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DESIGN, CONSTRUCTION AND SCF-TEST OF A LASER-RANGED TEST MASS FOR THE DEEP SPACE GRAVITY PROBE MISSION AND SCF-TEST OF A HOLLOW RETROREFLECTOR FOR THE GPS-3

Work Package 5200 of the 3-Year Study (June 2007, June 2010) of the Italian Space Agency on "Cosmology and Fundamental Physics (COFIS)"

S. Berardi[1], A. Boni[1], C. Cantone[1], S. Dell'Agnello[1], G. O. Delle Monache[1], M. Garattini[2], N. Intaglietta[1], C. Lops[3], M. Maiello[4], M. Martini[2], R. Napolitano[5], L. Porcelli[2], M. Tibuzzi[5]

[1] *INFN, Laboratori Nazionali di Frascati (LNF), Via E. Fermi 40, Frascati, I-00044, Italy*
[2] *INFN-LNF and Dept. of Physics, University of Rome "Tor Vergata"*
[3] *INFN-LNF and Dept. of Physics, University of Rome "Roma Tre"*
[3] *INFN-LNF and Dept. of Physics, University of Rome "Sapienza"*
[5] *INFN-LNF and Dept. of Mechanical Engineering, University of Rome "Tor Vergata"*

Abstract

The "Satellite/lunar laser ranging Characterization Facility" (SCF) of INFN-LNF in Frascati, Italy, is devoted to the characterization of the detailed thermal properties and the optical performance of laser-ranged payloads (the "SCF-test") for GNSS (Global Navigation Satellite System Constellation), Space Geodesy and Fundamental Physics applications [1][2]. The Optical Lab is an LNF facility dedicated to the far field diffraction pattern (FFDP) industrial acceptance test of laser cube corner retroreflectors (CCR) for space applications. We tested about 200 flight CCRs to be deployed in space by imminent launches at these two LNF facilities. These launches are for the current American GPS-2 by NASA (32 CCRs) and for the European VEGA Program (115 CCRs), by ESA/ASI. Some of the tested CCRs are for undisclosed missions by other space agencies. 37 flight quality CCRs belong to the so-called LAGEOS "Sector" loaned by NASA-GSFC to LNF for testing.

Deep Space Gravity Probe (DSGP) is a mission led by NASA-JPL (S. Turyshev is the PI), proposed to NASA and to the ESA "Cosmic Vision" program to study the anomalous deceleration of the Pioneer 10 and 11 probes and other important interplanetary science topics. In the context of a three-year study on "Cosmology and Fundamental Physics" (COFIS) funded by ASI and led at national level by P. de Bernardis we designed a prototype laser-ranged test mass for the DSGP satellite formation. This mass is being built at LNF and will be SCF-Tested at the SCF.

We also want to collaborate with NASA-GSFC (J. McGarry et al) on the test of innovative CCRs for the GPS-3. The goal of this R&D is to assess the functionality of the hollow retroreflector design. This is a prerequisite to propose the deployment of these retroreflectors on the GPS-3. We report the results of the FFDP test of a hollow CCR prototype in air and isothermal conditions. In view of the SCF-Test, which could modify its structure, we did a geometric survey of the CCR with a contact coordinate measuring machine (CMM). We also started structural modeling of hollow CCRs.

Thermal and FFDP Characterization (SCF-Test) of Laser Retroreflector Arrays

The space characterization of laser cube corner retroreflectors (CCRs) for GNSS, Space Geodesy and Fundamental Physics applications at INFN-LNF is described in [1][2][3].

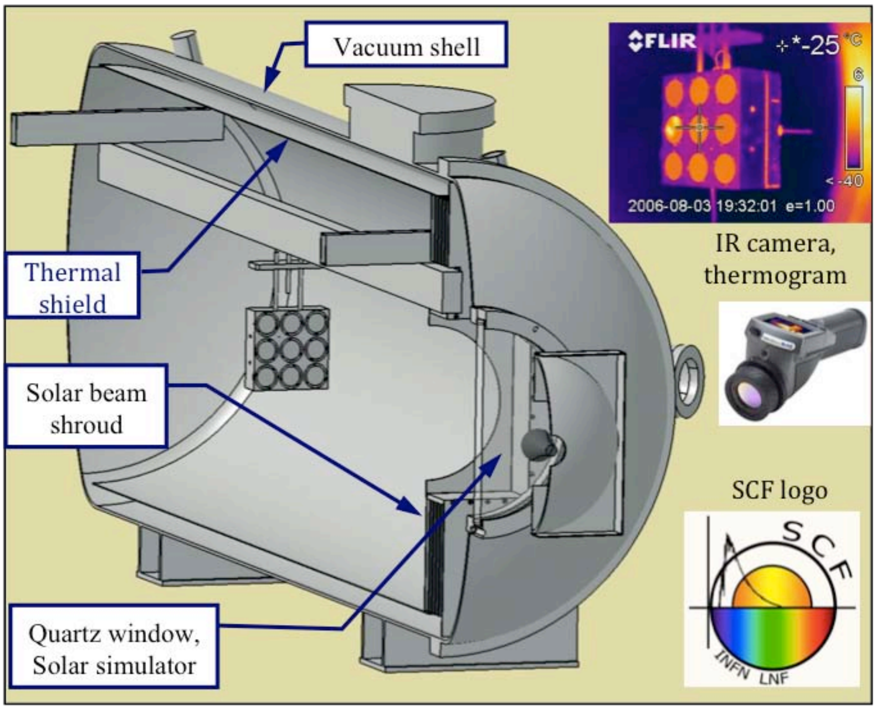

Figure 1 – The SCF with the LAGEOS matrix built at LNF. A temperature photo taken with the IR camera and the IR camera are shown at the right. Bottom right is the SCF logo.

The Pioneer Anomaly and the DSGP Mission

The so-called "Pioneer Anomaly" (PA) is the apparent deceleration of the Pioneer 10 and 11 spacecrafts with respect to the $1/r^2$ force-law. Several explanations due to instrumental or new physics effects have been advocated. Detailed understanding of the thermal recoil forces acting on the old probes and any new mission is of the utmost importance in order to disentangle potential new physics from instrumental effects (see [5] and references therein). This is the area where INFN-LNF can give an original contribution with its expertise and the SCF-Test. In fact, the PA is about 10^{-9} m/sec^2. With our SCF we can characterize TTs smaller than, for example, 10% of the largest TTs experienced by LAGEOS, that is, about 10^{-10} m/sec^2 [3]. This means that with the SCF measurements and our software suite we can model the effect of TTs [3] on DSGP test masses of the order of 1% of the PA.

To probe gravity in the outer solar system and avoid the experimental complications of the old Pioneer spacecrafts, a new concept of interplanetary mission has been conceived by JPL and other European research groups (including LNF, through COFIS). This is the satellite formation shown in fig. 2. DSGP proposed to NASA and as a candidate ESA mission for Cosmic Vision, will study gravity at large distance from the sun (up to 80 AU) and will verify the PA. Presently the formation consists of a main active satellite that will release few spherical laser-ranged test masses. The motion of the masses with respect to Earth will be measured through radio waves (Earth to active satellite) and through SLR (active satellite to test masses), with an SLR distance of 250 m to 1 Km. The deep space test masses are spheres equipped with CCRs. The mother-ship active spacecraft, unlike the Pioneer probes, will be forward-backward symmetric. Starting from Saturn, more than one test mass will be released by the mother-ship during the interplanetary journey, in order to test the $1/r^2$ force-law in different regions of the solar system (and especially at large distances form the Sun).

Laser-ranged Test Masses for DSGP

We propose the deployment of several test masses during the mission. We also propose that they are made of different materials, also to test the weak equivalence principle in deep space, which has never been done before.

The test mass characterization will consist of: FFDP test in isothermal conditions; FFDP and thermal test in the SCF conditions. In deep space the magnitude thermal TTs is enormously reduced compared to those suffered by LAGEOS near the Earth, since in the beyond Saturn (>10AU) the solar constant is reduced by more than two orders of magnitude compared to the Earth solar constant AM0 (1370 W/m^2). TTs are proportional to the Surface/Mass (S/M) ratio and to the solar constant in AM0 units:

- LAGEOS (30 cm radius, 400 Kg weight): (S/M)×AM0 = 7 (cm^2/Kg)×AM0,
- DSGP (>10AU, r = 8 cm, w = 2 Kg): (S/M)×AM0 < 1 (cm^2/Kg)×AM0.

This means that several test masses small and light enough to be conveniently carried by an interplanetary spacecraft will have a good SLR performance and can be well SCF-Tested and modeled keeping the TT background well under control with respect to the value of the PA.

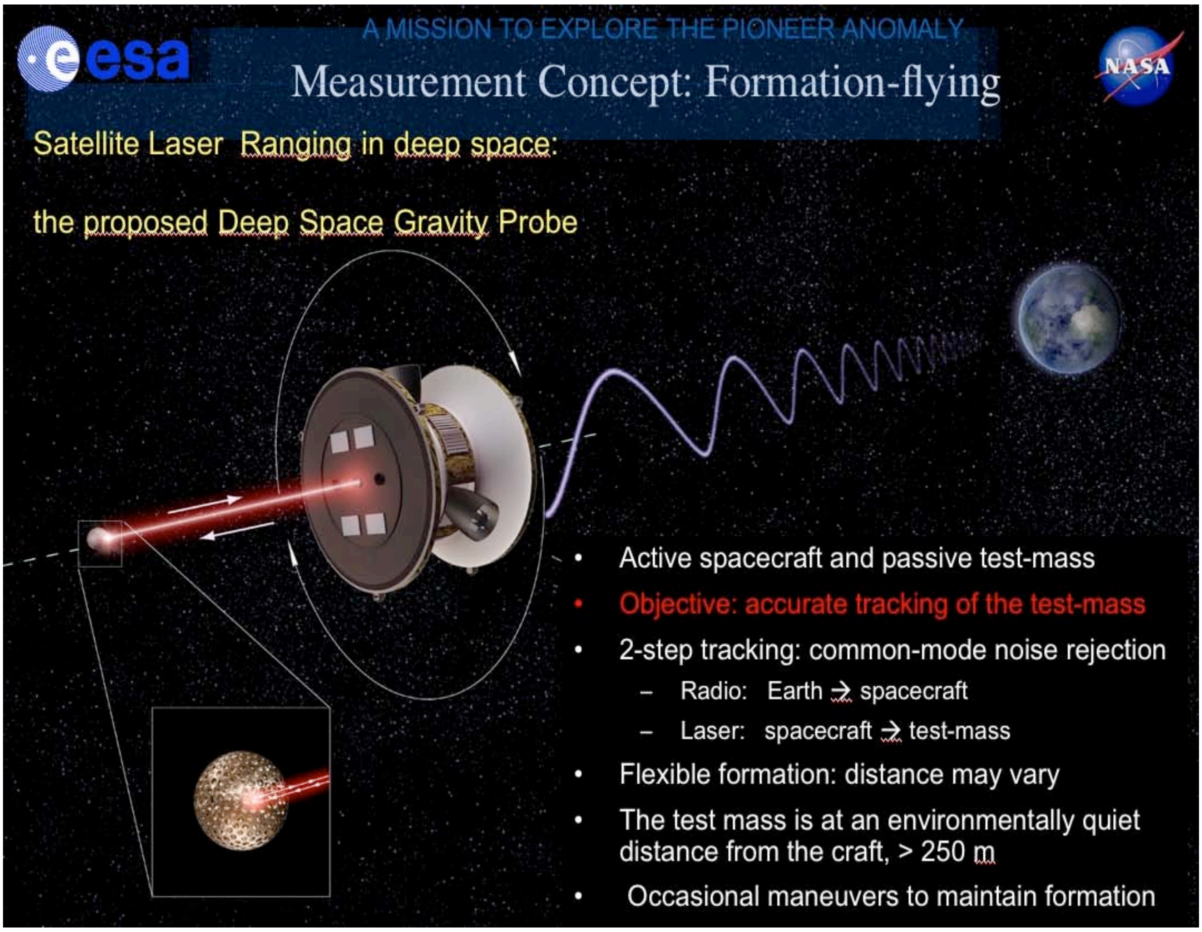

***Figure 2**. Concept of the DSGP satellite formation.*

Shell-only Test Mass Built at INFN-LNF

This is a spherical aluminum shell of 16 cm diameter, equipped with 100 CCRs, each of active area of approximately 18 mm. The test mass mechanic structure has been funded by LNF, as well as the future SCF-Test campaign. This is an original concept developed by G. O. Delle Monache and the other LNF authors. The mechanical drawing and machining of the prototype has been realized by the SPCM service of the LNF Technical Division.

The 110 retroreflectors for this prototype have been purchased, FFDP-tested individually and found to meet the optical specifications. They are now being mounted on one of the two shells (see Appendix 1) and for this partially equipped shell we will make full FFDP modeling using an original software approach developed at LNF. Once the test mass will be complete we will perform a full SCF-Test by the end of the COFIS project.

Figure 3. *Shell-only DSGP test mass.*

"Russian" Sphere from IPIE

This is a sphere completely manufactured with fused silica layers (with partial aluminum jacket). The first type of sphere was built from the Institute of Precision Instrumentation Engineering (IPIE) of Moscow, and has been spatially characterized from the ROSKOSMOS in December 2001 with the launch of the Meteor-3M satellite. This sphere is a single CCR.

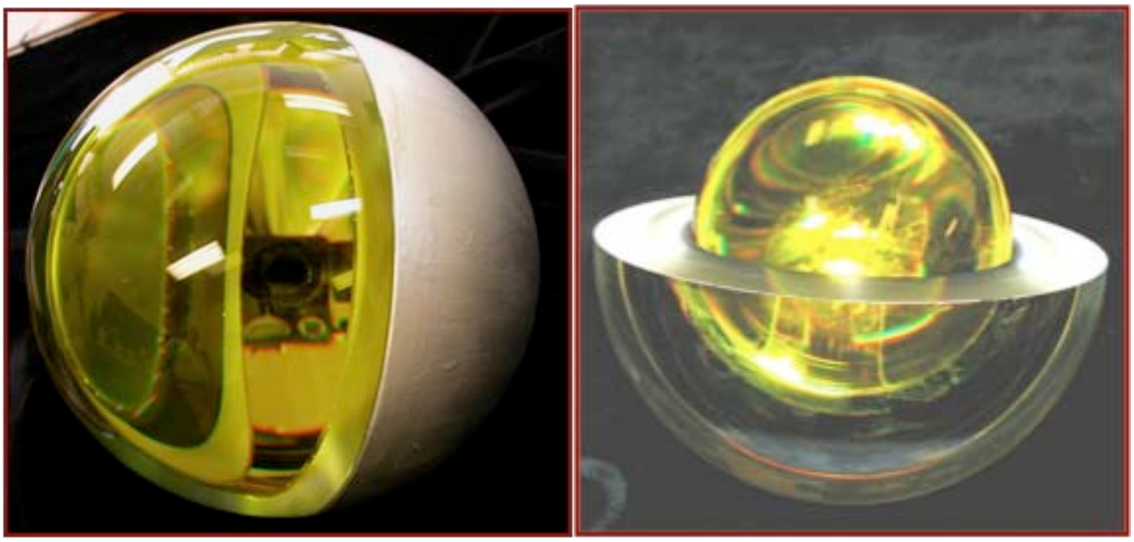

Figure 4. *Russian sphere.*

Commercial Sapphire Sphere

Sapphire spheres of a few cm diameter and index of refraction close to 1.9 are commercially available from Edmond Scientific. Given the short SLR distances, we will study whether also these light spheres might be used as test masses, despite their lower retro-reflection yield compared to the IPIE spheres.

Optical Design and FFDP of the Shell-only Test Mass

The plots of fig. 5 show the FFDP simulations for the range of dihedral angles offsets (DAO) of the CCRs that are being purchased for the COFIS study: = [-1.0”, 1.0”]. Our optical modeling is performed with the CodeV commercial software by ORA, Inc. (see [5]).

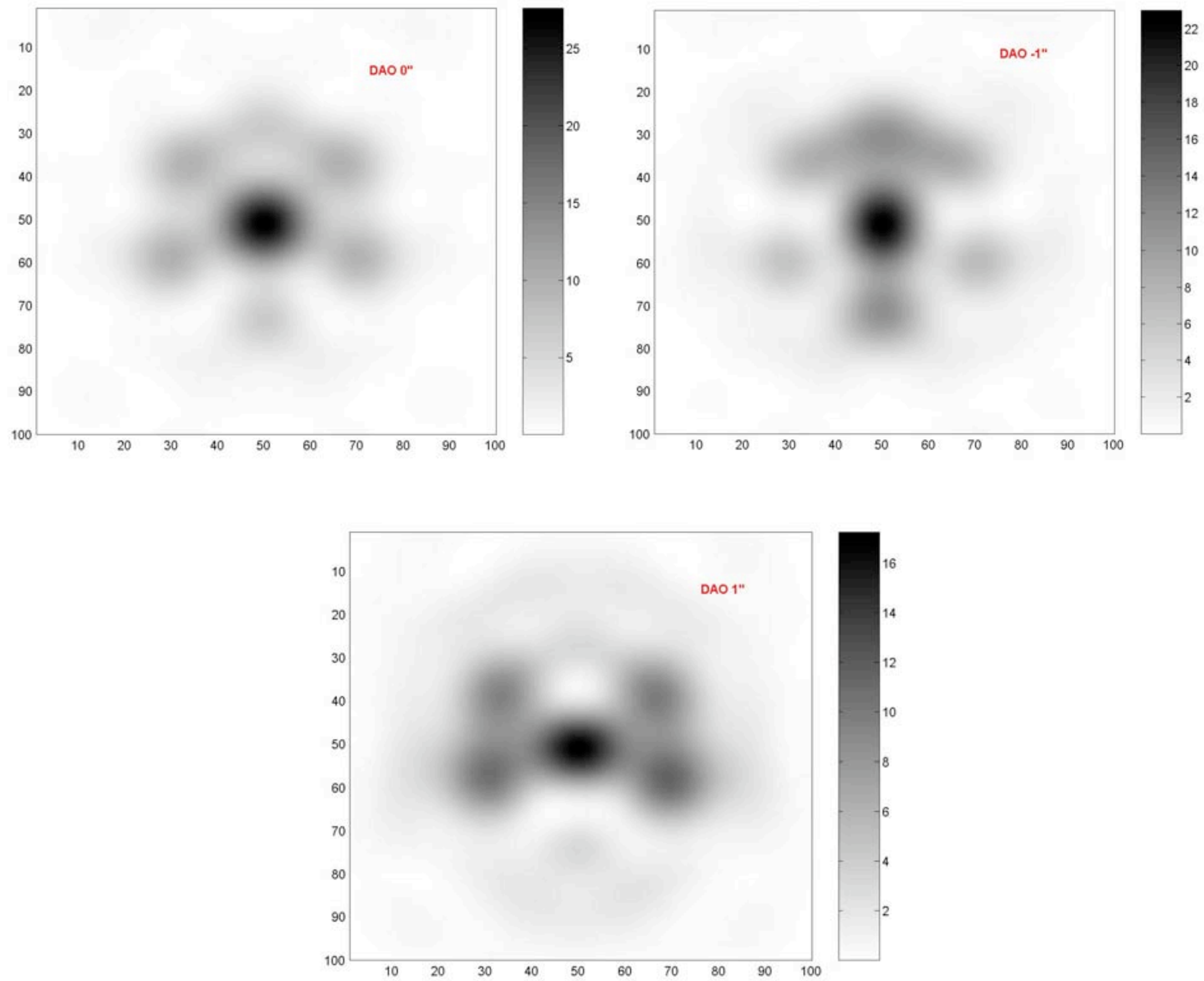

Figure 5. *FFPDs for the DSGP CCR with DAO= 0.0 arcsec (top left), -1.0 arcsec (top right) and 1.0 arcsec (bottom). The FFDP horizontal and vertical scales are in μrad. The FFDP intensity (gray scale) is in units of Airy peak of a perfect mirror of the same CCR diameter.*

Design of a Laser Ranging System Onboard DSGP

We assume a reference distance of 1 Km between the active DSGP spacecraft (equipped with the laser) and the SLR test masses (fig. 6, top). Our design foresees a cm-size telescope, at a location of about 3-5 cm away from the laser position in order to detect the FFDP retro-reflected by the CCR (fig. 6, bottom). This choice is based on the plots of fig. 5. The laser beam is assumed to be coincident with the longitudinal symmetry axis of the spacecraft.

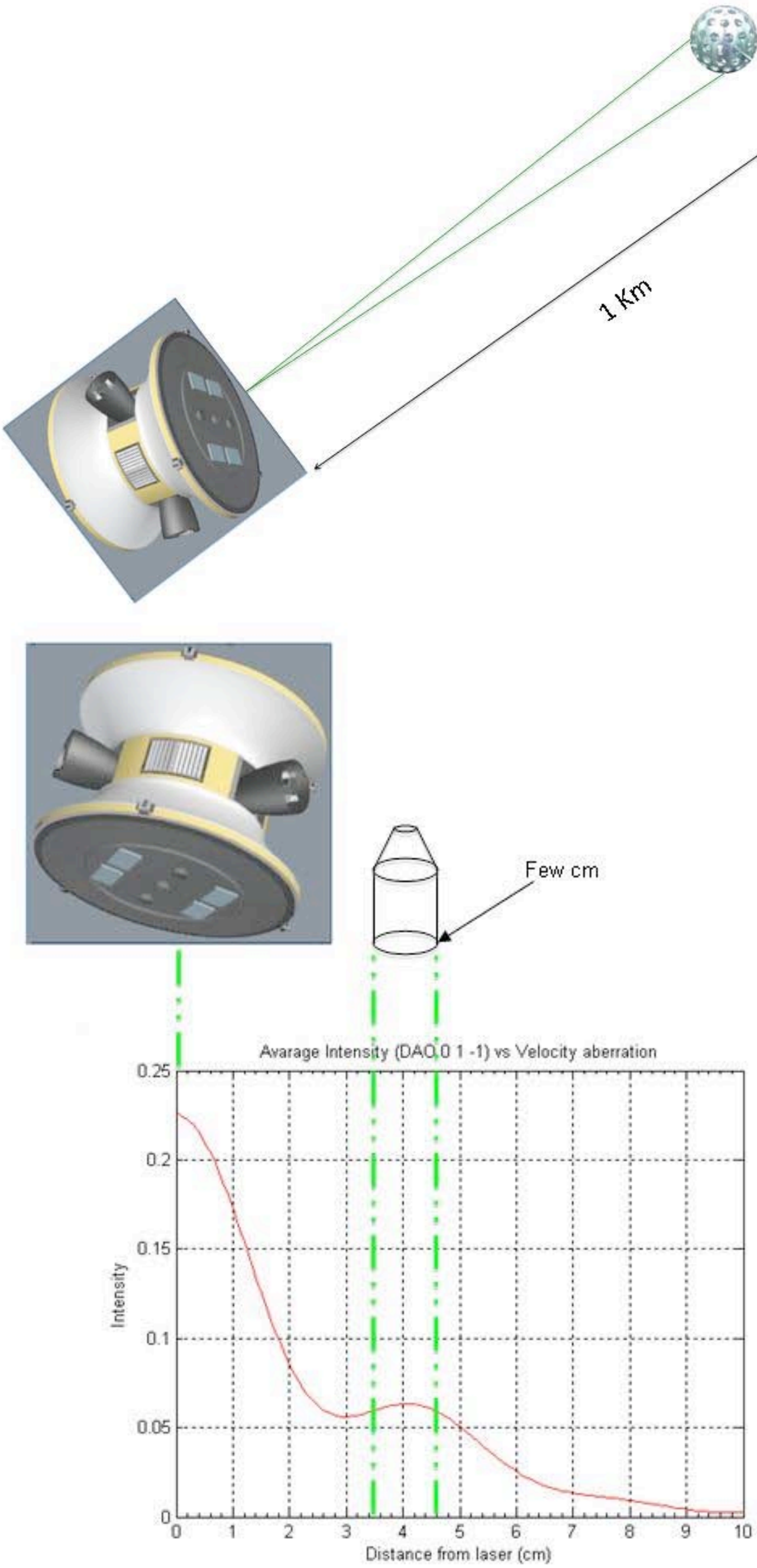

Figure 6. *DSGP satellite formation (top). Average FFDP intensity vs. transverse position of the telescope on the mother-ship (bottom), in the assumption that the test mass is located at 1 Km distance and is equipped with COFIS CCRs.*

Inheritance of the Laser System

With COFIS we are designing the very first laser ranging system for satellite formation flying in deep space. The hardware to be used for an actual implementation will inherit from technology successfully flown by NASA in previous or on-going space missions: the MOLA, MLA and LOLA space-qualified payloads.

- **MOLA.** The Mars Orbiter Laser Altimeter, MOLA, is an instrument on the Mars Global Surveyor (MGS), a spacecraft that was launched in 1996. MOLA has operated with great success, collecting important Mars altimetry data, until June 30, 2001.

- **MLA.** The purpose of the Mercury Laser Altimeter (MLA) is to measure the topography or surface relief of the northern hemisphere of Mercury. The MLA measures the range or distance between the MESSENGER probe and the surface of Mercury using a laser transmitter and receiver.

- **LOLA.** The Lunar Orbiter Laser Altimeter (LOLA) onboard of the Lunar Reconnaissance Orbiter (LRO) will be launched in May 2009. LOLA will provide a precise global lunar topographic model and geodetic grid that will serve as the foundation to select future landing sites and for spacecraft landing and safe return to and from the Moon. The LRO altimetry and gravity maps will add to the maps that are currently being measured by the Kaguya, Chandrayaan and Chang'e orbiters by Japan, India and China. The LOLA instrument pulses a single laser through a Diffractive Optical Element to produce five beams that illuminate the lunar surface. For each beam, LOLA measures time of flight, pulse spreading, and transmit/return energy. LOLA will be also subject to one-way laser ranging from the most performing ILRS stations, including ASI'S MLRO in Matera, Italy.

Particular care will have to be taken in choosing appropriately low laser intensity for two main reasons:

- Minimize onboard power consumption, which at the same time maximizes the laser lifetime;
- Avoid any damage the onboard light detector, in itself chosen with the lowest power consumption possible.

On this matter we will inherit from the LOLA detailed protocols and agreement concerning the laser ranging by the ILRS.

One clear, major advantage of the light detector on DSGP is that it will be facing the deep space, thus avoiding the enormous light background of the sun, planet infrared and albedo emissions that all the detectors of planetary laser altimeters have to fight overcoming great technical difficulties.

FFDP Test of a Hollow CCR for the GPS-3

With the SCF the hollow CCR can be characterized in realistic climatic conditions. With the SCF and Optical Lab, their FFDP measured in air and isothermal conditions as a basic industrial acceptance test. Being lighter than the traditional, solid fused silica cubes, these CCR are promising candidates in order to equip the future GNSS constellations.

In 2008 the LNF group has concluded an agreement with NASA-GSFC (Goddard Space Flight Center) from which in late 2008 we acquired a hollow CCR to test at LNF (see fig. 7).

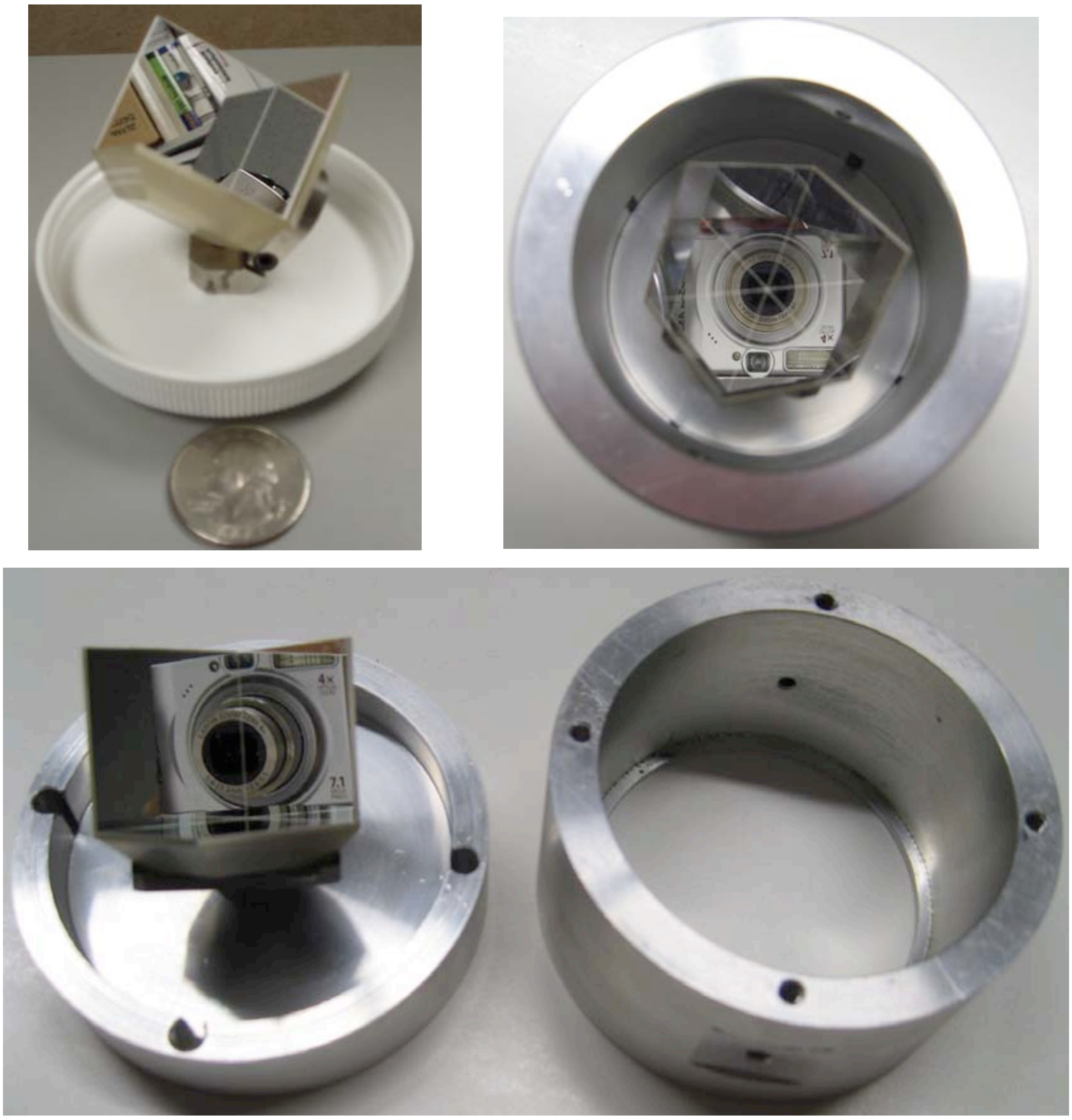

***Figure 7**. The NASA-GSFC hollow retroreflector now at LNF for the COFIS study: CCR at GSFC compared to a 1/4 dollar coin (top left); CCR at LNF mounted in the cavity that will be used for the SCF-Test (top right); CCR and cavity disassembled (bottom).*

This hollow CCR is made by three pyrex faces, with a metallic reflective surface coating of optical quality. The joints are done with stycast glue for space applications. The unit is supported at the bottom by an invar foot. A newer design replaces pyrex with the more expensive zerodur and invar will be, possibly, replaced by a lighter and more expensive ULE.

This CCR has been extensively tested in isothermal conditions with two different wavelength, 532 nm and 633 nm (fig. 8), and it satisfies the optical specs of DAO = 0.0 arcsec ± 0.5 arcsec, and of a surface optical quality and planarity of wavelength/4.

532 nm:

633 nm:

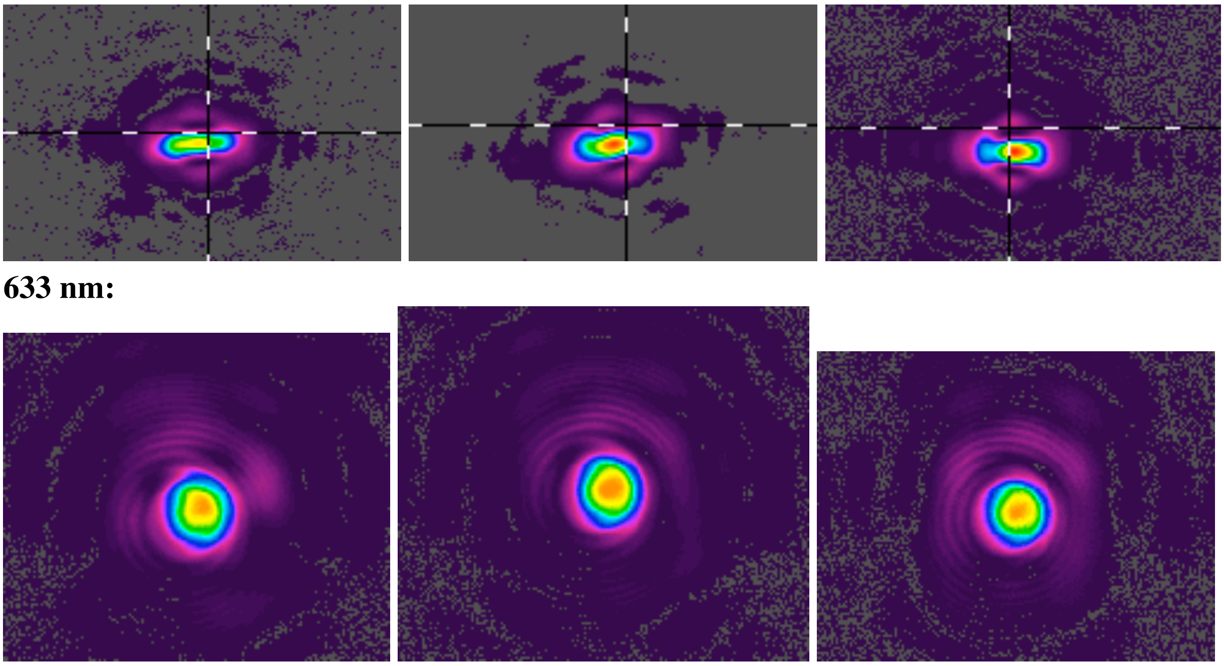

Figure 8*. FFDP test of the NASA-GSFC hollow retroreflector with 532 nm (top, performed at the SCF) and 633 nm (bottom, performed at the Optical Lab) wavelength.*

In view of the SCF-Test, which could modify its structure, we did a geometric survey of the CCR with a contact CMM, a POLI device (see fig. 10). Optical FFDP measurements are sensitive to deformations of, typically, 0.5 arcsec in angle and wavelength/4. As such, they are superior than contact measurements. In fact, the typical dimensional accuracy of our CMM over small volumes is ≤ 5 microns. However, if the SCF environment will produce non-elastic warping of the cube shape of tens of microns, the CMM geometric survey will be a useful diagnostics to detect faults spots and/or faulty joints and important input data for the structural modeling. CMM measurements agree with the FFDP test results, within the reduced accuracy of the former. A sample CMM output data are reported in Appendix 2.

In October 2009 we started the SCF-Testing of this hollow CCR to check its stability in space conditions. We also developed a structural model and analysis to be tuned to the SCF-Test data. This is the first test of a hollow reflector in realistic space conditions.

Conclusions

The research activity of WP5200 of the COFIS study reached all goals foreseen in 2007, 2008 and 2009. The program is very well underway in all its aspects. By complementing the COFIS funding with additional local support by LNF, we are carrying out an original research activity in collaboration with the Goddard and JPL laboratories of NASA.

Acknowledgments

We wish to acknowledge the support to this research work granted by ASI in the framework of the COFIS three-year study led by the ASI Manager E. Tommasi. Special thanks to the National Scientific Coordinator, P. de Barnardis, and to his Administrative Secretary, M. V. Marchet, for managing to provide financial support to LNF temporary personnel in a timely fashion despite the general technical difficulties encountered.

We also wish to thank M. Calvetti, the INFN-LNF Director, C. Sanelli, Head of the LNF Technical Division and V. Chiarella, Head of the LNF Research Division, for local support granted for the operation of the LNF space test facilities and for the access to the LNF Cryogenics and Mechanics Workshops. In particular, we thank to the SPCM service of the LNF Technical Division for the mechanical design and machining of the DSGP aluminum prototype. We also thank V. Vullo and F. Vivio of the Department of Mechanical Engineering of the University of Rome "Tor Vergata" for the collaboration on the structural analysis.

References

[1] *ETRUSCO: Extra Terrestrial Ranging to Unified Satellite COnstellations*, S. Dell'Agnello, R. Vittori, G. O. Delle Monache et al, INFN-LNF Report LNF-07/8(IR).

[2] *MoonLIGHT: Moon Laser Instrumentation for General relativity High-accuracy Tests,* D. G. Currie, S. Dell'Agnello, G. O. Delle Monache, R. Vittori, et al, INFN-LNF Reports LNF-06/28(IR), an approved NASA Project of the LSSO Program (Lunar Sortie Scientific Opportunity), and LNF-07/02(IR), a Study financed by ASI (Observation of the Universe from the Moon).

[3] *Probing Gravity in NEOs with High-Accuracy Laser-Ranged Test Masses*, A. Bosco, C. Cantone, S. Dell'Agnello, G. O. Delle Monache, et al, Int. Jou. Mod. Phys. D, Vol. 16, No. 12A (2007) 2271-2285.

[4] *Optical Far Field Diffraction Pattern Test of Laser Retroreflectors for Space Applications in Air and Isothermal Conditions at INFN-LNF*, A. Boni, C. Cantone, S. Dell'Agnello, G. O. Delle Monache, M. Garattini, N. Intaglietta, C. Lops, M. Martini, L. Porcelli, INFN-LNF Report LNF-08/26(IR) (2008).

[5] *Thermal recoil force, telemetry and the Pioneer Anomaly*, V. T. Toth and S. Turyshev, Phys. Rev. D79, 043011 (2009).

Appendix 1. Mounting of the INFN-LNF prototype model of DSGP SLR Test Mass

Figure 10. Mounting of the DSGP test mass retroreflectors.

Appendix 2. Results of CMM Survey of the Hollow CCR

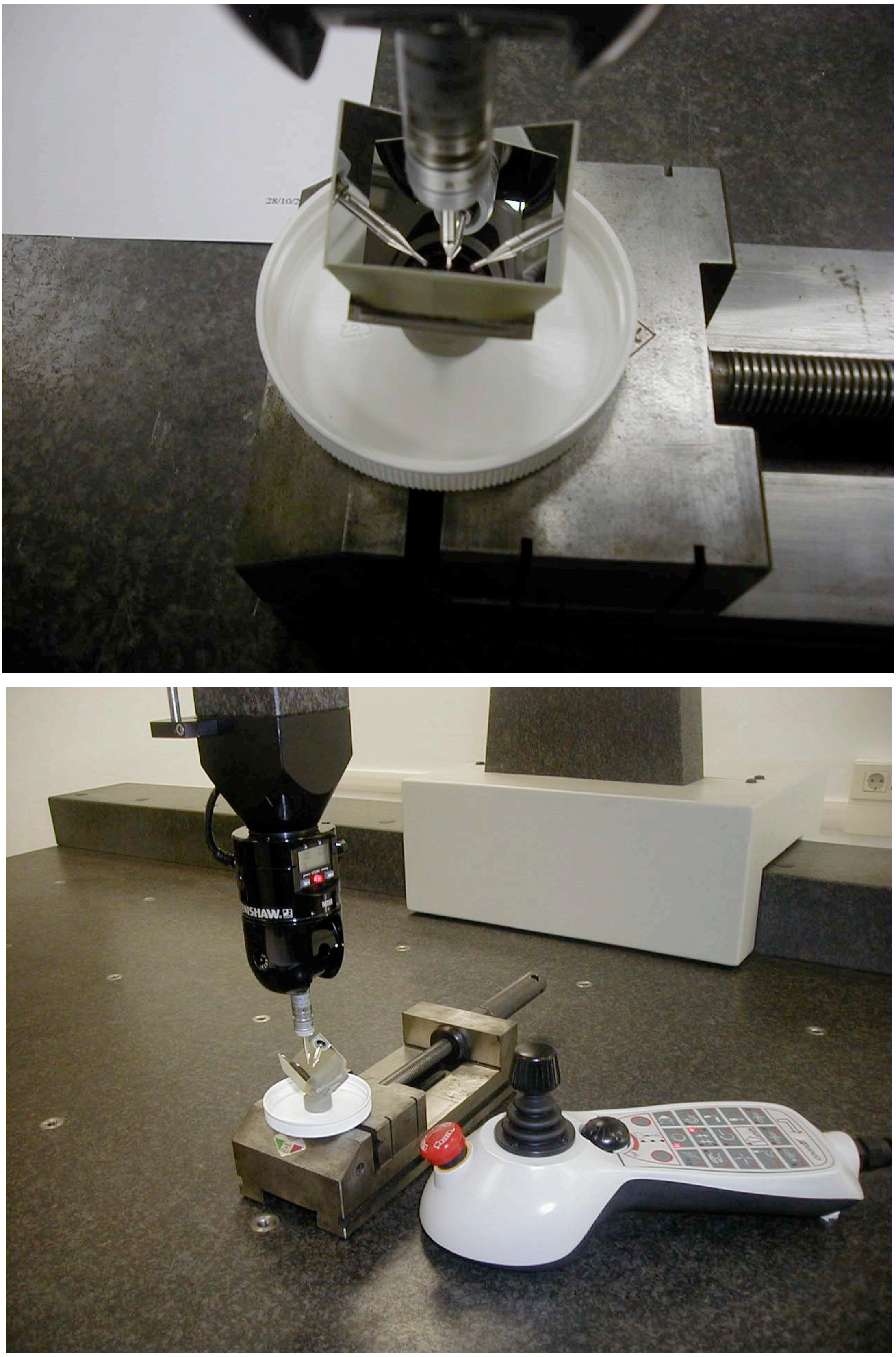

***Figure 10**. Dimensional survey of the hollow retroreflector with the LNF contact Coordinate Measuring Machine.*

Output of the CMM survey

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MODE/MAN
RECALL/D(MAC)
WKPLAN/XYPLAN
UNITS/MM,ANGDEC,TEMPC
DECPL/DIST,4,VEC,8,ANGLE,4,TEMP,1
SCNMOD/OFF
TECOMP/OFF
PRCOMP/ON
PTBUFF/ON
SNSET/SEARCH,10.000
SNSET/APPRCH,5.0000
SNSET/RETRCT,5.0000
SNSET/DEPTH,0.0000
SNSET/CLRSRF,OFF
FLY/5.0000
FEDRAT/MESVEL,MMPS,3.5
FEDRAT/POSVEL,PCENT,0.75
FEDRAT/ROTVEL,PCENT,0.75
FEDRAT/SCNVEL,PCENT,0.75
ACLRAT/MESACL,PCENT,0.75
ACLRAT/POSACL,PCENT,0.75
V(TEXT)=VFORM/ALL
V(HTML)=VFORM/DME,'HTM',ALL
V(SPCLIGHT)=VFORM/STAT,'SDD',ALL
V(GENSTAT)=VFORM/STAT,'SDD/L',ALL
V(ARCOSTAT)=VFORM/STAT,'SDD/C',ALL
V(QSSTATQ)=VFORM/STAT,'DFQ',ALL
V(QSSTATD)=VFORM/STAT,'DFD',ALL
V(GRAPHF)=VFORM/DME,'DMG',ALL
V(GRAPHV)=VFORM/DME,'DMG/V',ALL
V(GRAPHP)=VFORM/DME,'DMG/P',ALL
V(GRAPHO)=VFORM/DME,'DMG/O',ALL
V(GRAPHA)=VFORM/DME,'DMG/A',ALL
$$ *** Fine sezione default ***
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ENDMES
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  PTMEAS/CART,-999.3459,-604.8270,-559.7917,-1.00000000,0.00000000,0.00000000
ENDMES
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MEAS/POINT,F(POI_1),1
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ENDMES
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SNSET/APPRCH,2.0000
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SNSET/RETRCT,2.0000
SNSET/SEARCH,5.0000
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OUTPUT/FA(PLA_4),TA(FLAT_2)
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OUTPUT/FA(PLA_5),TA(FLAT_3)
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GEOALG/ANGLB,DEFALT
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GEOALG/ANGLB,DEFALT
OUTPUT/FA(PLA_3),FA(PLA_5),TA(ANGLB_2)
T(ANGLB_3)=TOL/ANGLB,89.9984,-0.0200,0.0200
GEOALG/ANGLB,DEFALT
OUTPUT/FA(PLA_4),FA(PLA_5),TA(ANGLB_3)
ENDMES
ENDFIL
DMISMN/''
```