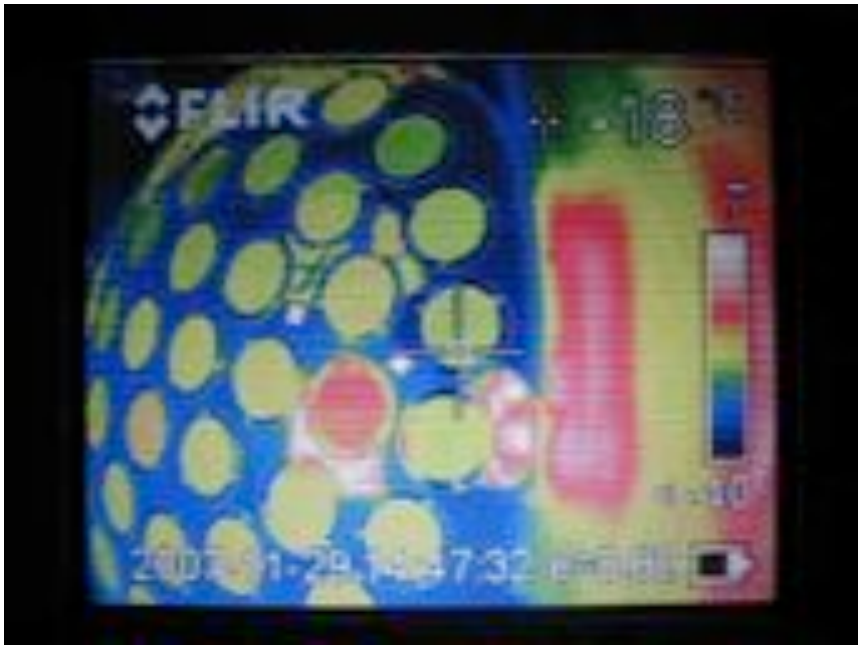
2) **Thermal behavior**: measured thermal constants in various conditions. This database of constants useful for POD.



Making thermal SCF movies

SCF-Test of LAGEOS Sector:

IR movie of Sector moving from AM0 (sun simulator) window to laser window at 90°. IR camera is in between

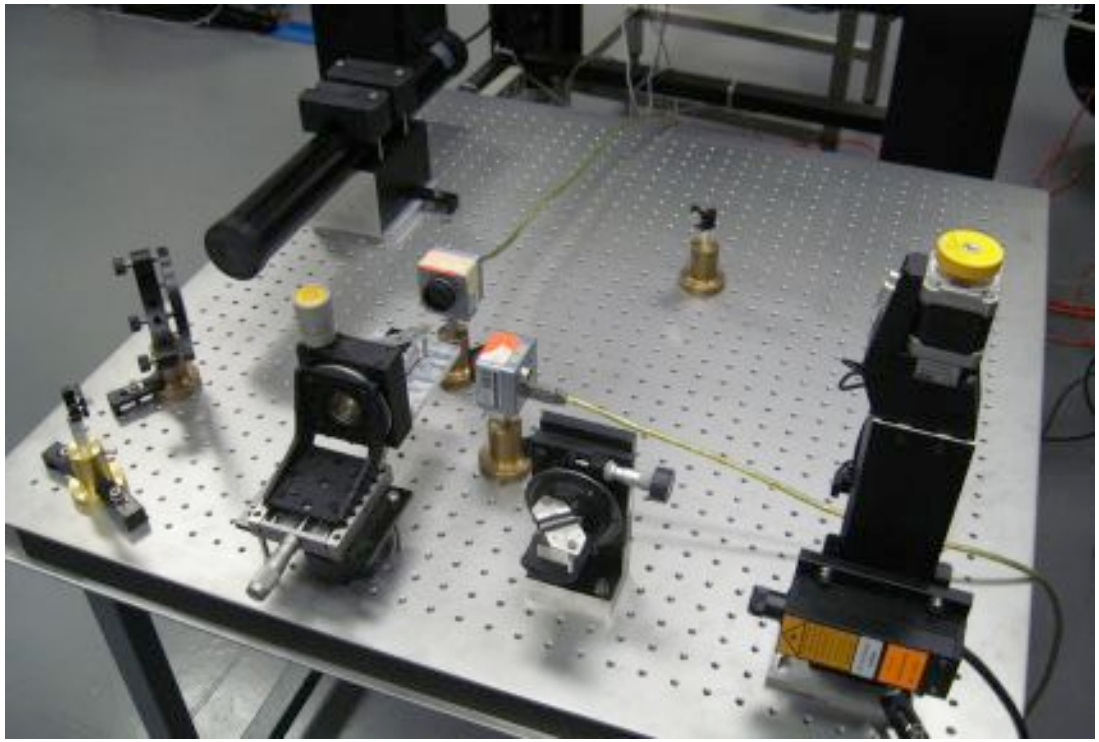


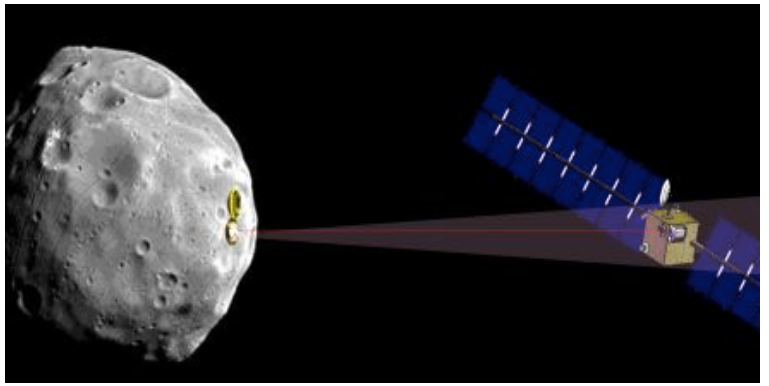
For ESA's test of Galileo reflectors, rotation accomplished in ~1-2 sec

Unique new tool: SCF-Test/Revision-IR

Space characterization of retroreflectors for laser ranging/altimetry at 1064nm from orbiters of the Moon (like **LRO**), Mars-Phobos-Deimos (**GETEMME** proposed), icy/rocky moons of Jupiter and Saturn (future Europa and Encelado landers).

Science: fundamental gravity, planetary science, space exploration

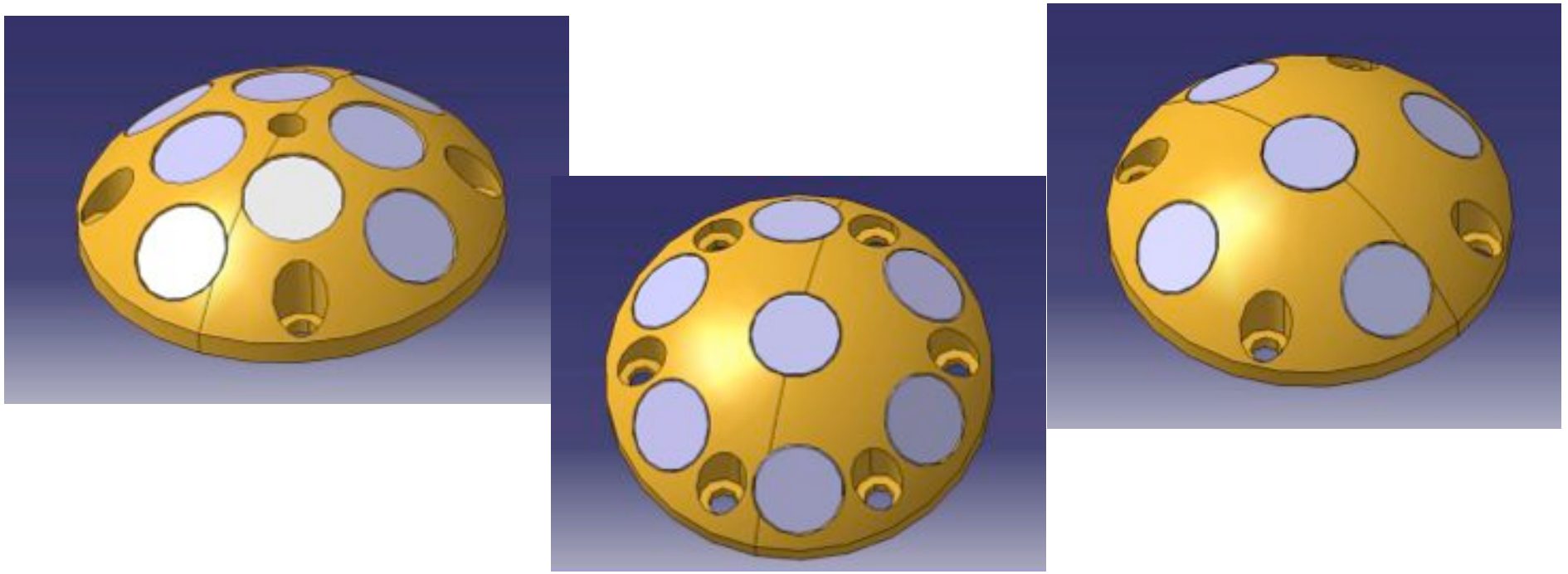




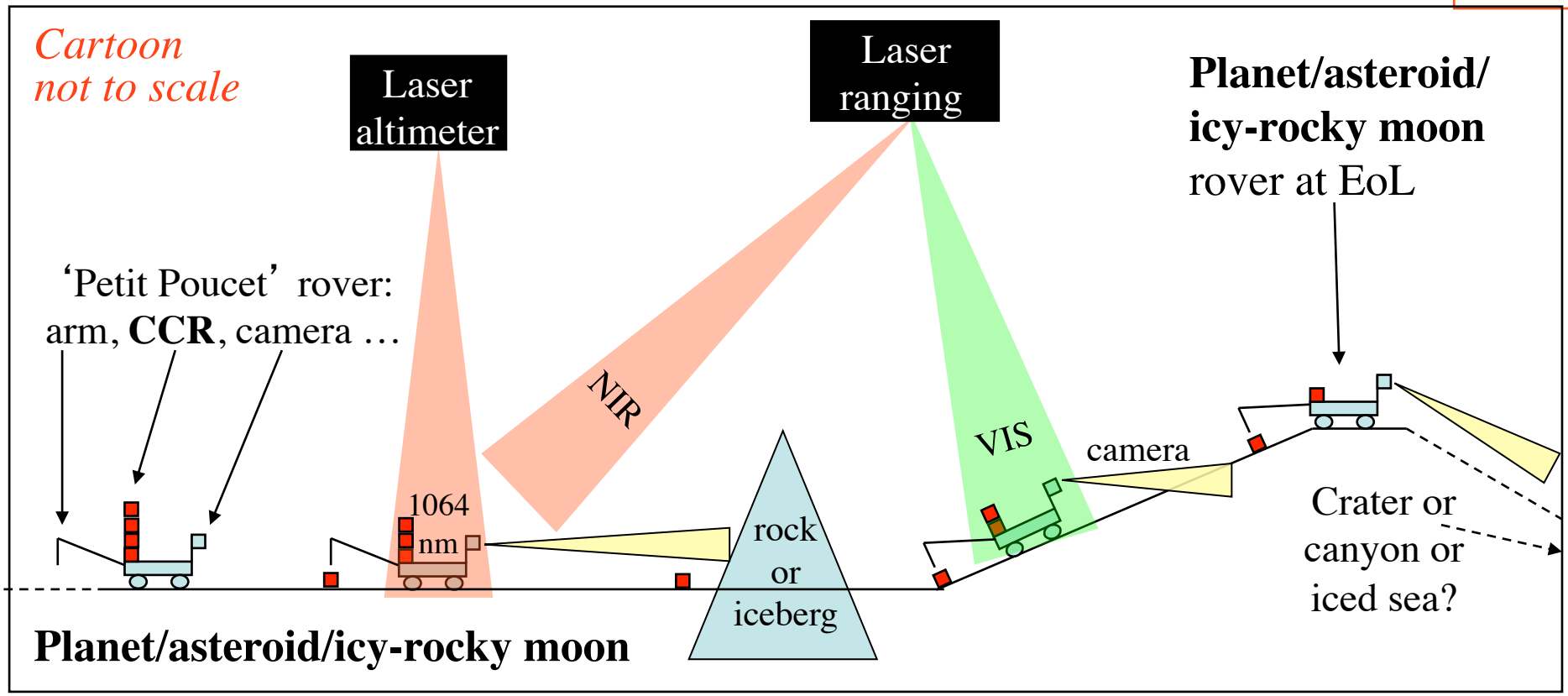
GETEMME:
Gravity, **E**instein's **T**heory, and **E**xploration of **M**artian **M**oons' **E**nvironment

Payload for planetary laser ranging/altimetry

- **INRRI: IN**strument for landing-**R**oving laser ranging/altimetry **R**etroreflector **I**nvestigations
- Passive, ~25 gr, ~60 mm×20 mm
- Proposed dor Landers/Rovers on moons and (Exo)Mars 2018
- ExoMars: approved strategic cornerstone ESA-Roskosmos mission



INRRIs at: Moon; Mars; Jupiter & Saturn moons



- From orbiters selenolocate activity of rover thanks to reflectors
  - LRO, ExoMars, GETEMME
- **INRRI networks**
- Also on far side of Earth's Moon

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

[RD-10]

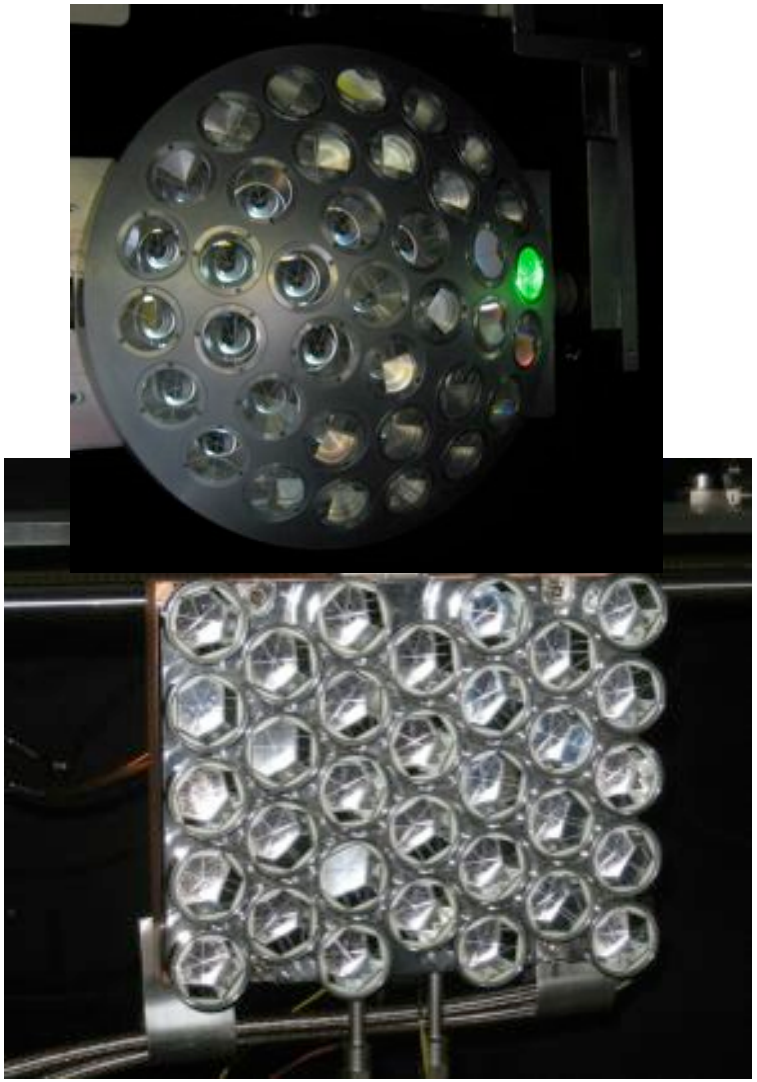
Optimized for Galileo and GPS-3

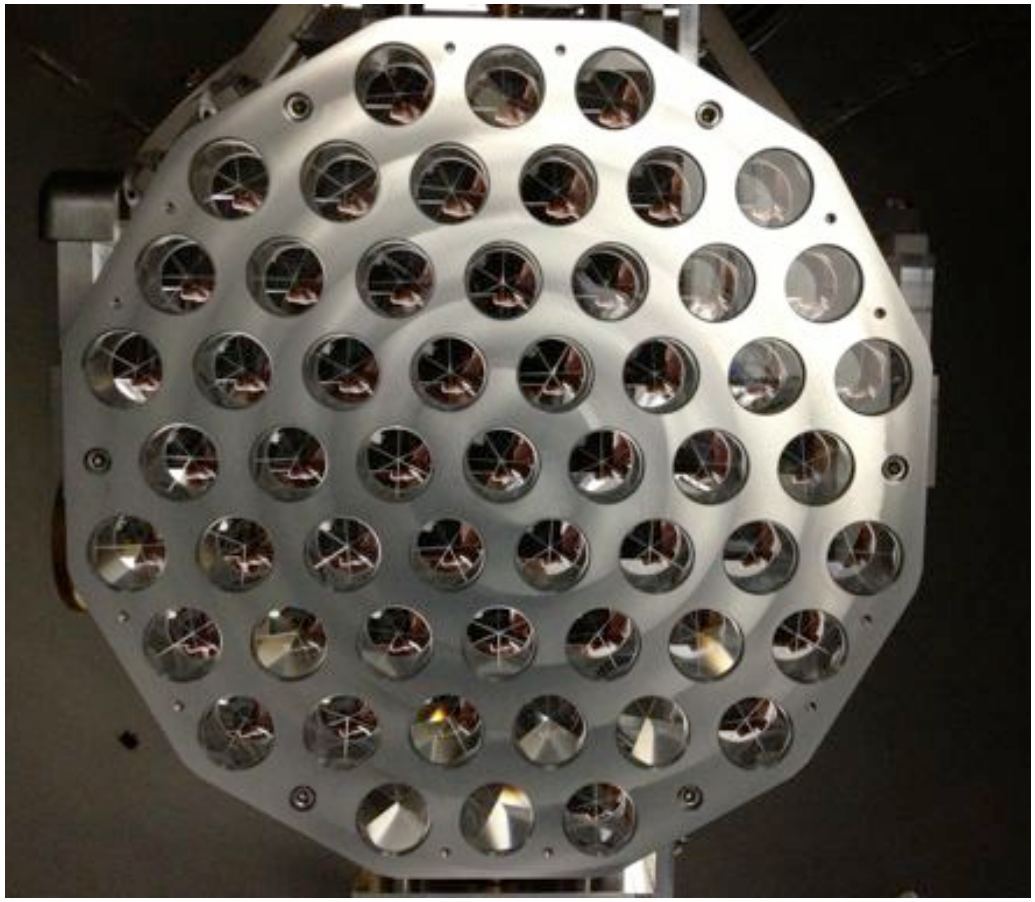
PI:
S. Dell'Agnello

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

SCF-Tested retroreflector arrays:

LAGEOS model, GPS flight reflector array
modern GNSS array for Galileo/GPS3 by INFN-ASI





For ASI did industrial optical acceptance test of LARES (in-air nominal specs, NO SCF-TEST!)

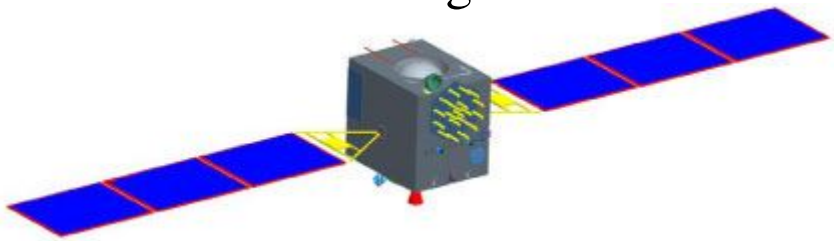
Global Navigation Satellite System (GNSS):

~100 satellites with laser retroreflectors (CCRs)

European Galileo:
30 satellites

Russian GLONASS:
24 global satellites

Chinese COMPASS:
20 global and 5
regional satellites



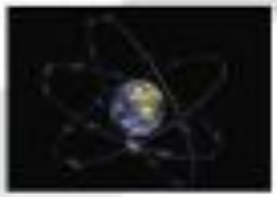
Galileo IOV (In-Orbit validation)

IOV1, IOV2 launched on Oct. 2011

IOV3, IOV4 launched on Oct. 2012

Galileo implementation plan

FOC Phase 2
All services
Total 30 satellites and ground segment



FOC Phase 1
Open Service, Search & Rescue,
Public Regulated Service
Total 18 satellites and ground segment

In-Orbit Validation
4 IOV satellites and ground segment

Galileo System Testbed
GIOVE A, GIOVE B, GIOVE mission segment

GALILEO
GIOVE

2 IOV satellites launched Oct. 2011
2 launched Oct. 2012

Galileo Services

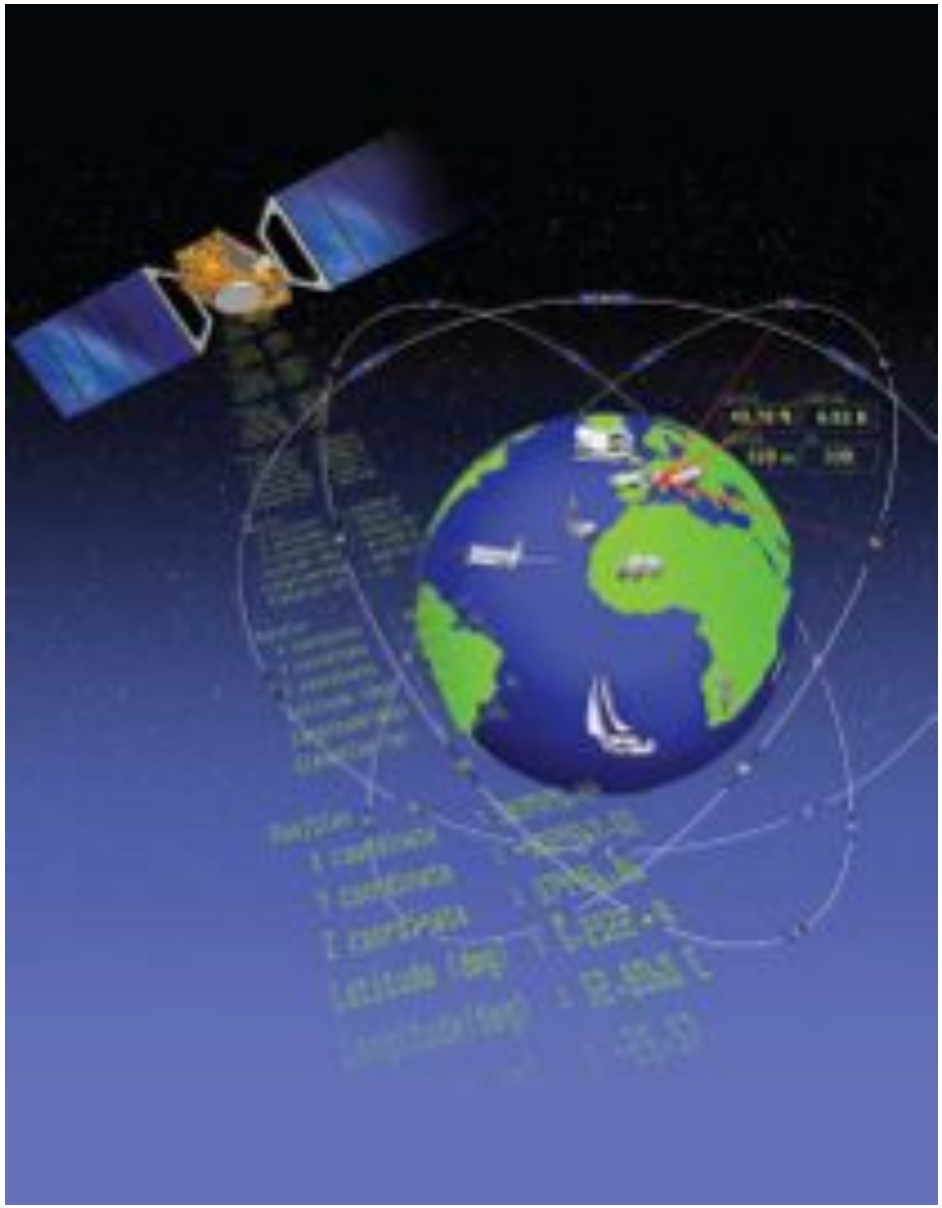
• **Open Service:** the Galileo navigational signal will be accessible by the general public free of charge, providing improved global positioning. It's the only open GNSS

• **Public Regulated Service:** two encrypted signals with controlled access for specific users such as governmental bodies.

• **Search and Rescue Service:** Galileo will contribute to the international Cospas–Sarsat system for search and rescue. A distress signal will be relayed to the Rescue Coordination Centre and Galileo will inform the user that their situation has been detected.

• **Safety-of-Life Service:** standard already available for aviation (ICAO standard) thanks to EGNOS, Galileo will further improve the service performance.

• **Commercial Service:** Galileo will provide a signal for high data throughput and highly accurate authenticated data (time synchronization), particularly interesting for professional users.

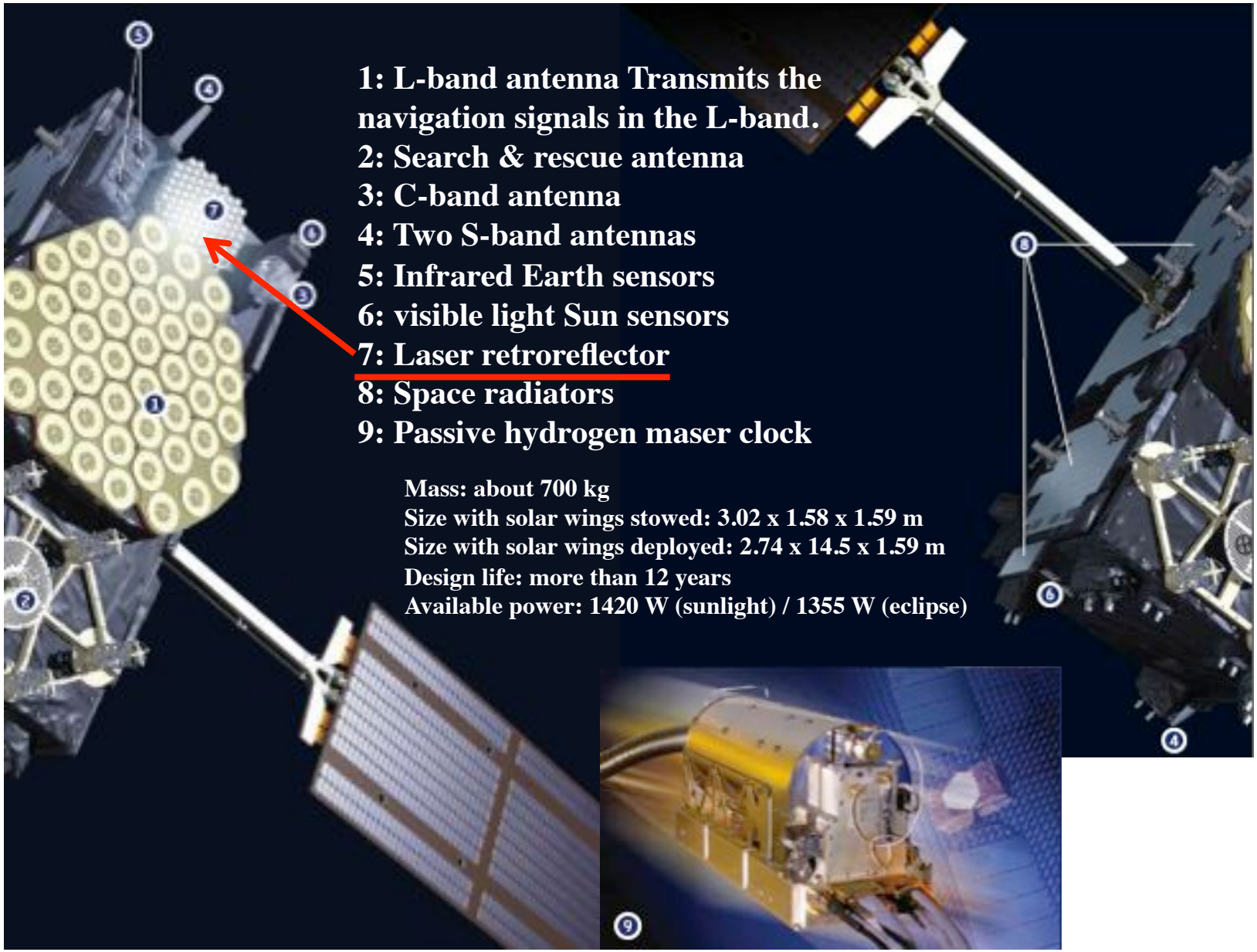


Why Europe needs Galileo?

Galileo is a strategic program:

- The European Commission (EC) estimates that 6-7% of European GDP, around 800 billion by value, is dependent on satellite navigation.
- The EC and European Space Agency (ESA) joined forces to build Galileo: Europe's independence is the chief reason.
- By being inter-operable with GPS and GLONASS, Galileo will allow positions to be determined accurately for most places on Earth, even in high rise cities where buildings obscure signals from satellites low on the horizon.
- Galileo will achieve better coverage at high latitudes.
- Europe will be able to exploit the opportunities provided by satellite navigation to the full extent.

First 4 Galileo IOV satellites



Internal anatomy of the Galileo IOV satellite

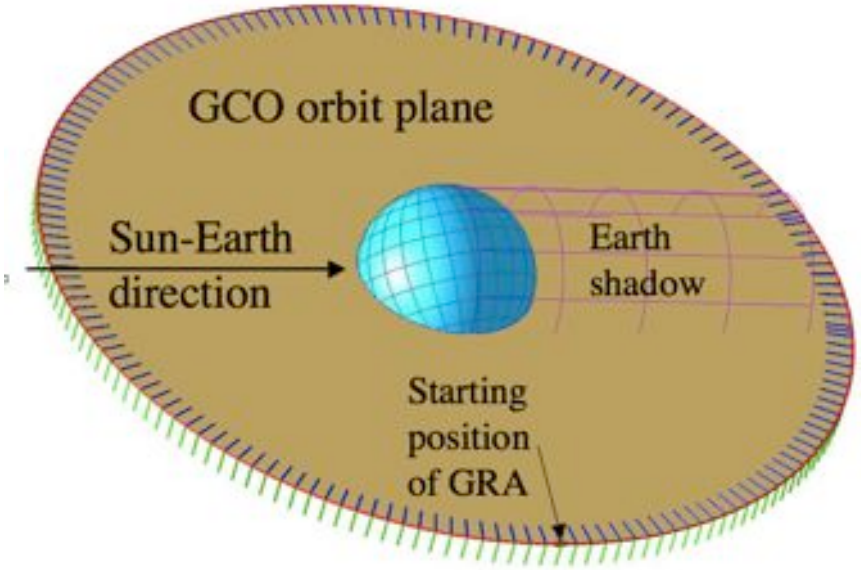
- **Rubidium clock:** an atomic clock based on a different technology, ensuring redundancy to the masers. It is accurate to within 1.8 nanoseconds over 12 hours.
- **Clock monitoring and control unit:** provides the interface between the four clocks and the navigation signal generator unit. It also ensures that the frequencies produced by the master clock and active spare are in phase, so that the spare can take over instantly should the master clock fail.
- **Navigation signal generator unit:** generates the navigation signals using input from the clock monitoring and control unit and the uplinked navigation and integrity data from the C-band antenna. The navigation signals are converted to L-band for broadcast to users.
- ***Laser retroreflector array:*** *absolute/accurate positioning of the satellite.*
- **Gyroscopes:** measure the rotation of the satellite.
- **Reaction wheels:** control the rotation of the satellite. When they spin, so does the satellite, in the opposite direction. The satellite rotates twice per orbit to allow the solar wings to face the Sun's rays.
- **Magneto-torquer:** modifies the speed of rotation of the reaction wheels by introducing a magnetism-based torque (turning force) in the opposite direction.
- **Power conditioning and distribution unit:** regulates and controls power from the solar array and batteries for distribution to all the satellite's subsystems and payload.
- **Onboard computer:** controls the satellite platform and payload.

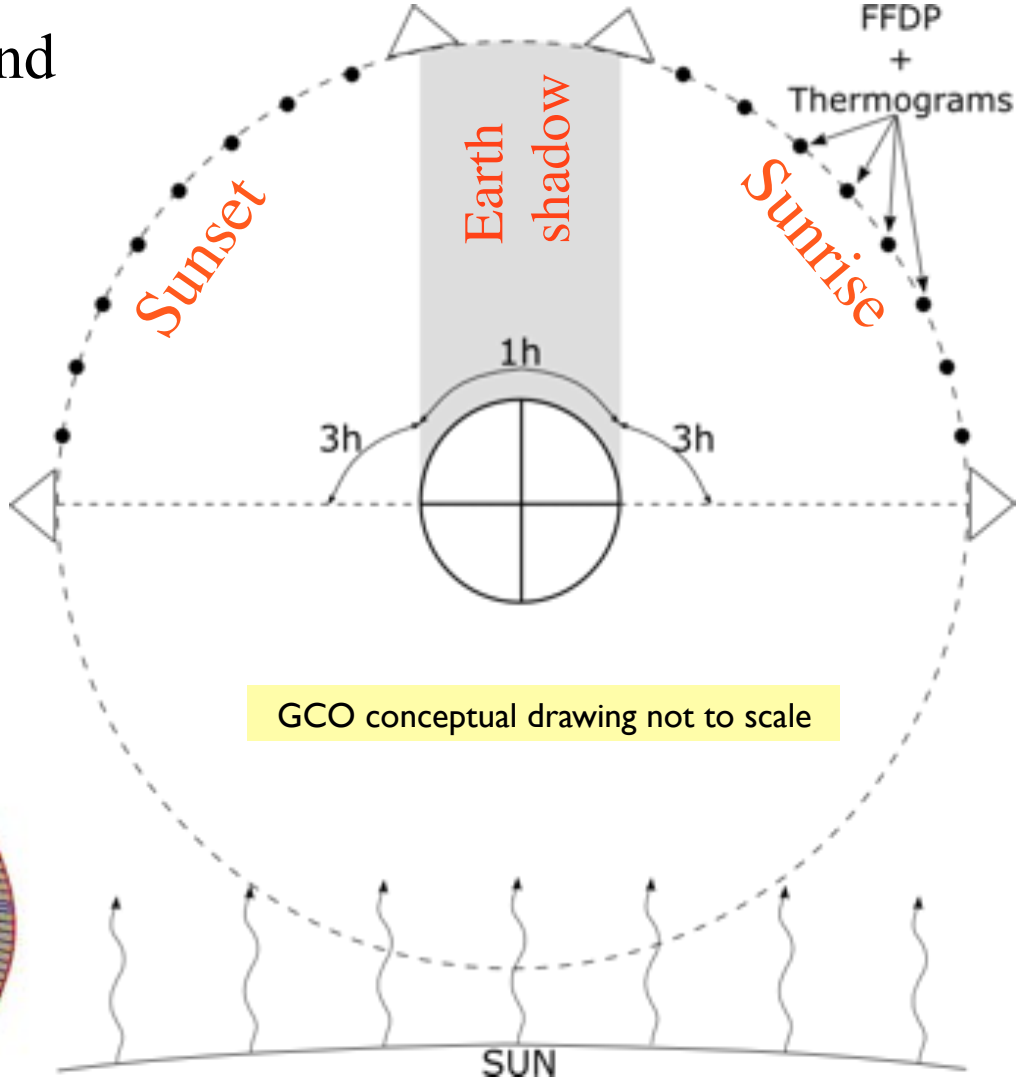
SCF-Test of Galileo Critical half-Orbit (GCO)

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

Galileo orbit:

- Altitude = 23222 km
- Period ~ 14 hr, shadow ~ 1hr





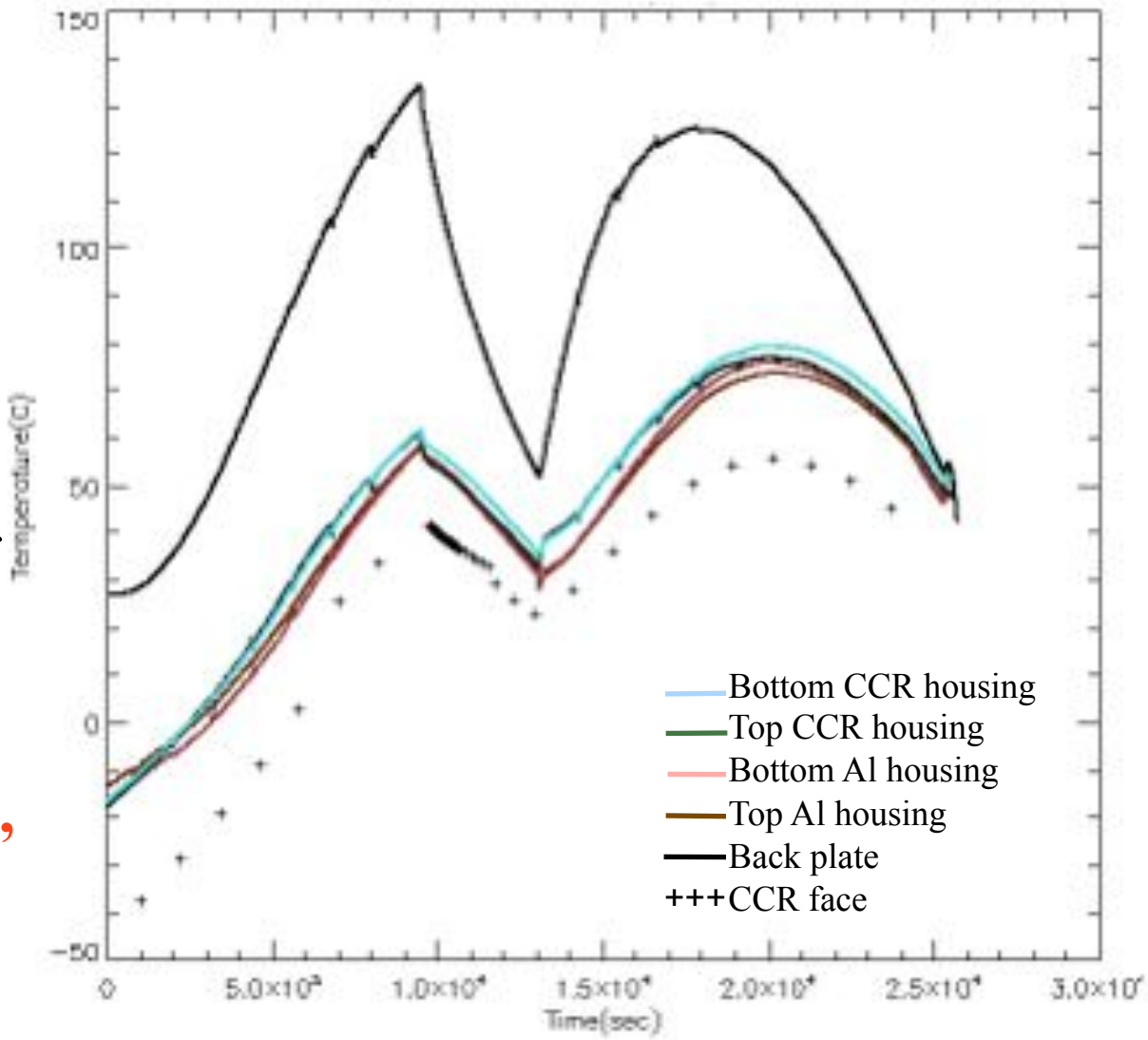
GCO conceptual drawing not to scale

Galileo reflector temperature measurements

Measured temperat. vs. time (& sun inclination):

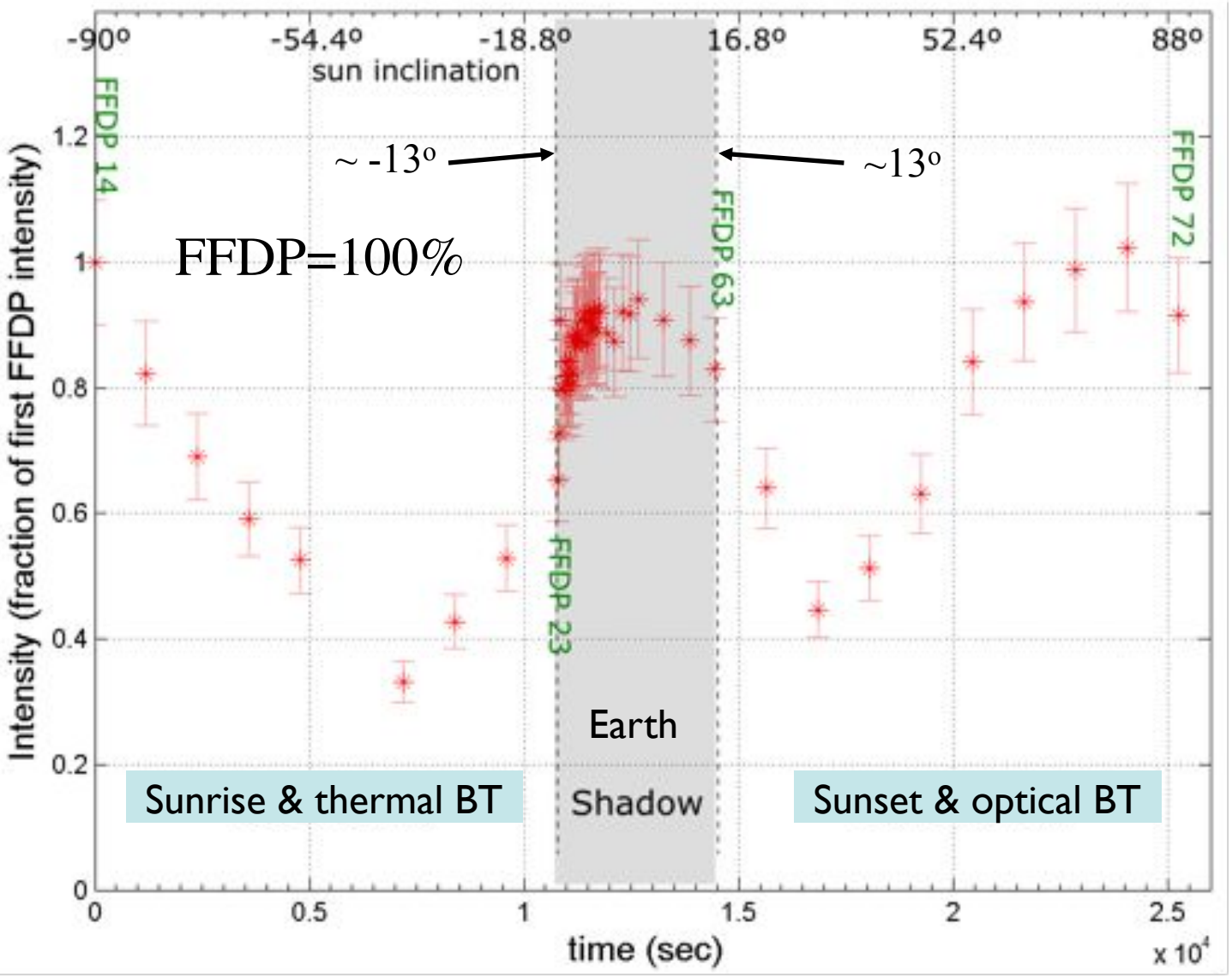
- 2 probes on CCR housing
- 2 probes on Al housing
- 1 probe on the back-plate
- IR camera thermograms of the outer CCR face

Note the very large temperature excursion, >100 K



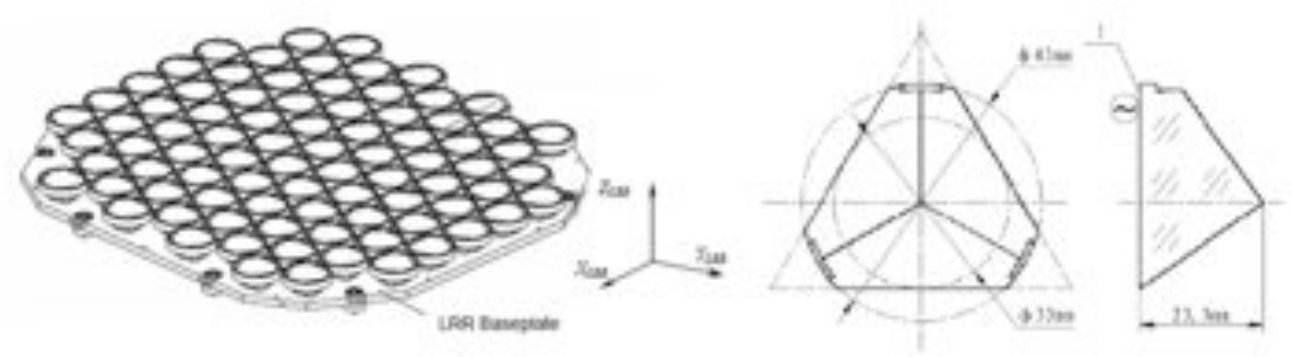
Galileo laser return intensity measurement

at 24 μrad "velocity aberration"



Recognition of Italian work for Galileo by ESA on website of International Laser Ranging Service

Galileo retroreflector array location



Galileo retroreflector array | Galileo corner cube configuration

Retroreflector information courtesy of ESA

RetroReflector Array (RRA) Characteristics:

Additional information about the Galileo retroreflector array can be found in the Galileo-101 and -102 ILRS SLR Mission Support Request Form. Specifications for the Galileo extracted from this support request form:

- Number of CCRs: 84
- CCR size: 33 mm diameter, 23.3 mm height
- Material: Doped fused silica (Suprasil 311)
- Coating: Reflective surface uncoated, incident surface coated with indium tin oxide

Additional information:

- ESA presentation on Galileo retroreflector design
- "ETRUSCO-2: An ASI-INFN Project of Technological Development and SCF-TEST of GNSS LASER Retroreflector Arrays"

INFN press release: IOV launch & SCF_Lab

GENERALE
CHI SIAMO
ORGANIZZAZIONE
PRESIDENZA
UFFICIO COMUNICAZIONE
AMMINISTRAZIONE CENTRALE
ELENCO TELEFONICO
OPPORTUNITÀ DI LAVORO
ATTIVITÀ
FISICA PARTICELLARE
ASTROPARTICELLARE
FISICA NUCLEARE
FISICA TEORICA
RICERCA TECNOLOGICA
ESPERIMENTI
PUBBLICAZIONI INFN
TESI INFN
SERVIZI
PORTALE INFN
AGENDA INFN
EDUCATIONAL
WEBCAST
MULTIMEDIA
EU FP7
Privacy Policy
Trasparenza valutazione e merito

27-10-2011: LANCIO DEI PRIMI DUE SATELLITI DI GALILEO

ELENCO COMPLETO

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Galileo, la costellazione europea di navigazione satellitare, e' un programma di bandiera dell'Unione Europea. Il lancio dei primi due satelliti Galileo in-Orbit Validation (IOV) il 21 ottobre 2011 (http://www.esa.int/SPECIALS/Galileo_IOV/) ha segnato formalmente la nascita della costellazione. Il lancio rimarra' nella storia anche come il primo in cui il lanciatore Russo Soyuz e' partito da una base fuori della Russia. Altri due satelliti Galileo IOV saranno lanciati nel 2012. Assieme ai due satelliti sperimentali GIOVE (Galileo In-Orbit Validation Elements) gia' in orbita, i satelliti IOV costituiranno il primo nucleo operativo della costellazione completa di 30 satelliti. Sviluppato in collaborazione tra la European Space Agency (ESA) e la Commissione Europea, Galileo fornira' un posizionamento di alta precisione e servizi di navigazione e sincronizzazione temporale per utenti di tutto il mondo, come servizio civile con copertura continua. Ogni satellite combina il miglior orologio atomico mai mandato in orbita per la navigazione ? dotato di un? accuratezza di un secondo su tre milioni di anni ? con un potente sistema di trasmissione dei dati di navigazione. I satelliti IOV convalideranno il progetto del?intero sistema prima del completamento e del lancio del resto della costellazione.
I satelliti GIOVE e IOV di Galileo hanno a bordo matrici di retroriflettori laser necessarie per la calibrazione assoluta della posizione dei satelliti con precisione centimetrica, grazie alla misura del tempo di volo di impulsi laser corti "sparati" dalle stazioni dello International Laser Ranging Service (http://ilrs.gsfc.nasa.gov/). Questo inseguimento laser dei satelliti (satellite laser ranging, in inglese) fornira' a Galileo un posizionamento accurato e assoluto, cioe' relativo al sistema di riferimento internazionale terrestre (http://www.iers.org/IERS/EN/DataProducts/ITRS/itrs.html). Quest?ultimo ? una terna di assi cartesiani co-rotante col nostro pianeta, la cui origine (centro di massa della Terra o geocentro) e la cui unit? di misura (metro orbitale) sono definiti con un contributo predominante dell?inseguimento laser, assieme ad altre tecniche geodetiche (inclusa la very long baseline interferometry e la stessa navigazione satellitare).

I Laboratori Nazionali di Frascati (LNF) dell?Istituto Nazionale di Fisica Nucleare (INFN) hanno compiuto la caratterizzazione spaziale delle prestazioni dei retroriflettori laser usati su due dei 24 satelliti dell?attuale costellazione GPS americana e sui due satelliti europei GIOVE, in collaborazione con la NASA e l?Universit? del Maryland (College Park, MD, USA). In collaborazione con l?ESA e l?Agenzia Spaziale Italiana (ASI), i LNF hanno iniziato nel 2010 a lavorare alla caratterizzazione di prototipi di retroriflettori laser impiegati sui satelliti Galileo IOV. I test di laboratorio sono stati effettuati presso un apparato sperimentale dedicato dei LNF, costruito principalmente per Galileo e altre costellazioni satellitari, denominato SCF (dal suo acronimo inglese Satellite/Lunar laser ranging Characterization Facility). Questo lavoro e' inserito nell?ambito delle attivita' della Commissione Scientifica Nazionale di Gruppo 5 (CSN5) e del progetto ASI-INFN di sviluppo tecnologico, ETRUSCO-2.

Factsheet di Galileo e brochure dei satelliti IOV a cura dell?ESA possono essere consultati agli indirizzi web:
? http://download.esa.int/docs/Galileo_IOV_Launch/Galileo_factsheet_20110801.pdf.
? http://download.esa.int/docs/Galileo_IOV_Launch/BR-297_Galileo_web.pdf.

Lo "SCF-Test" e i risultati derivati sono di proprieta' intellettuale dell'INFN riconosciuta da NASA, ESA e ASI, come riportato in:
? Advances in Space Research 47 (2011) 822?842.
? 3rd Int. Colloquium - Galileo Science (2011), http://www.congrex.nl/11a12/

SITI COLLEGATI ALLA NOTIZIA

CONFERENZE
02-11-2011 THIRD INTERNATIONAL WORKSHOP MELODI
23-09-2012 CHANNELING 2012 - 5TH INTERNATIONAL CONFERENCE "CHARGED AND NEUTRAL PARTICLES CHANNELING PHENOMENA" SEPTEMBER 23-28, 2012 ALGHERO, ITALY
16-10-2012 DARK FORCES SEARCHES AT COLLIDERS

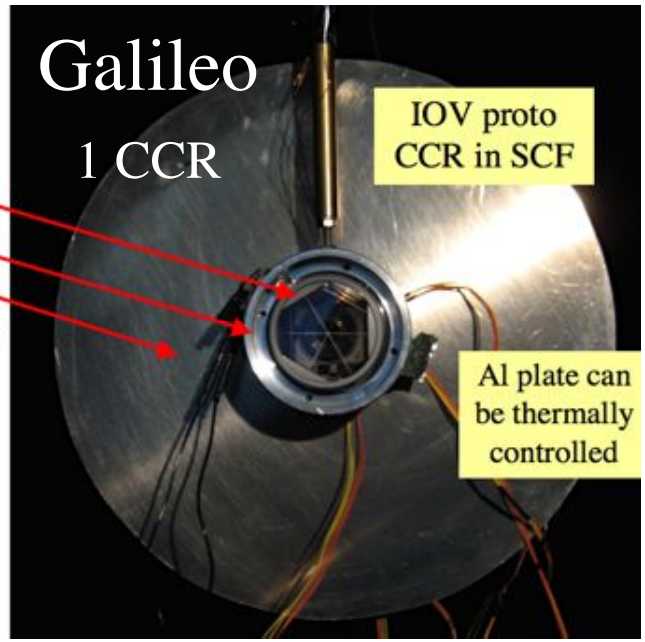
RASSEGNA
STAMPA
VIDEO

COMUNICATI STAMPA
28-10-2011 ANTONIO MASIERO ELETTO NUOVO MEMBRO DELLA GIUNTA INFN
27-10-2011 LANCIO DEI PRIMI DUE SATELLITI DI GALILEO
26-10-2011 SI INSEDIA IL NUOVO PRESIDENTE DELL'INFN

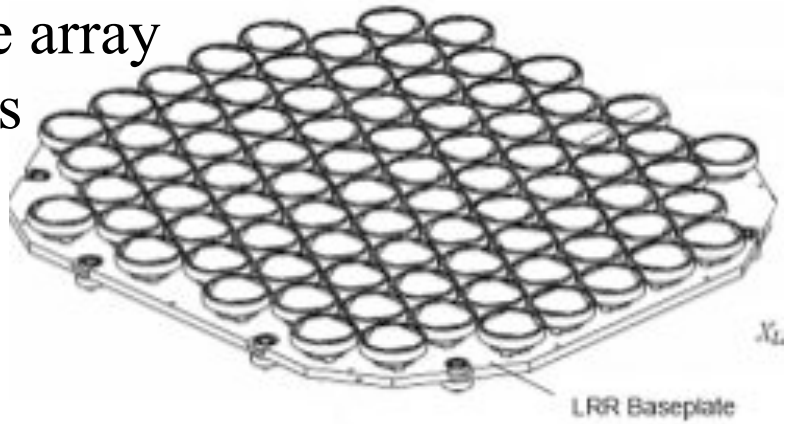
LHC ITALIA
asimmetrie.it

ETRUSCO-IOV Contract (**ESA-Galileo-INFN**):

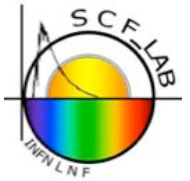
SCF-Test of IOV reflectors (CCRs)



Full-size array
84 CCRs



ETRUSCO-IOV Contract (1 year)



- Kick-off meeting on October 15, 2013
- Build 7-CCR array, test 1-by-1 & whole array
- Loan of flight 84-CCR array for Galileo IOV, to be SCF-Tested with additional Contract
- Draft ESA-INFN **MoU** for access to SCF_LAB R&D
  - ESA for Galileo / Galileo-V2 / EGNOS-V2
  - ESA contractors for any mission with retroreflectors

European Space Technology Master Plan (ESTMP)

Ultimate goal: publish SCF and SCF-Test in ESTMP, as INFN-CSN5 technology

- ESTMP analogous of the Particle Data Book (PDG) in fundamental and particle physics

- SCF/SCF-Test proposed for VQR as INFN technological product

With co-funding INFN keeps IPR

- Potential patents and royalties are Agency/ contract dependent

ETRUSCO-IRNSS: Non-competitive Invitation to Tender on SCF-Test of retroreflectors of the Indian GNSS (**IRNSS**) by the Indian Space Research Organization (ISRO)

S. Dell'Agnello (INFN-LNF) et al

GOVERNMENT OF INDIA
DEPARTMENT OF SPACE
LEOS - ISRO
1st CROSS, 1st STAGE, PEENYA INDUSTRIAL ESTATE, BANGALORE 560058
PURCHASE

Ph No: 080-28398836
Fax 080-28391964

Date :28/11/2011

INVITATION TO TENDER

Our Ref No : LEAO **2011-000261-01**

M/s 100464
INSTITATO NAZIONALE DI FISICA NUCLEARE (INFN)
VIA ENRICO FERMI, 40-00044
FRASCATI (ROME)
ITALY
Ph: 00 39 0694031 Fx: -

Tender Due: 16:00 **Hrs ISTon** 12/12/2011

Dear Sirs,

Please submit your sealed quotation , in the Tender Form enclosed here along with the descriptive catalogues / pamphlets /literature ,superscribed with Our Ref.No. and Due Date for the supply of the following items as per the terms & conditions mentioned in Annexure(Form No: ENCLOSED)

S.No.	Description of Items with Specifications	Unit	Quantity
1	FAR FIELD DIFFRATION PATTERN(FFDP)CHARACTERIZATION OF CORNER CUBE RETRO REFLECTOR ASSEMBLY IN THE SPACE CLIMATE CONDITIONS AS PER ENCLOSED RFP SPECIFICATIONS	set	1

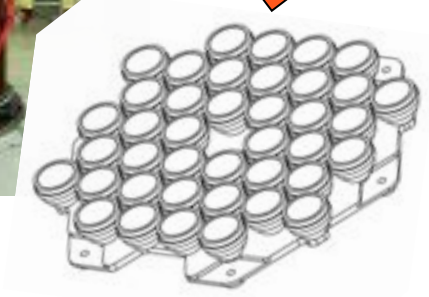
DELIVERY AT: LEOS-STORES
MODE OF DESPATCH BY ROAD
DUTY EXEMPTIONS WE ARE EXEMPTED FROM PAYMENT OF CUSTOM DUTY/ EXCISE DUTY.
SPECIAL INSTRUCTIONS NIL
SPECIFIC TERMS ENCLOSED

S.SUBRAMANYA
PURCHASE OFFICER
For and on behalf of the President of India
The Purchaser

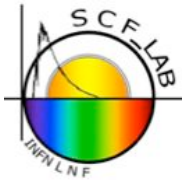
ISRO-INFN Contract for SCF-Test of IRNSS

Ongoing activity

Laser Reflector Array



G-CALIMES: Defense-INFN Contract



- Continuation, enhancement and major extension of ETRUSCO program with development of fundamental geometrodynamics networks in Earth and Space for
  - **Galileo**, and other **GNSS**
  - **GMES**: Global Monitoring for Environment and Security
  - Galileo-Cosmo-skymed Absolute Laser Intercalibration

GMES: from ESA Bulletin Feb. 2012

→ GLOBAL MONITORING FOR ENVIRONMENT AND SECURITY

GMES Space Component getting ready for operations

Monitoring of Environment with Galileo ("SatNav") and

Synthetic Aperture Radar (SAR)

SAR: Italy's CosmoSkyMed (CSK) and ESA's Sentinel-1

Next to Galileo, Global Monitoring for Environment and Security (GMES) is one of the two European Union flagship programmes in space, and another example of how space policy can contribute to improving European citizens' lives.

While the future of Galileo is secured through the EC's proposal to provide sufficient operational funding within the general budget of the EU, the long-term future of GMES has yet to be secured. Unexpectedly, last year the EC proposed to finance GMES outside the EU Multi-Annual Financial Framework (MFF), which covers the period 2014–20, suggesting instead to organise the required funding through a new intergovernmental mechanism.

In the GMES Space Component, the Sentinels and ground segment are currently in the final stages of their development and are getting ready for launch from 2013 onwards. Pre-operational data delivery from existing national and third party missions is well under way. What is most urgently needed now is securing the operational funds and consolidating the governance including Sentinel ownership and data policy.

ETRUSCO-GMES (CSN5, co-funding of G-CALIMES)

Unify observations of Galileo & Cosmo constellations, through absolute laser inter-calibrations

> GMES will provide us with crucial imagery and data on the environment, which will enable us to understand better and mitigate climate change. It will also make our agriculture and fishery more efficient. This in turn will guarantee better food quality and food security. It will also be of great help in crisis response in emergency situations during natural or manmade disasters.
>
> [illegible], President of the European Commission, November 2011

Who are the users of GMES?

Based on global observations, GMES services, developed in close collaboration with users, will provide essential information in three Earth-system domains (atmosphere, marine and land) and three cross-cutting domains (emergency management, security and climate change).

These services, once operational, will provide standardised multi-purpose information common to a broad range of EU policy-relevant application areas:

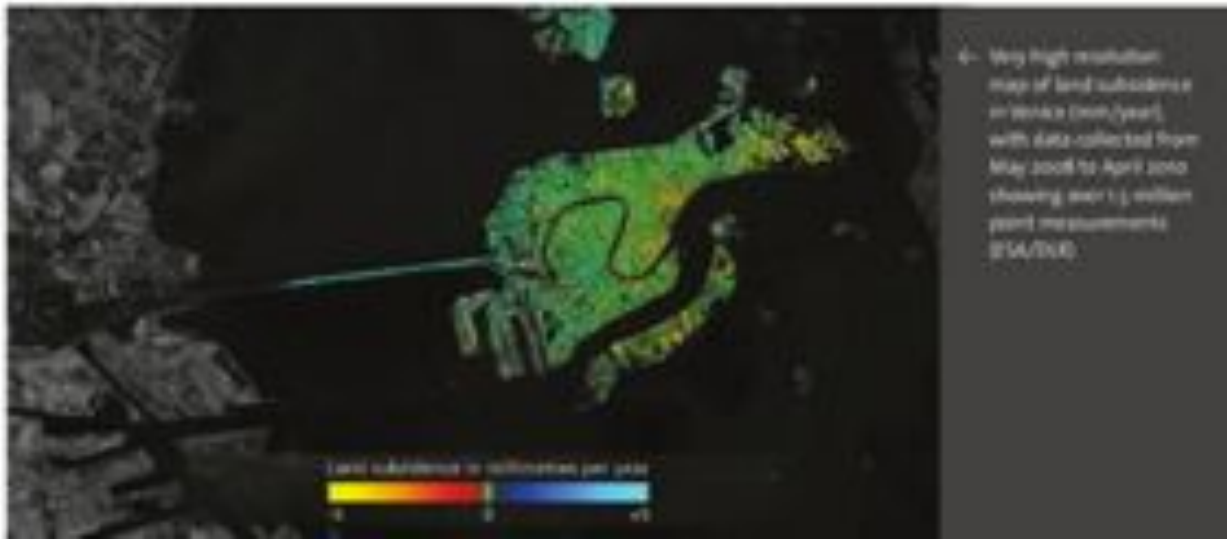
- GMES Marine Monitoring Service focused on areas such as marine safety and transport, oil spill monitoring, water quality, weather forecasting and the polar environment.

European Union Satellite Centre), private business and individual citizens. A large variety of commercial industry segments will also benefit through the development and provision of operational geo-services.

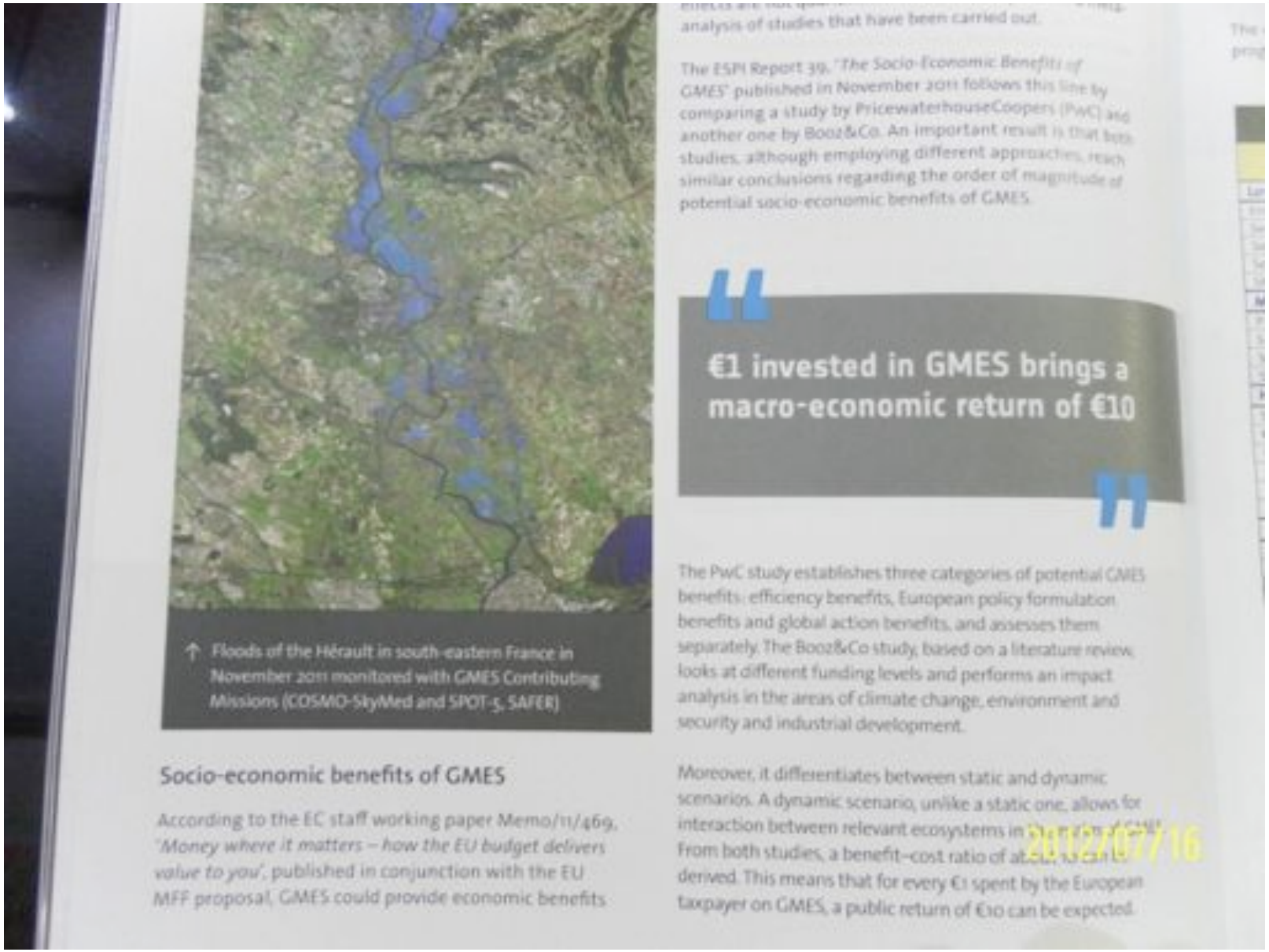
At a regional level, GMES is already used to monitor air quality, map coastlines, regional areas and urban expansion and to manage marine and agricultural resources. GMES also plays a key role in disaster management and prevention.

On air quality for instance, GMES currently provides daily (three-day) air quality forecasts and historical records of key industrial pollutants such as ozone, nitrogen dioxide, sulphur dioxide and aerosols for the major cities and regions of Europe. The forecasts form the basis for the management of health risks of citizens suffering from asthma or other symptoms. The

From ESA Bulletin Feb. 2012



GMES: from ESA Bulletin Feb. 2012



analysis of studies that have been carried out.

The ESPI Report 39, *'The Socio-Economic Benefits of GMES'* published in November 2011 follows this line by comparing a study by PricewaterhouseCoopers (PwC) and another one by Booz&Co. An important result is that both studies, although employing different approaches, reach similar conclusions regarding the order of magnitude of potential socio-economic benefits of GMES.

€1 invested in GMES brings a macro-economic return of €10

The PwC study establishes three categories of potential GMES benefits: efficiency benefits, European policy formulation benefits and global action benefits, and assesses them separately. The Booz&Co study, based on a literature review, looks at different funding levels and performs an impact analysis in the areas of climate change, environment and security and industrial development.

Moreover, it differentiates between static and dynamic scenarios. A dynamic scenario, unlike a static one, allows for interaction between relevant ecosystems in [illegible]. From both studies, a benefit–cost ratio of at [illegible] is derived. This means that for every €1 spent by the European taxpayer on GMES, a public return of €10 can be expected.

↑ Floods of the Hérault in south-eastern France in November 2011 monitored with GMES Contributing Missions (COSMO-SkyMed and SPOT-5, SAFER)

Socio-economic benefits of GMES

According to the EC staff working paper Memo/11/469, *'Money where it matters – how the EU budget delivers value to you'*, published in conjunction with the EU MFF proposal, GMES could provide economic benefits

Another application and EU flagship programme: GMES - Observing our planet for a safer world

Managing natural resources and biodiversity, observing the state of the oceans, monitoring the chemical composition of our atmosphere: all depend on accurate information delivered in time to make a difference. The European initiative for the **G**lobal **M**onitoring for **E**nvironment and **S**ecurity (GMES) will provide data to help deal with a range of disparate issues including climate change and border surveillance. Land, sea and atmosphere - each will be observed through GMES, helping to make our lives safer.

The purpose of GMES is to deliver information on environment and security which correspond to identified **user needs**

SCF_Lab @ LNF

LNF infrastructure for

R&D and industrial Services on laser retroreflector-based

Geometrodynamics for Gravity, GNSS, GMES, EO, …

SCF_Lab

Satellite/Lunar/GNSS

laser ranging and altimetry

Characterization **F**acilities **Lab**oratory

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