An Addition to the Suite of Geodetic Satellites Supporting the ITRF: LARES-2

Erricos Pavlis[1], M Kuzmicz-Cieslak[2], E C Pavlis[2], I Ciufolini[3], A Paolozzi[4], and C Paris[4]

[1]Affiliation not available
[2]Goddard Earth Sciences Technology and Research II (GESTAR II), UMBC
[3]Enrico Fermi Research Centre
[4]School of Aerospace Engineering, Sapienza University of Rome

December 27, 2022

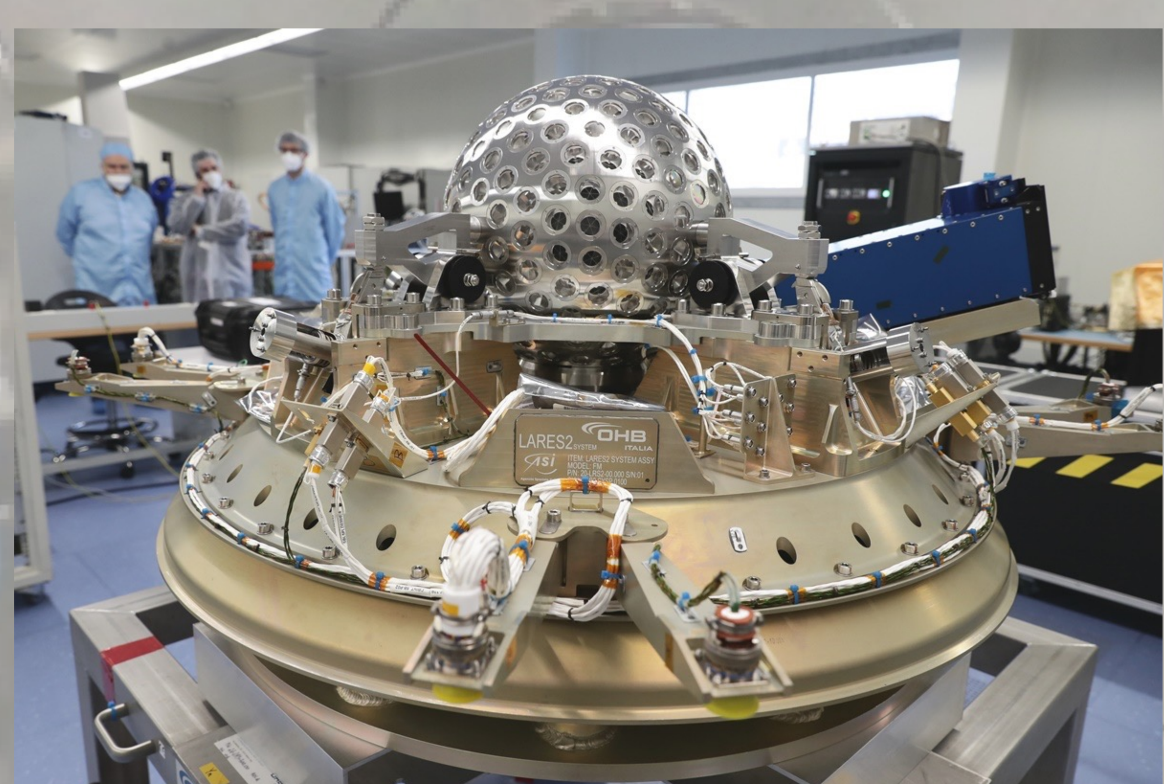
An Addition to the Suite of Geodetic Satellites Supporting the ITRF: LARES-2

M. Kuzmicz-Cieslak[1], **E. C. Pavlis[1]**, I. Ciufolini[2], A. Paolozzi[3] and C. Paris[3]
[1]Goddard Earth Sciences Technology and Research II (GESTAR II), UMBC, Maryland, USA, epavlis@umbc.edu
[2]Enrico Fermi Research Centre, Rome, Italy
[3]School of Aerospace Engineering, Sapienza University of Rome, Italy

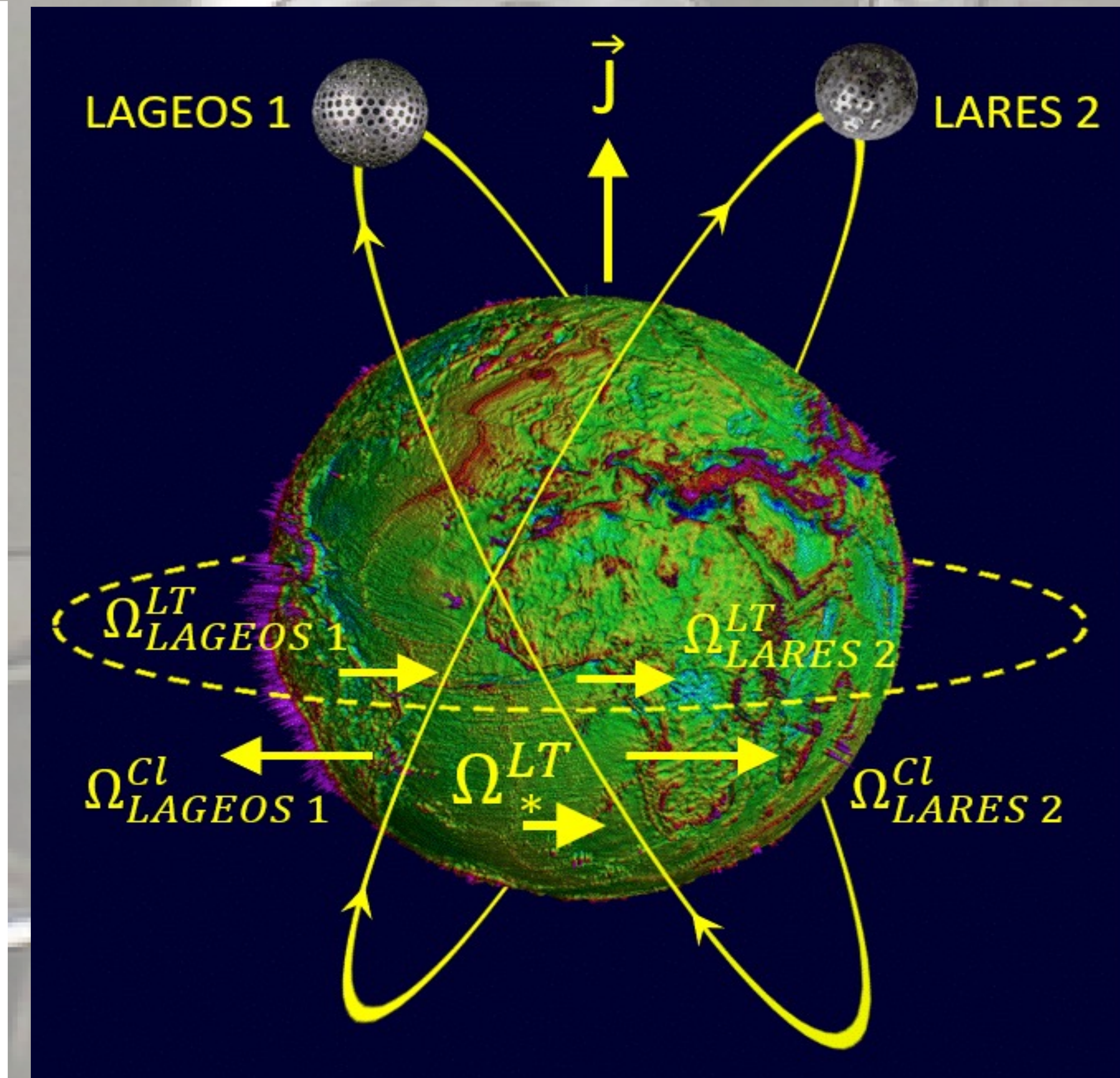
Abstract

Geodetic network infrastructure has evolved with increasing pace the past decade with remarkable additions of modern hardware, replacing aging, '80s vintage equipment throughout the globe. The Satellite Laser Ranging—SLR network is the slowest in making changes designed and planned more than a decade ago [Pearlman et al., 2019a]. This is in part due to the voluntary nature of establishing such installations and to a greater part the high cost and limited availability of the one-of-a-kind equipment. NASA, partners and international agencies, embarked on updates with standardization will help in the long term [Merkowitz et al., McGarry et al., Wilkinson, et al., 2019]. SLR needs more than updating the network to deliver the accuracy required today. New "targets" must also be used that support mm-accuracy. LAGEOS was conceived and built in the early '70s with a ~5 mm accuracy in mind [Pearlman et al., 2019b]. This limitation forced analysts to develop approaches of data analysis to ensure that even with such data one can reach the required 1-mm accuracy [Luceri et al., 2019]. Along with the network updates a parallel effort was thus initiated to modernize the space segment as well. Initially with the design and launch of LARES in 2012 [Pavlis et al., 2015] and following that, the design of LARES-2 [Ciufolini et al., 2017, Paolozzi et al., 2019], which was successfully launched on July 13, 2022 [https://www.nature.com/articles/d41586-022-02034-x]. The new mm-accurate target was quickly acquired first by the Matera, Italy station only three days after launch and although very early in the mission, the data were of remarkably high quality and insignificant bias. This prompted a quick evaluation and a test inclusion of this target in the limited list of SLR targets supporting the ITRF development. With an orbit nearly identical to LAGEOS (with supplementary inclination), taking full advantage of all the appropriate models designed and applied to LAGEOS, we achieved 7-day orbital fits of 3-5 mm even without a tuned target signature correction! We will present an overview of the initial analysis of LARES-2 data focusing on comparing them to contemporaneously taken LAGEOS data, we will show results from our initial inclusion of LARES-2 in developing ILRS products for ITRF development and discuss the ILRS plans for its full integration.

Ciufolini, Phys. Rev. Lett (1986)
Ciufolini, Int. J. of Mod. Phys. A (1989)
Pearlman et al., J Geod 93, 2161–2180 (2019a). https://doi.org/10.1007/s00190-019-01241-1
Merkowitz et al., J Geod 93, 2263–2273 (2019). https://doi.org/10.1007/s00190-018-1204-5
McGarry et al., J Geod 93, 2249–2262 (2019). https://doi.org/10.1007/s00190-018-1191-6
Wilkinson, et al. J Geod 93, 2227–2247 (2019). https://doi.org/10.1007/s00190-018-1196-1
Pearlman et al. J Geod 93, 2181–2194 (2019b). https://doi.org/10.1007/s00190-019-01228-y
Luceri et al. J Geod 93, 2357–2366 (2019). https://doi.org/10.1007/s00190-019-01319-w
Pavlis et al. EEEIC (2015), pp. 1989-1994. https://doi.org/10.1109/EEEIC.2015.7165479
Paolozzi et al. J Geod 93, 2437–2446 (2019). https://doi.org/10.1007/s00190-019-01316-z
Ciufolini et al. Eur. Phys. J. Plus 132, 336 (2017). https://doi.org/10.1140/epjp/i2017-11635-1

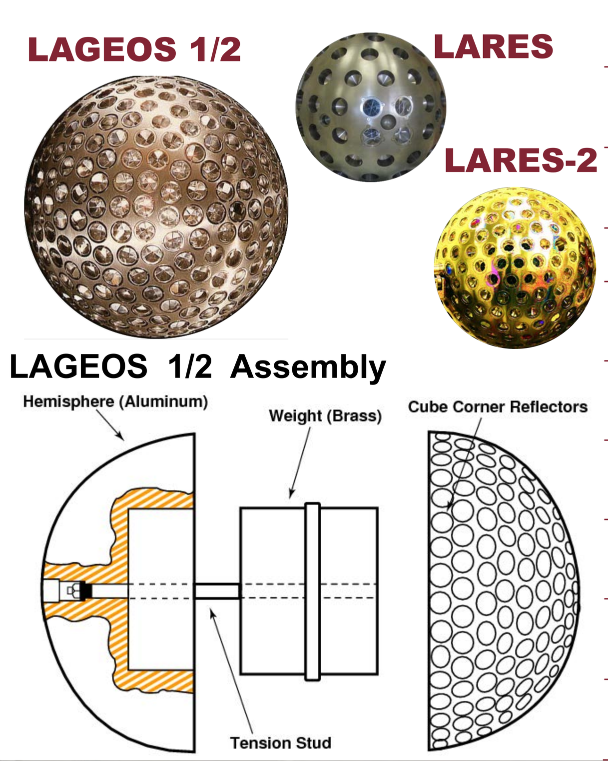


LARES 2 mounted on release mechanism



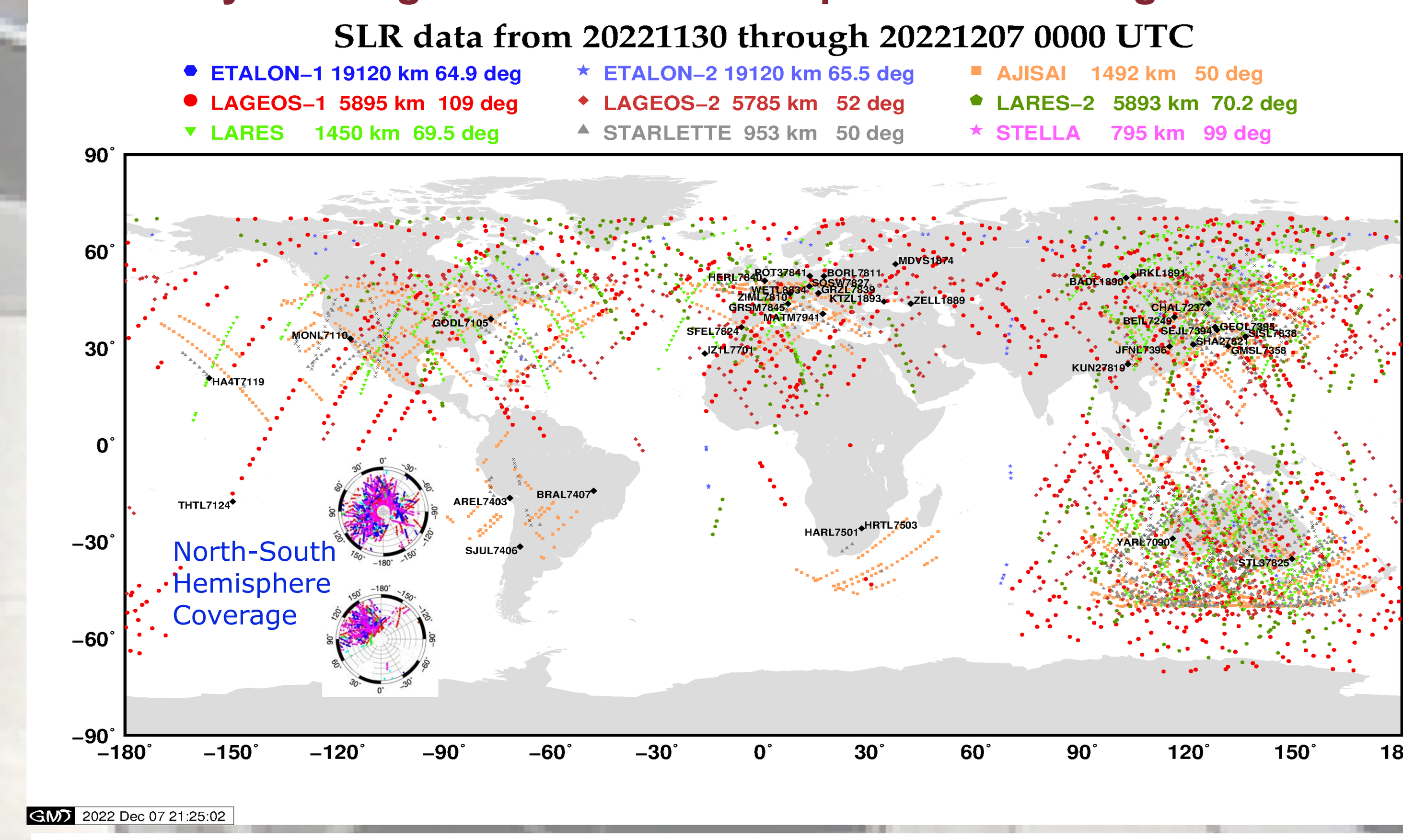
LARES-2 was designed and launched with the primary goal being the test of frame-dragging due to the *Lense-Thirring* (**LT**) prediction of GR, with an accuracy of ***0.2%*** or better, to perform other tests of General Relativity and Fundamental Physics theories and to support Space Geodesy and Geodynamics. Using two LAGEOS-type satellites in orbits with the same semi major axis and supplementary inclinations eliminates the effect of all J_{2n} zonal harmonics on the observed gravitomagnetic precession Ω^{LT}.

Satellite Design: LAGEOS 1/2 vs LARES vs LARES-2



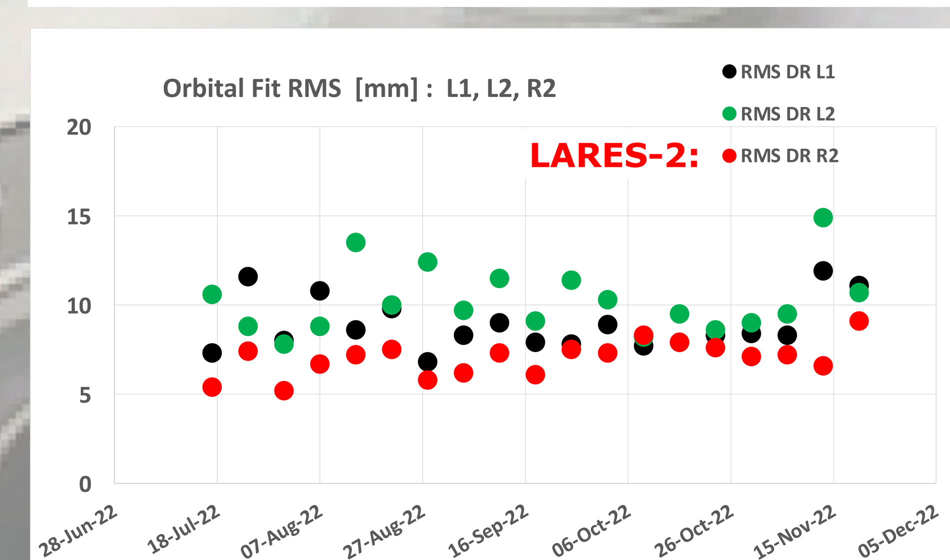
	LAGEOS 1/2	LARES	LARES-2
Launch Year:	• 1976 (L1) • 1992 (L2)	2012	2022
Mass:	• 406.9 kg (L1) • 405.3 kg (L2)	386.8 kg	294.8 kg
Diameter:	600 mm	364 mm	424 mm
Body:	Assembly	Single piece	Single piece
Material(s):	Al alloy hemispheres; Brass alloy core	Tungsten alloy (ρ = 18000 kg/m^3)	Nickel alloy
Diameter of CCRs	1.5 in	1.5 in	1.0 in
Number of CCRs:	426	92	303
Eccentricity:	• 0.0045 (L1) • 0.0135 (L2)	0.0005	0.0003
Altitude:	• 5860 km (L1) • 5620 km (L2)	1430 km	5856 km

Weekly tracking of the "Geodetic" spheres including LARES-2



JCET (GESTAR II) Preliminary Data Analysis and Bias Estimation

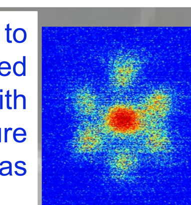
The purpose of these analyses is to evaluate the quality of the data and to determine corrections to the nominal CoG correction of 174 mm for each of the tracking stations. The resulting "tailored" values, one for each tracking station, will be subsequently used for an initial solution in combination with the LAGEOS and Etalon data, to produce weekly TRF solutions and compare to the current official ILRS products that exclude LARES-2 (so far). It is anticipated that very soon there will be a release of the engineering model for these corrections tailored to all ILRS stations, current, past and future. Naturally, when that model becomes available it will be adopted as the official set of corrections. It will be interesting to compare the empirical values to the engineering ones, so that this approach might become an alternative in the future, while waiting for the official engineering model release (~early 2023).



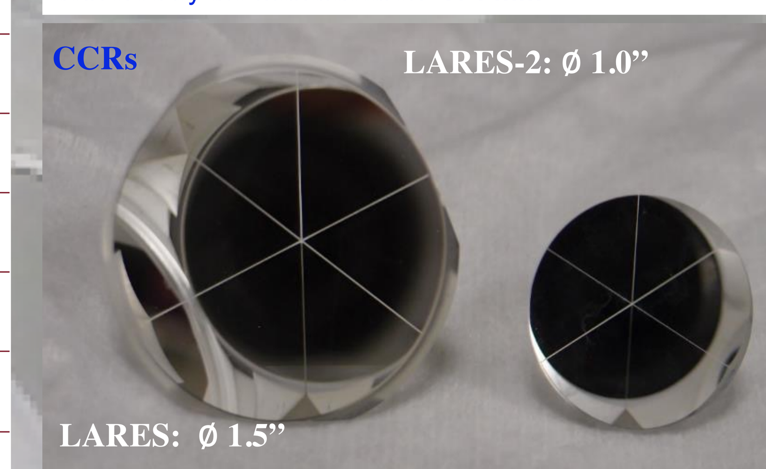
ILRS Site	ID#	Analysed Arcs	Empirical CoG Correction [mm]
Riga	1884	4	177.2
Yarragadee	7090	18	177.0
Greenbelt	7105	16	169.8
Monument_Peak	7110	14	176.4
Haleakala	7119	16	173.0
Changchun	7237	16	172.0
HartRAO_NASA	7501	9	182.3
Borowiec	7811	3	171.0
Shanghai	7821	15	170.7
Mt._Stromlo2	7825	17	178.6
Graz	7839	17	171.4
Herstmonceux	7840	18	169.1
Potsdam3	7841	12	169.9
Grasse_MeO	7845	17	173.9
Matera	7941	15	167.4
Wettzell@1064	8834	17	172.3

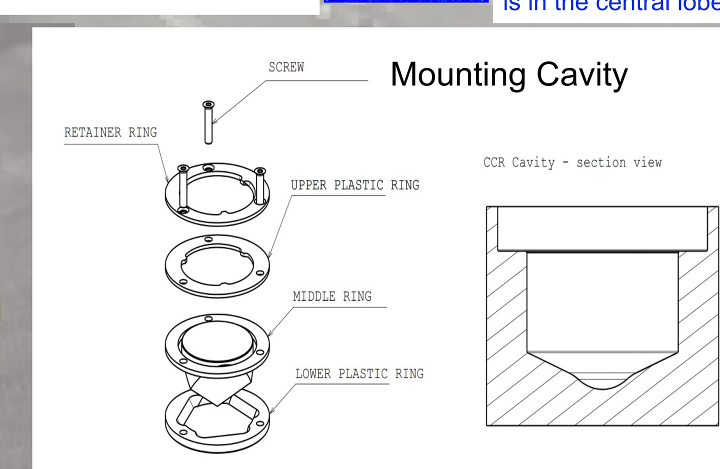
CCRs : LARES-2 vs LARES

The satellite structure is superior compared to all other geodetic spheres due to a special distribution of the retroreflectors (CCRs), a specifically designed mounting system, and the 1 inch CCRs (COTS). LARES-2 is the first satellite with both, a very low area-to-mass ratio (second only to LARES) and a target signature correction (CoG) with an accuracy below 1 mm. Nominal CoG correction as delivered by the manufacturer: ***174 mm***

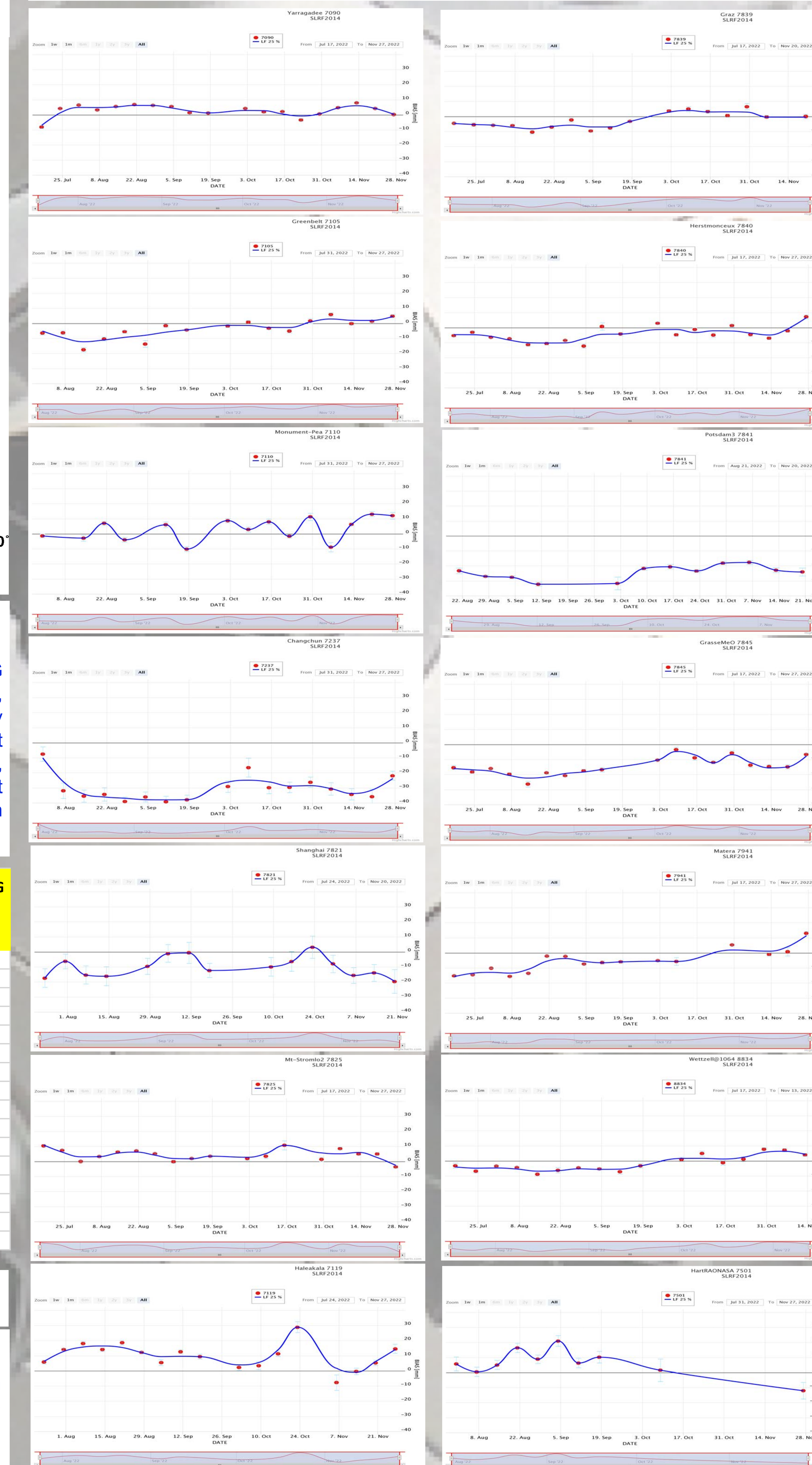


A LARES-2 CCR *Far Field Diffraction Pattern* heated at 70 °C, during a thermo-vacuum test. Most of the return energy is in the central lobe.





LARES-2 Freely Estimated Mean Weekly Range Biases
Nominal Target Signature Correction Applied: 174 mm



Summary

- LARES-2 launched on July 13, 2022, to support relativity tests and geodetic science products;
- It is successfully tracked by most of the core ILRS tracking systems;
- Although the official engineering model for target signature correction is not available yet, data analysis using the nominal correction of 174 mm and the free adjustment of station-dependent biases indicate that in most cases the nominal value is only a few mm off.
- Using these corrections we generated an empirical model to be used for the initial analysis phase, until the final engineering model is available.
- For the best ILRS systems the RMS of fit is at a few mm and below 5 mm.

SAPIENZA UNIVERSITÀ DI ROMA
CENTRO RICERCHE ENRICO FERMI
LARES

POSTER G21A-03

AGU FALL MEETING
Chicago, IL & Online Everywhere
12–16 December 2022
SCIENCE LEADS THE FUTURE

Acknowledgements: This work is performed with funding support under NASA Grant 80NSSC22M0001. NASA's support is gratefully acknowledged.

UMBC
GESTAR II