



QVS



23rd International Workshop on Laser Ranging Kunming, 20-26 October 2024

The Newly Refurbished San Fernando Laser Station

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QVS

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- *Prior status*
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ESTACIÓN DE SEGUIMIENTO LÁSER
REAL INSTITUTO Y OBSERVATORIO DE LA ARMADA



Space Geodesy at ROA

ROA has been a pioneer in Spain in the tracking of artificial satellites.

Photographic Techniques

- 1958. Baker-Nunn camera
- 2010. TFRM Robotic Telescope Modernization

Satellite Laser Ranging (SLR)

- 1968. French Geodesic Campaign (CNES-GRGS)
- 1979. Transfer agreement to Spain
- 1999. Entry into ILRS
- 2017. Space debris project
- 2019. End of last quarantine





ESTACIÓN DE SEGUIMIENTO LÁSER
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Space Geodesy at ROA

Both **collaborative objects** and **space debris** tracking.

SFEL has contributed with national and international networks in **geodetic** and **SST** purposes, also with companies in the space sector.



ILRS tracking tasks.

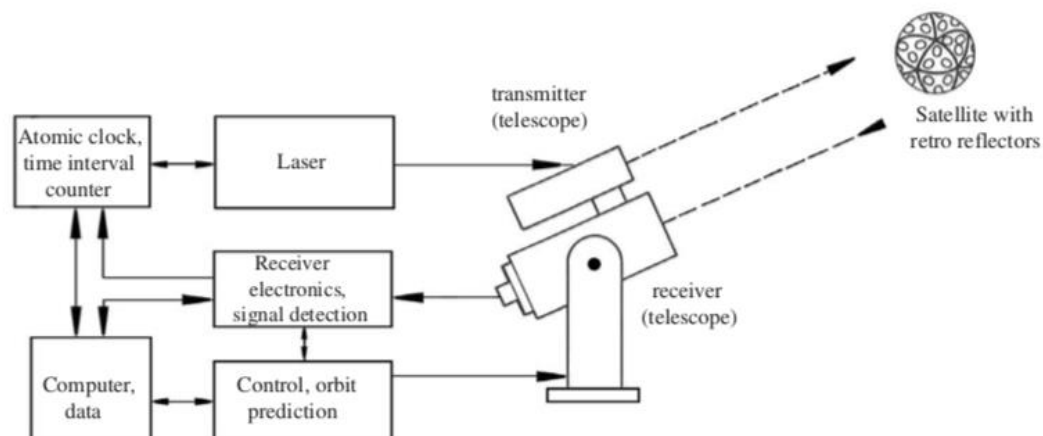
- LEO-MEO
- EKSPLA PL2251 (500mW @532 30ps 10Hz)

Space debris tracking

- LEO
- EKSPLA NL317 (25W @532 8ns 10 Hz)



Prior Status



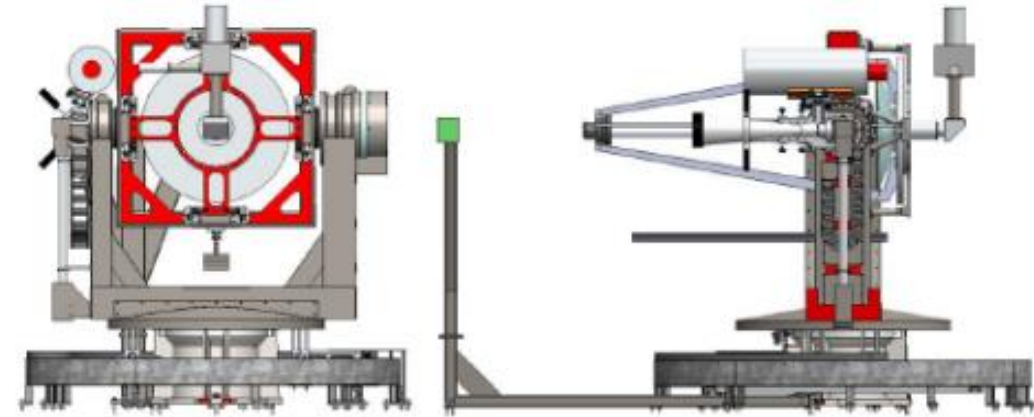
- Control subsystem: **FPGA-RGG** developed by SFEL
- ToF measurement subsystem: **Event Timer** A032
- Time&Freq subsystem: ROA-PPS Synchro, Rubidium and White Rabbit

Altazimuth Mount (weakness):

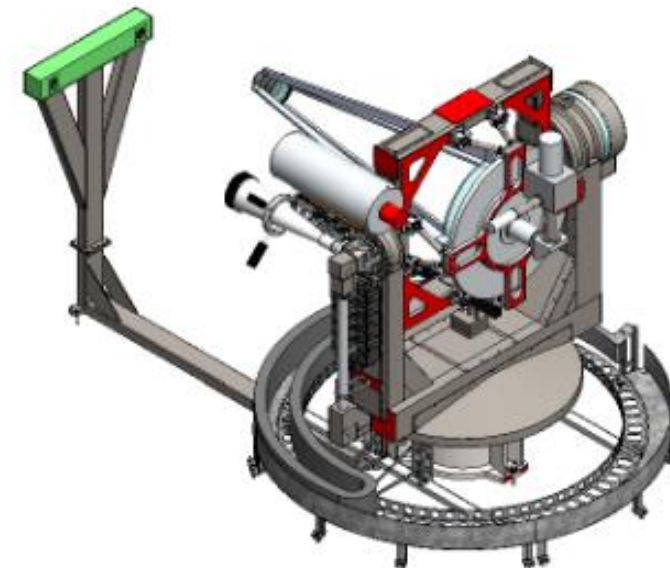
- 600 mm Cassegrain Telescope
- Launcher Telescope - micrometric mechanical pointing
- Finder Telescope - Analogic camera



v Mount



- Ready for 80 cm mirror & modular additions
- Incorporates coudé path
- Invariant point error <0.5mm



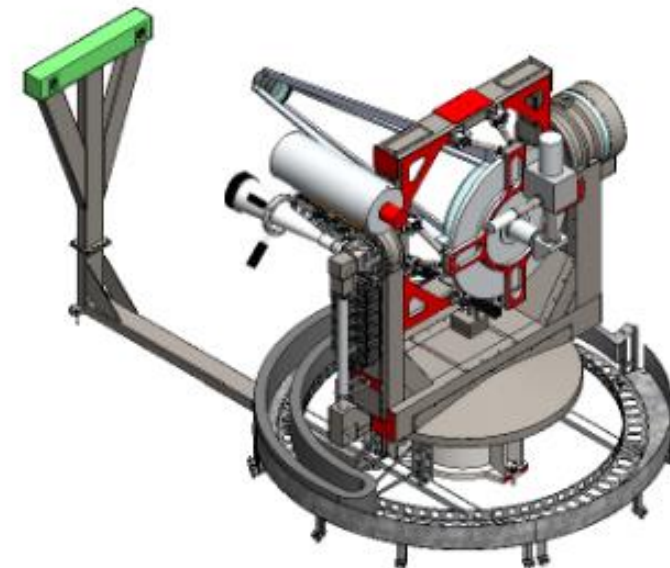
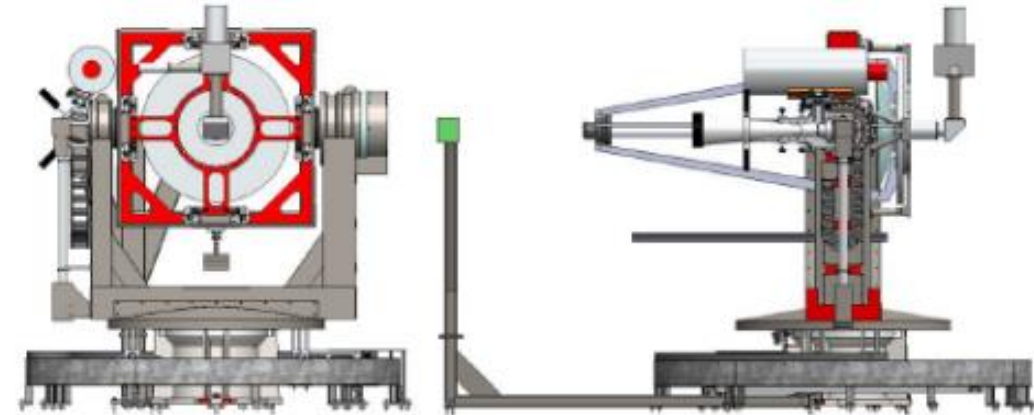


Key Aspects of the New Mount (AMELAS)

Delivered by AVS (18th July 2024)

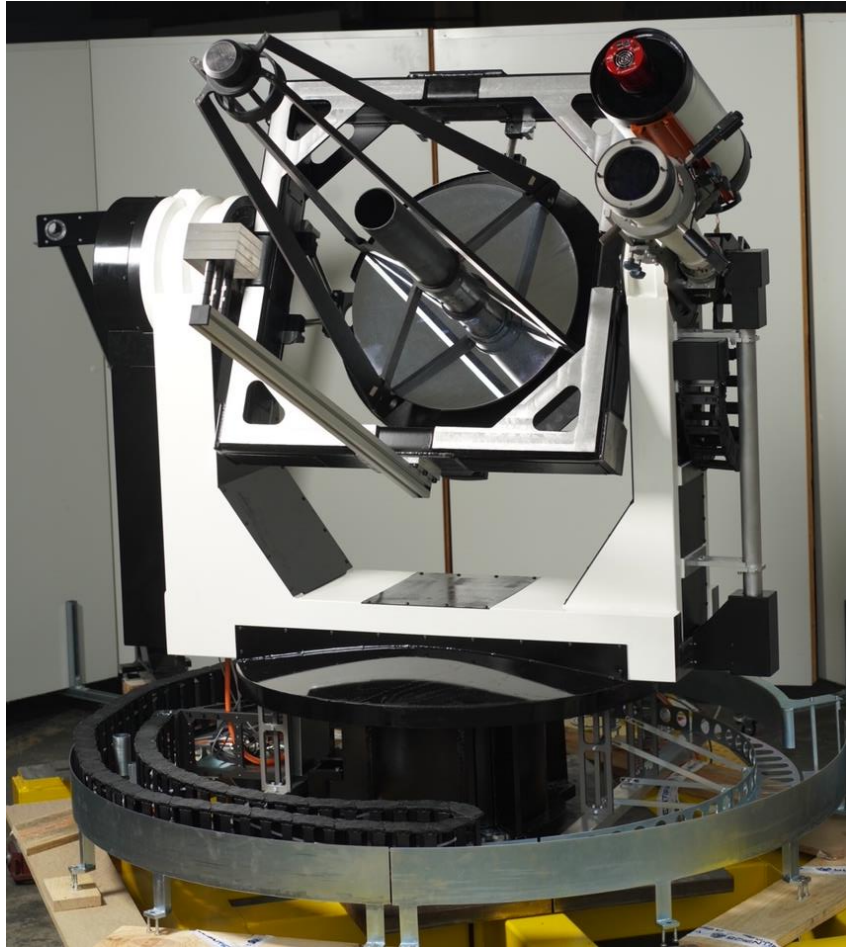
Main characteristics

- *Supports arcsec pointing*
- *Direct drive & top components*
- *Ready for 80 cm mirror & modular additions*
- *Incorporates coudé path*
- *Invariant point error <0.5mm*



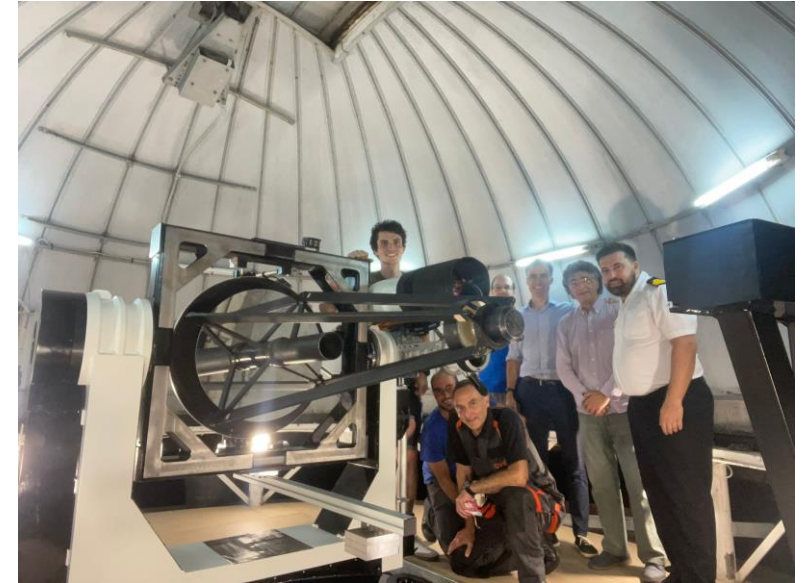


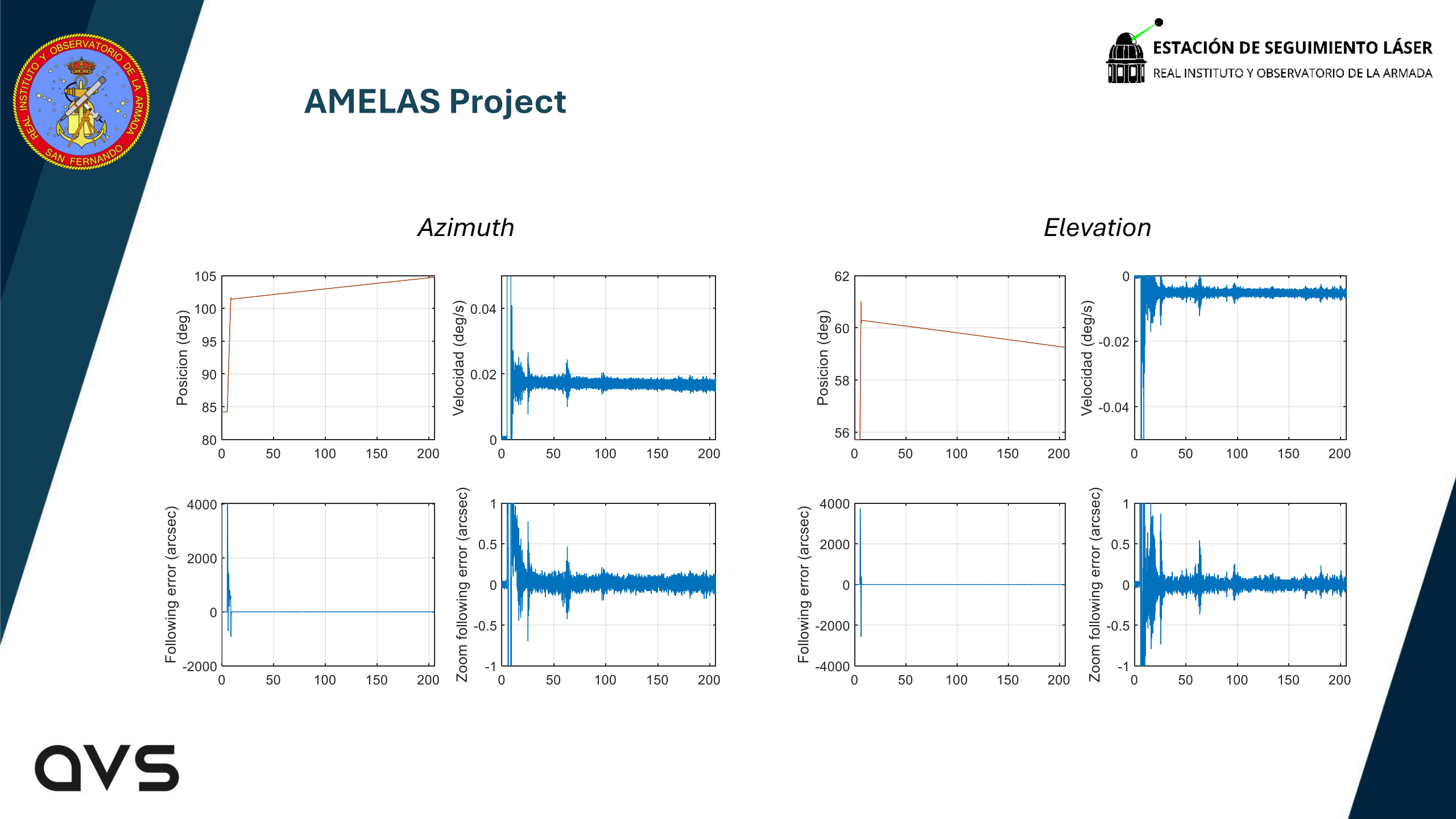
AMELAS Project





AMELAS Project

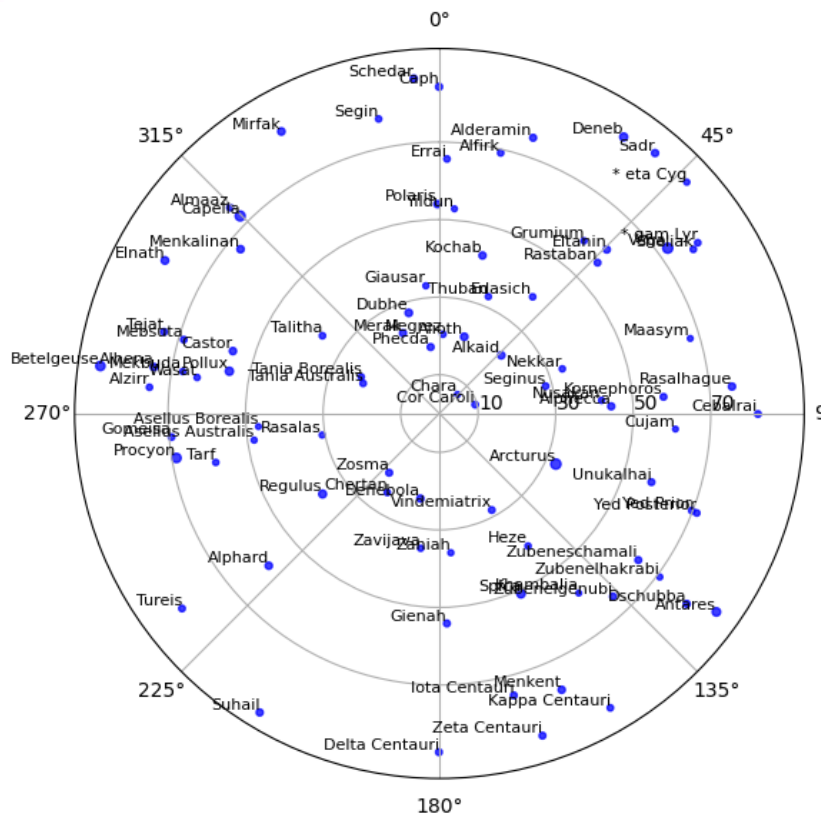




Pointing model

Current task:

- Pointing offset of about 80 stars
- Coefficients not only contribute to correct the pointing but also provide info on those factors that need to be optimized
- Corrections are currently in a range (max-min) of 20 arcsec



TF	tube flexure – $\sin \zeta$ law
TX	tube flexure – $\tan \zeta$ law
IE	index error in elevation
IA	index error in azimuth
CA	nonperpendicularity of elevation and pointing axes
AN	NS misalignment of azimuth axis
AW	EW misalignment of azimuth axis
NPAAE	nonperpendicularity of azimuth and elevation axes
ACES	Az centring error (sin component)
ACEC	Az centring error (cos component)
ECES	El centring error (sin component)
ECEC	El centring error (cos component)
NRX	Horizontal displacement of Nasmyth rotator
NRY	Vertical displacement of Nasmyth rotator
AUX1A	Az change supplied through auxiliary reading 1
AUX1S	LR change supplied through auxiliary reading 1
AUX1E	El change supplied through auxiliary reading 1

ZH	AAT HA Z-gear effect in HA
ZE	AAT HA Z-gear effect in polar axis elevation
HF	AAT main east-west horseshoe flexure
HGES	36 ^m gear error in HA – sin
HGEC	36 ^m gear error in HA – cos
DGES	9° gear error in Dec – sin
DGEC	9° gear error in Dec – cos
TFP	AAT tube flexure – non-Hooke's-law term
HFX	AAT residual horseshoe east-west
HFD	AAT residual horseshoe north-south
CD4A	AAT coude 4 collimation error A component
CD4B	AAT coude 4 collimation error B component
CD5A	AAT coude 5 collimation error A component
CD5B	AAT coude 5 collimation error B component

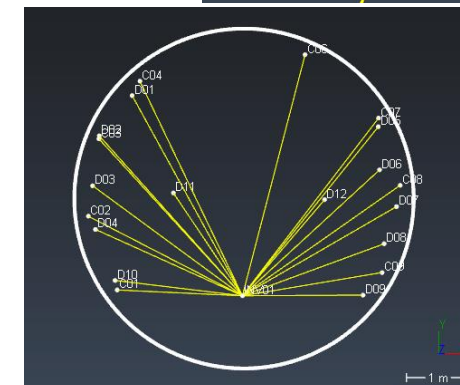
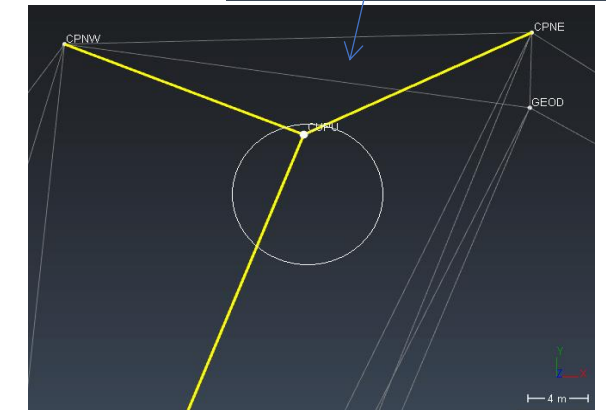
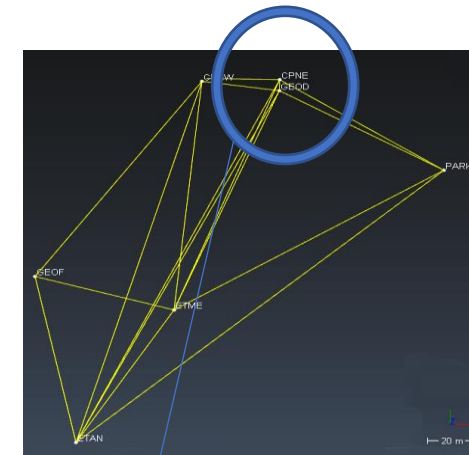
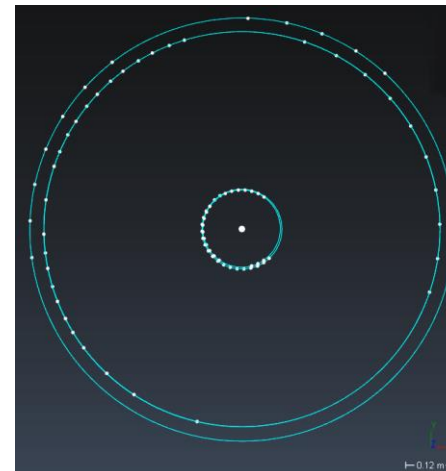
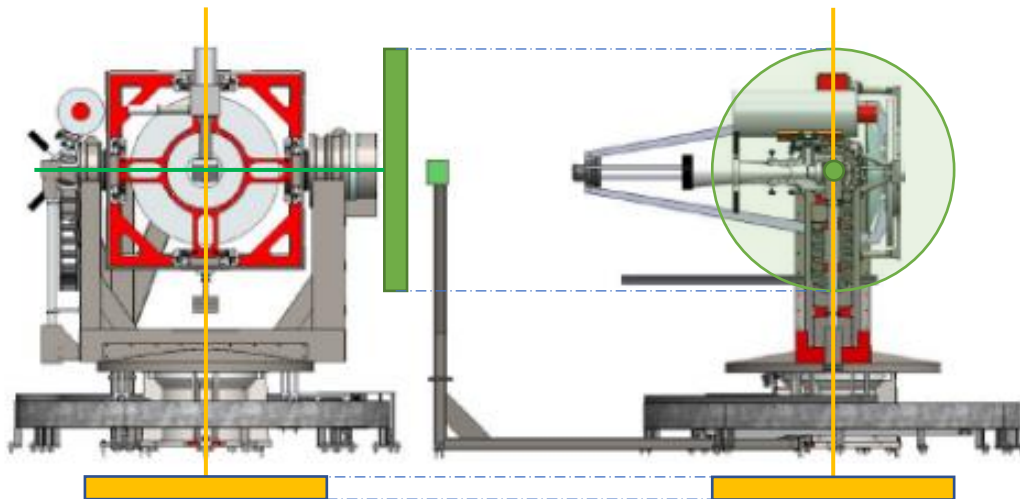


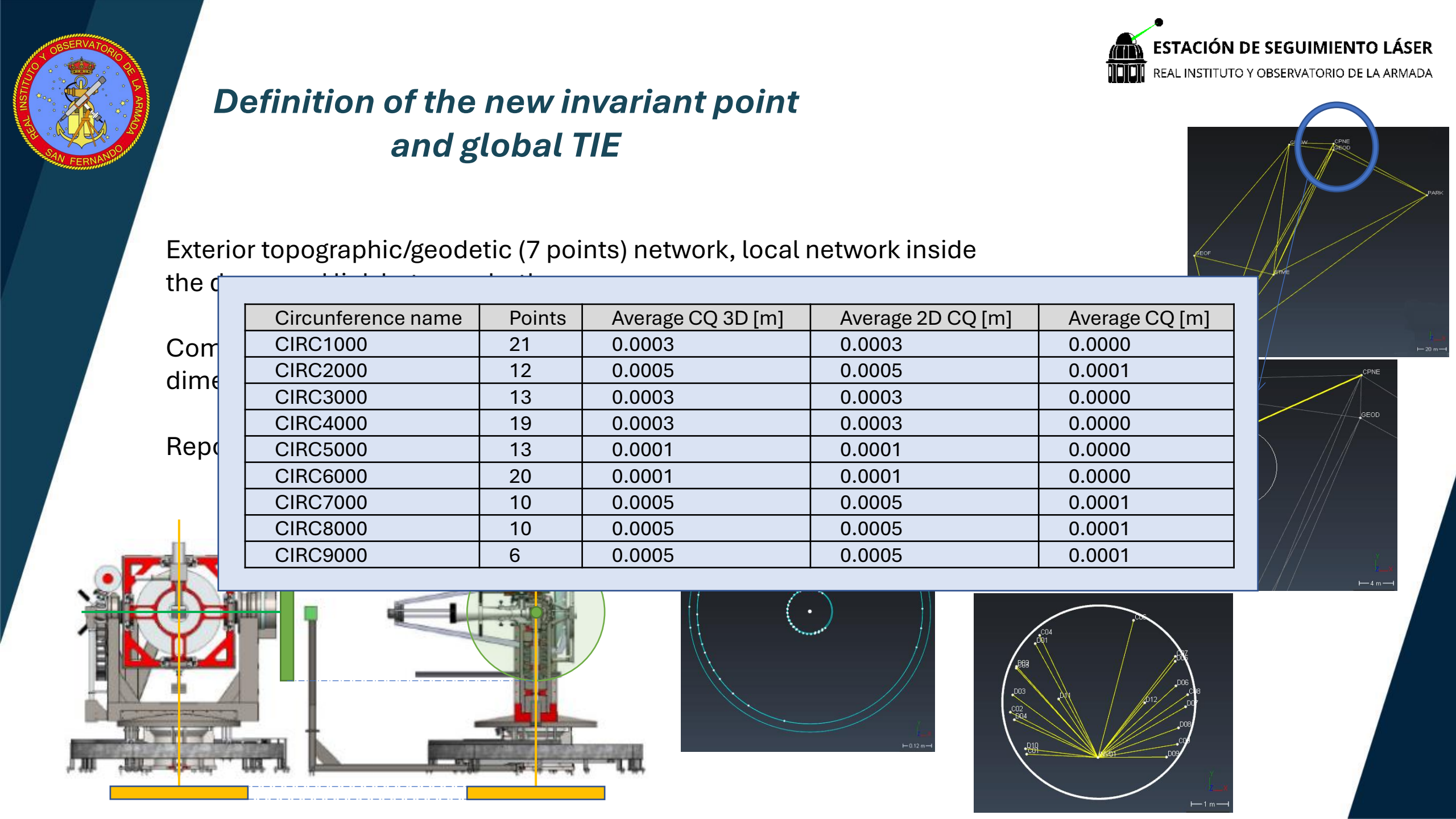
Definition of the new invariant point and global TIE

Exterior topographic/geodetic (7 points) network, local network inside the dome and the link between both.

Combine classical topography and geodesy methodologies and dimensional control and measurement of structures.

Report will be submitted to ILRS.

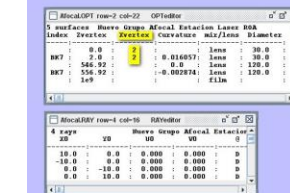
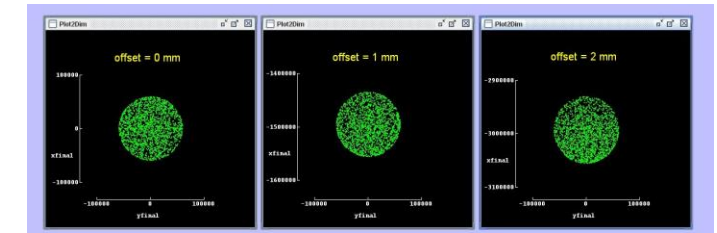
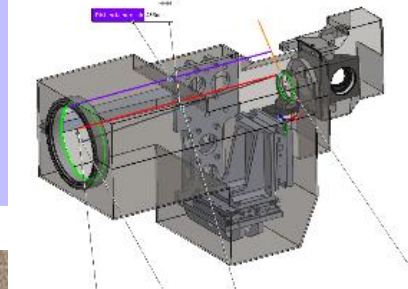




Improvement in other subsystems

New ToF Measurement System

- Eventech ESST 7 Series
- Extremely precise & reliable time tagging device
- 1.5 ps RMS time-tag precision

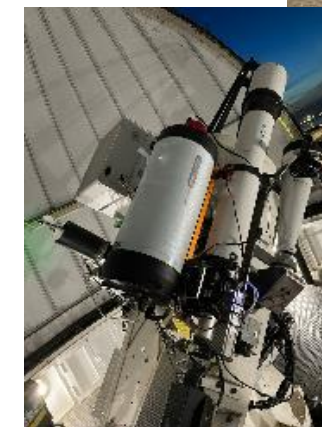
A screenshot of a software interface showing a table of data. The table has columns for 'x', 'y', 'z', 'x2', 'y2', 'z2', 'x3', 'y3', 'z3', 'x4', 'y4', 'z4', 'x5', 'y5', 'z5', 'x6', 'y6', 'z6', 'x7', 'y7', 'z7', 'x8', 'y8', 'z8', 'x9', 'y9', 'z9', 'x10', 'y10', 'z10', 'x11', 'y11', 'z11', 'x12', 'y12', 'z12', 'x13', 'y13', 'z13', 'x14', 'y14', 'z14', 'x15', 'y15', 'z15', 'x16', 'y16', 'z16', 'x17', 'y17', 'z17', 'x18', 'y18', 'z18', 'x19', 'y19', 'z19', 'x20', 'y20', 'z20', 'x21', 'y21', 'z21', 'x22', 'y22', 'z22', 'x23', 'y23', 'z23', 'x24', 'y24', 'z24', 'x25', 'y25', 'z25', 'x26', 'y26', 'z26', 'x27', 'y27', 'z27', 'x28', 'y28', 'z28', 'x29', 'y29', 'z29', 'x30', 'y30', 'z30', 'x31', 'y31', 'z31', 'x32', 'y32', 'z32', 'x33', 'y33', 'z33', 'x34', 'y34', 'z34', 'x35', 'y35', 'z35', 'x36', 'y36', 'z36', 'x37', 'y37', 'z37', 'x38', 'y38', 'z38', 'x39', 'y39', 'z39', 'x40', 'y40', 'z40', 'x41', 'y41', 'z41', 'x42', 'y42', 'z42', 'x43', 'y43', 'z43', 'x44', 'y44', 'z44', 'x45', 'y45', 'z45', 'x46', 'y46', 'z46', 'x47', 'y47', 'z47', 'x48', 'y48', 'z48', 'x49', 'y49', 'z49', 'x50', 'y50', 'z50', 'x51', 'y51', 'z51', 'x52', 'y52', 'z52', 'x53', 'y53', 'z53', 'x54', 'y54', 'z54', 'x55', 'y55', 'z55', 'x56', 'y56', 'z56', 'x57', 'y57', 'z57', 'x58', 'y58', 'z58', 'x59', 'y59', 'z59', 'x60', 'y60', 'z60', 'x61', 'y61', 'z61', 'x62', 'y62', 'z62', 'x63', 'y63', 'z63', 'x64', 'y64', 'z64', 'x65', 'y65', 'z65', 'x66', 'y66', 'z66', 'x67', 'y67', 'z67', 'x68', 'y68', 'z68', 'x69', 'y69', 'z69', 'x70', 'y70', 'z70', 'x71', 'y71', 'z71', 'x72', 'y72', 'z72', 'x73', 'y73', 'z73', 'x74', 'y74', 'z74', 'x75', 'y75', 'z75', 'x76', 'y76', 'z76', 'x77', 'y77', 'z77', 'x78', 'y78', 'z78', 'x79', 'y79', 'z79', 'x80', 'y80', 'z80', 'x81', 'y81', 'z81', 'x82', 'y82', 'z82', 'x83', 'y83', 'z83', 'x84', 'y84', 'z84', 'x85', 'y85', 'z85', 'x86', 'y86', 'z86', 'x87', 'y87', 'z87', 'x88', 'y88', 'z88', 'x89', 'y89', 'z89', 'x90', 'y90', 'z90', 'x91', 'y91', 'z91', 'x92', 'y92', 'z92', 'x93', 'y93', 'z93', 'x94', 'y94', 'z94', 'x95', 'y95', 'z95', 'x96', 'y96', 'z96', 'x97', 'y97', 'z97', 'x98', 'y98', 'z98', 'x99', 'y99', 'z99', 'x100', 'y100', 'z100'. The table is titled 'micrOSPT row=2 col=22 OPTOUT'.

New launcher telescope

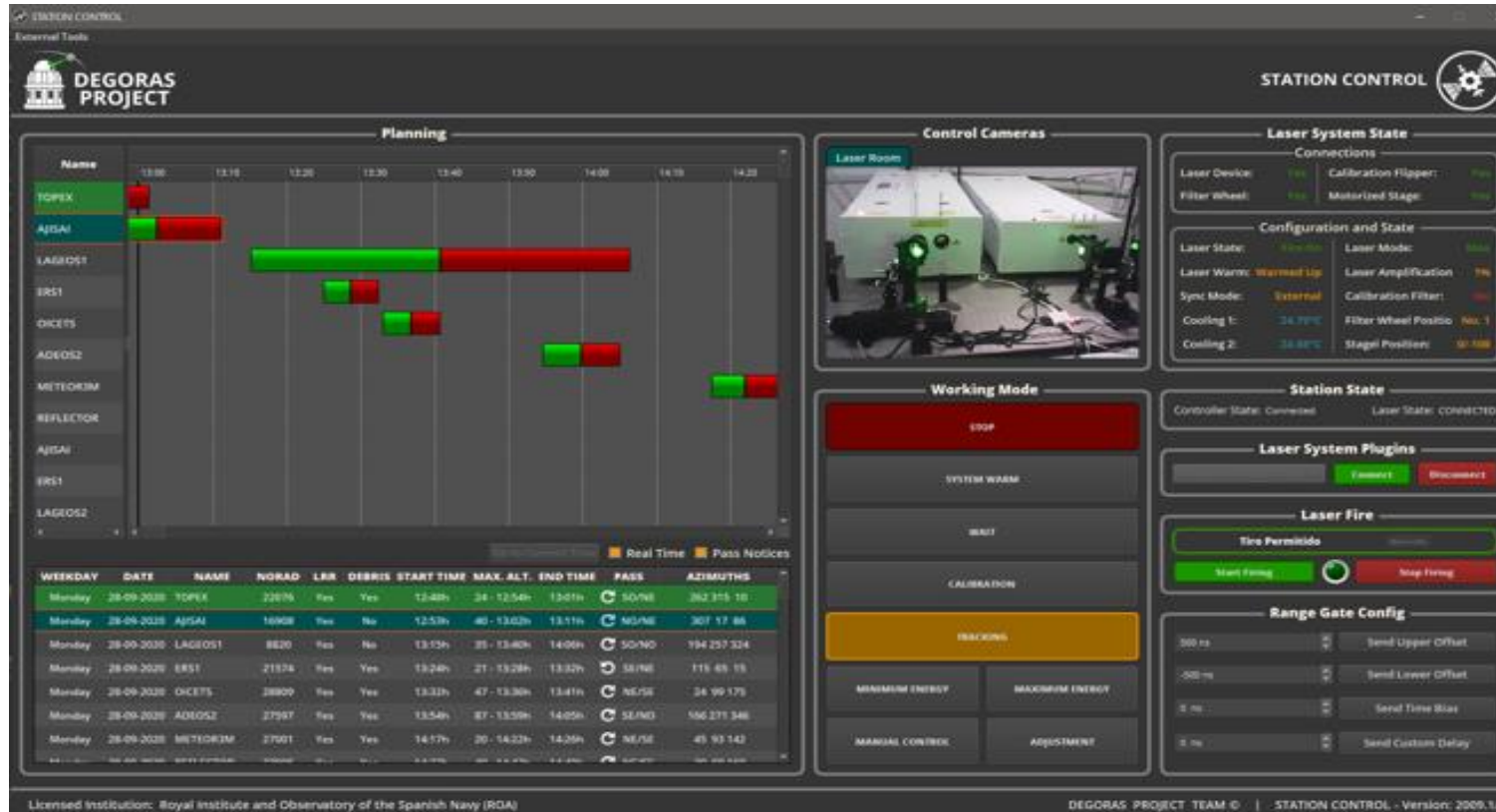
- Optomechnic based on COTS
- Beam pointing and divergence control (5''-120'')

New finder telescope

- Celestron RASA 8 + CMOS ZWO ASI 2600
- Useful for space debris



Improvement in other subsystems

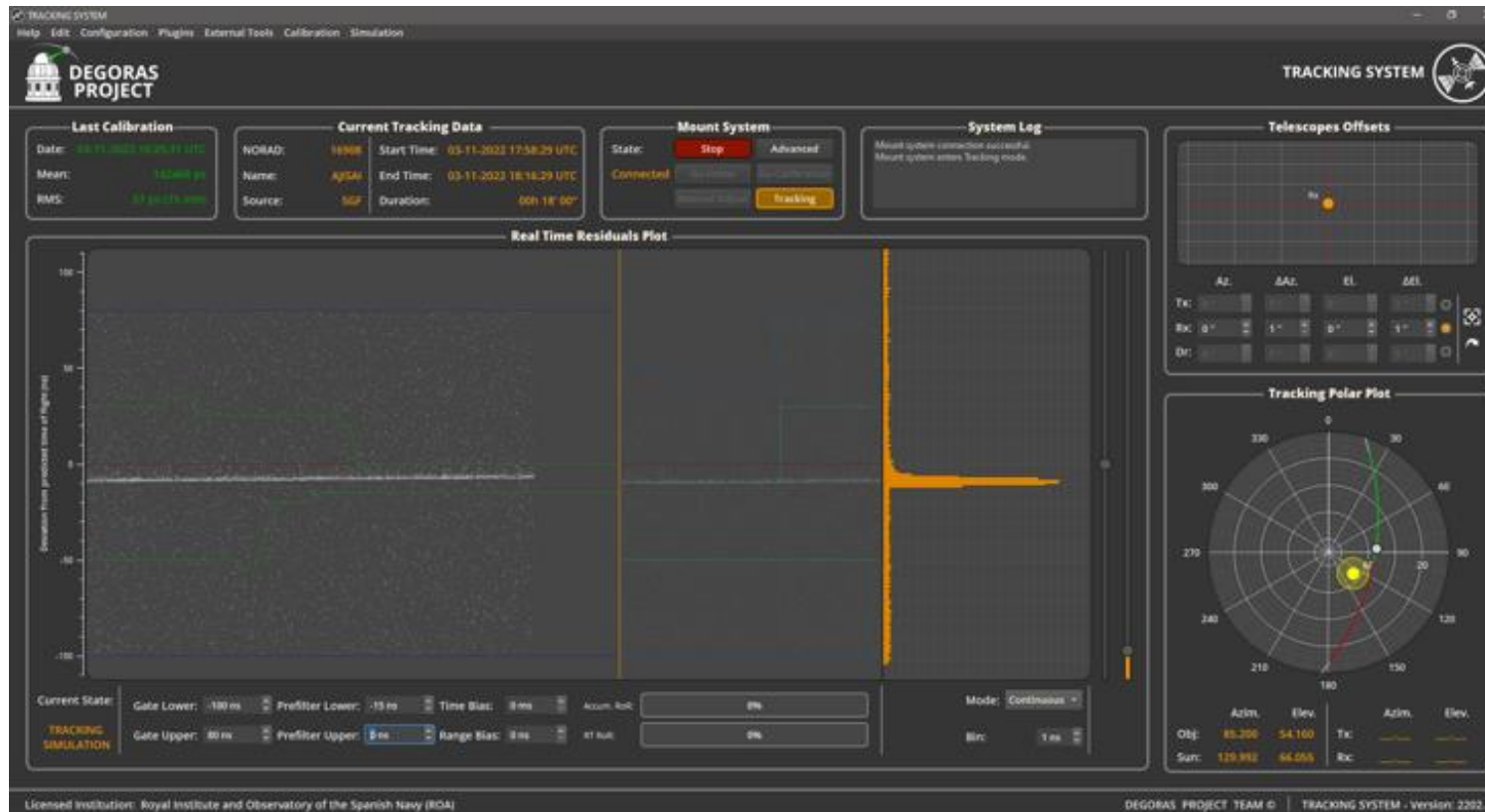


Software Development

- **Station Control**
- *Tracking Programme*
- *Space Objects Database*
- *Prediction Generator*
- *Safety System*
- *Mount Control*



Improvement in other subsystems



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Improvement in other subsystems

SPACE OBJECTS MANAGER

Help Edit Configuration Plugins External Tools

DEGORAS PROJECT

SPACE OBJECTS MANAGER

Space Objects Data Table

EN. POLICY	NORAD	NAME	ILRS NAME	COSPAR	ILRS ID	SIC	CLASSIFICATION	ILRS	DEBRIS	TRACK POLICY	PRIOR	CPF	ALTITUDE	RCS	NPI	BS	
Disabled	40128	GALILEO6	GALILEO205	2014-0008	1409052	7202	Satellite	Yes	No	Always	0	All	21605	0	300	5	
Disabled	40128	GALILEO5	GALILEO204	2014-0004	1409041	7201	Satellite	Yes	No	Always	0	All	21605	0	300	5	
Disabled	38036	GALILEO104	GALILEO104	2012-0008	1205052	7104	Satellite	Yes	No	Always	0	All	23220	13.22	0	300	5
Disabled	38037	GALILEO105	GALILEO105	2012-0004	1205041	7103	Satellite	Yes	No	Always	0	All	23220	10.305	0	300	5
Disabled	37847	GALILEO102	GALILEO102	2011-0008	1106052	7102	Satellite	Yes	No	Always	0	All	23220	46.772	0	300	5
Disabled	37846	GALILEO101	GALILEO101	2011-0004	1106041	7101	Satellite	Yes	No	Always	0	All	23220	51.370	0	300	5
Disabled	29056	ETIS	ETIS	2004-0004	0405041	1576	Geostationary	Yes	Yes	Always	0	All	36000	11	0	300	4
Disabled	20036	COSMOS2004	ITALON2	1989-000C	8902063	6146	Glossa Constellation	Yes	No	Always	0	All	19125	1.208	0	300	6
Disabled	19791	COSMOS1989	ITALON1	1989-001C	8902163	9525	Glossa Constellation	Yes	No	Always	0	All	19125	1.084	0	300	4
Enabled	23540	ERS2	ERS2	1995-021A	9502101	6176	Earth Resources, Brightest	Yes	Yes	Always	0	All	366	9.231	0	15	0
Enabled	21574	ERS1	ERS1	1991-050A	9105001	6177	Earth Resources, Brightest	Yes	Yes	Always	0	All	790	11.009	0	15	0
Enabled	27586	SWISSAT	SWISSAT	2002-000A	0200001	6178	Earth Resources, Brightest	Yes	Yes	Always	0	All	772	19.497	0	15	0
Enabled	2686	DIADEME2	DIADEME10	1967-014A	6701401	6704	Space & Earth Science	Yes	Yes	Always	0	All	581	0.627	0	15	0
Enabled	2674	DIADEME1	DIADEME1C	1967-011A	6701101	6703	Space & Earth Science	Yes	Yes	Always	0	All	545	0.527	0	15	0
Disabled	36588	CRYOSAT2	CRYOSAT2	2010-013A	1001301	8806	Space & Earth Science	Yes	No	Always	0	All	725	2.97	0	15	0
Disabled	41215	BEIDOU11	COMPASSM3	2010-006A	1006001	2011	Beidou Navigation System	Yes	Yes	Always	0	All	21300	0	300	5	
Disabled	26790	BEIDOU12	COMPASSM3	2012-018A	1207001	2004	Beidou Navigation System	Yes	No	Always	0	All	21325	5.623	0	300	5
Disabled	21115	BEIDOU11	COMPASSM1	2007-011A	0701101	2003	Experimental Navigation System	Yes	Yes	Always	0	All	21300	5.461	0	300	5
Disabled	40549	BEIDOU13	COMPASSM1	2013-018A	1307001	2006	Beidou Navigation System	Yes	Yes	Always	0	All	25166	0	300	5	
Disabled	41434	BEIDOU12	COMPASSM6	2010-021A	1002101	2012	Beidou Navigation System	Yes	No	Always	0	All	20677	0	300	5	
Disabled	37948	BEIDOU15	COMPASS15	2011-023A	1107301	2005	Beidou Navigation System	Yes	No	Always	0	All	25796	7.943	0	300	5
Disabled	37953	BEIDOU16	COMPASS16	2011-028A	1108801	2008	Geostationary Navigation System	Yes	Yes	Always	0	All	42141	7.943	0	300	5
Disabled	37364	BEIDOU19	COMPASS19	2011-013A	1101301	2003	Geostationary Navigation System	Yes	No	Always	0	All	25166	25.119	0	300	5

Enablement Policy: ☒ All ☐ Enabled ☐ Disabled | Layer Retro Reflector: ☒ All ☐ With ☐ Without | Debris: ☒ All ☐ Is ☐ Is not | ILRS: ☒ All ☐ Is ☐ Is not | Search:

Database | Name: ICATIR Database_v2 | Date: 2020-08-31 13:29:13 UTC | Objects | Enabled: 28 | Loaded: 305 | Displayed: 300 | Deselect All | Select All

Space Object Picture

Sets Tools

System Set: DEBRIS ILRS + ROCKETS
Loaded Set: DEBRIS ILRS + ROCKETS

Selected Set: DEBRIS ILRS + ROCKETS

Set as System Set and Load

New Set Delete Selected

Load Selected Save Selected

Set En. Policy Disabled

Database Tools

Add Space Object

Edit Selected Delete Selected

Load Database

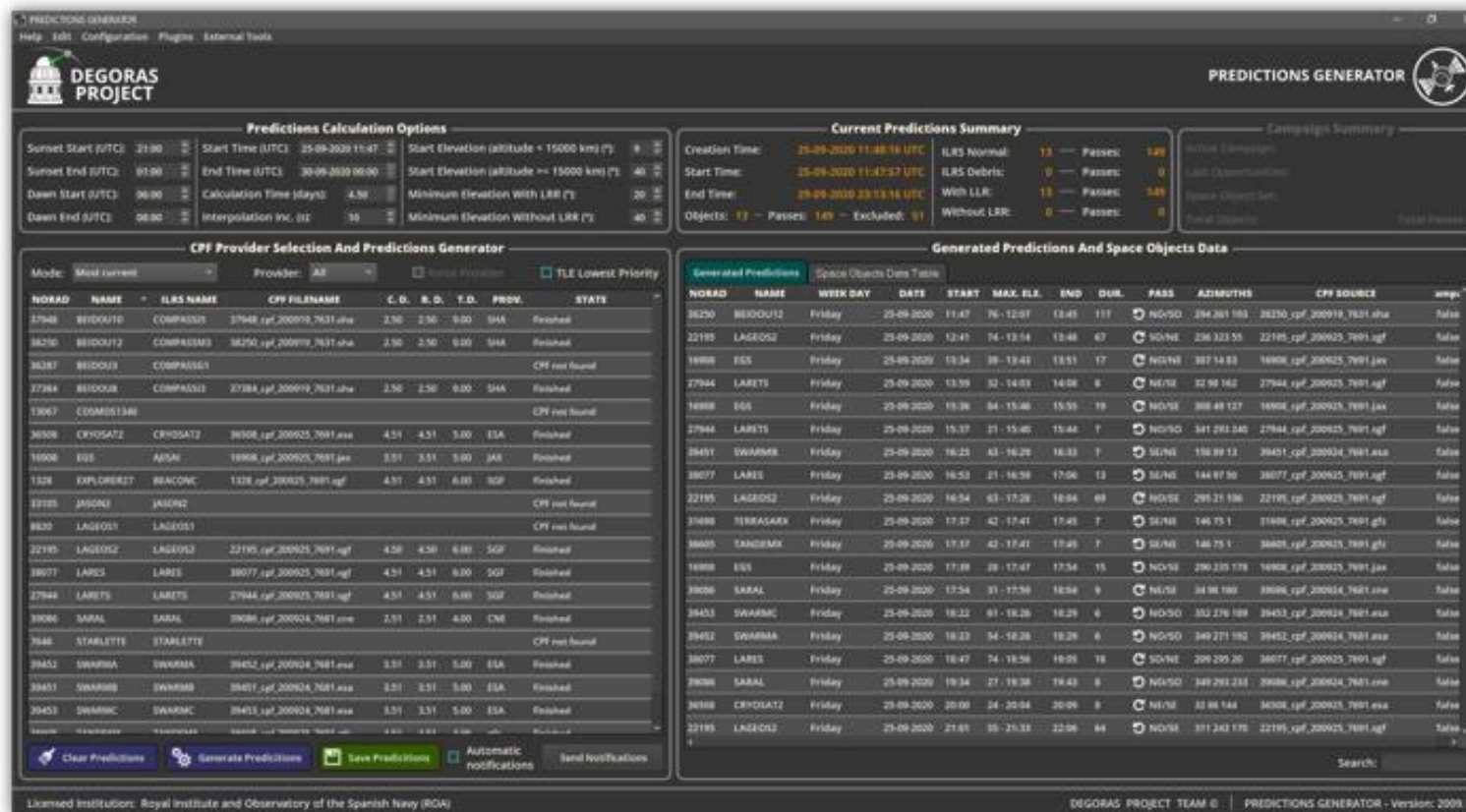
Save Database

DEGORAS PROJECT TEAM © | SPACE OBJECTS MANAGER - Version: 2009.20

Software Development

- Station Control
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- **Space Objects Database**
- Prediction Generator
- Safety System
- Mount Control

Improvement in other subsystems



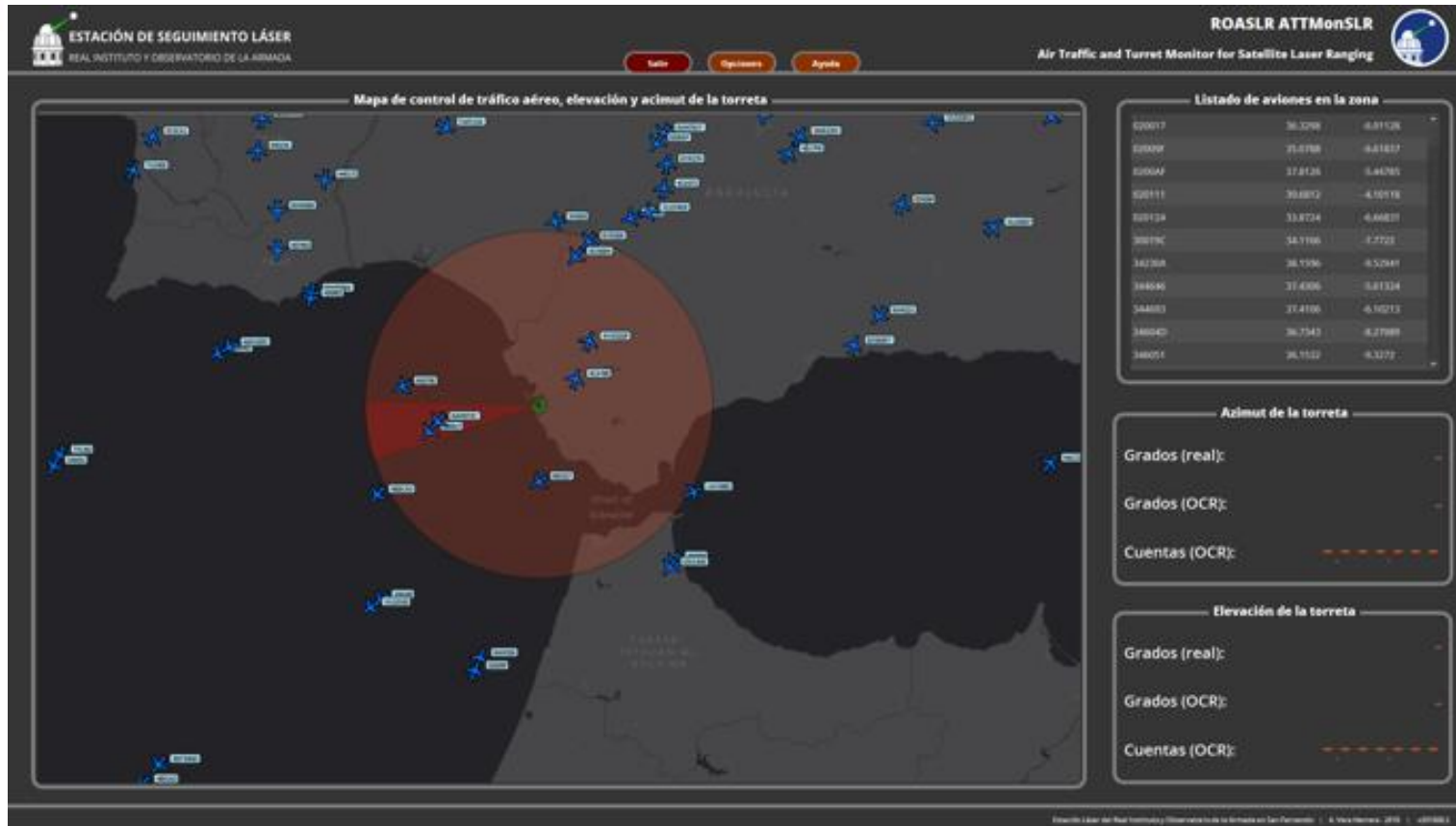
The screenshot shows the DEGORAS PROJECT Predictions Generator software interface. It features a dark theme and a complex layout with multiple panels. The top panel includes the software title and navigation tabs. Below this, there are sections for 'Predictions Calculation Options', 'Current Predictions Summary', and 'Campaign Summary'. The main area is divided into two large tables: 'Generated Predictions' on the left and 'Generated Predictions And Space Objects Data' on the right. The 'Generated Predictions' table lists various objects with columns for NORAD, NAME, ILRS NAME, CFP FILENAME, C.O., R.O., T.D., PROV., and STATE. The 'Generated Predictions And Space Objects Data' table provides more detailed information, including WEEK DAY, DATE, START, MAX. ELA., END, DUR., PASS, AZIMUTHS, CFP SOURCE, and IMP. At the bottom, there are buttons for 'Clear Predictions', 'Generate Predictions', 'Save Predictions', and 'Send Notifications', along with a license notice for the Real Instituto y Observatorio de la Armada (ROA).

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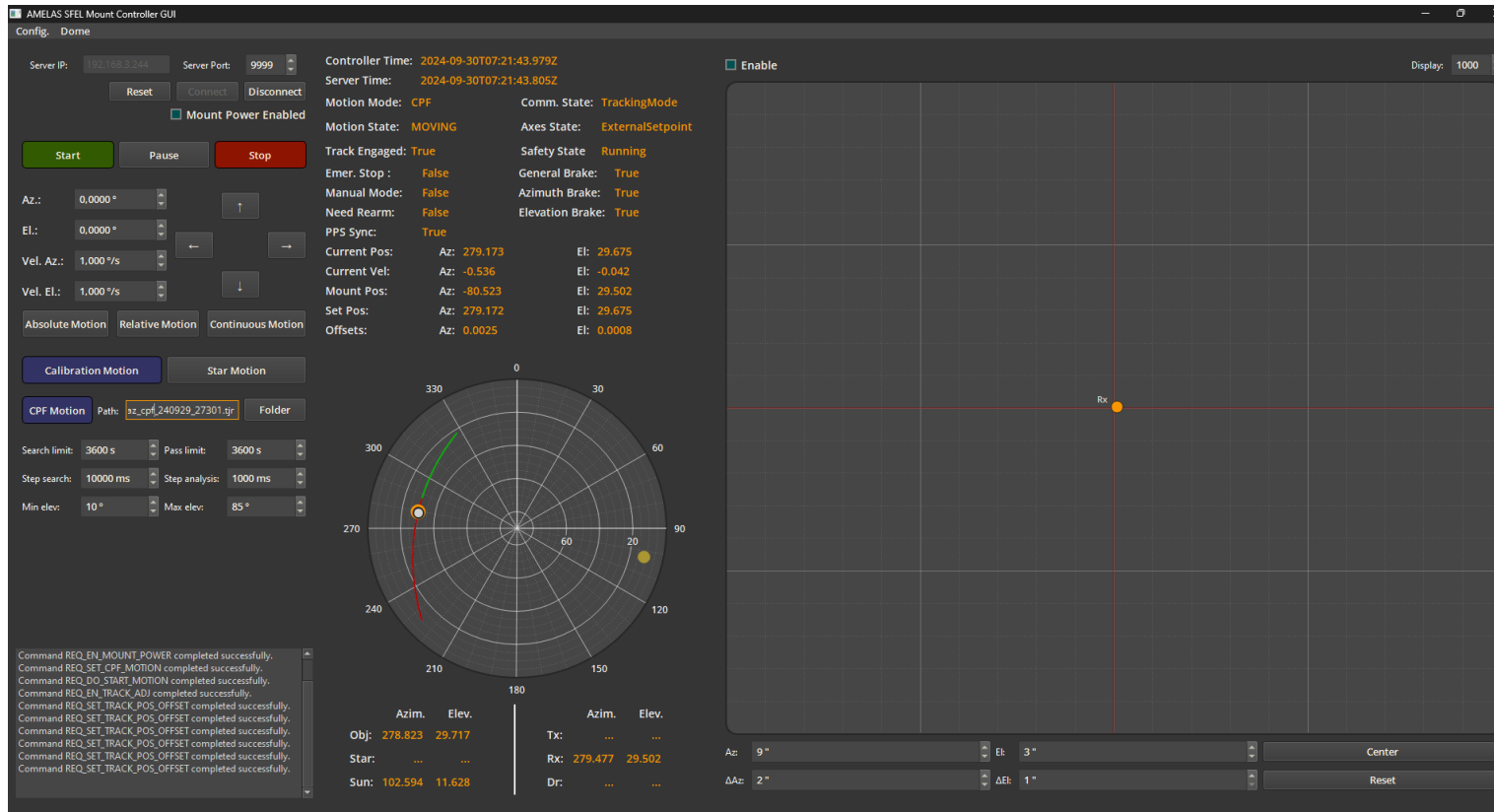


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Software Development

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Upcoming projects

TERELAS

New Cassegrain Telescope (800 mm)

1 arcsec star image

Lighter and greater reflectivity

Space debris

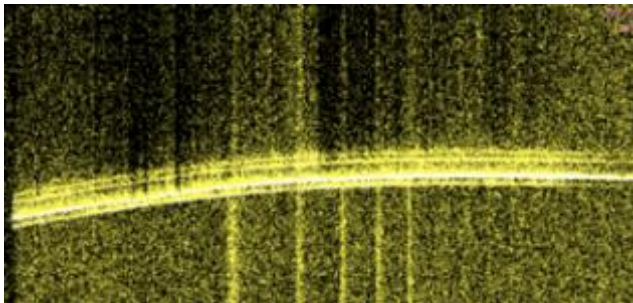
$$n_{pe} = \eta_q \left(E_T \frac{\lambda}{hc} \right) \eta_t G_t \sigma \left(\frac{1}{4\pi R^2} \right)^2 A_r \eta_r T_a^2 T_c^2$$

KIROA

New KHz laser

Combine in the same device ILRS and SST tasks

532 nm, 1-5 KHz, 20 W, < 75 ps



CUPROA

Speed >15°/s (re-entries)

Slit dome according to TERELAS aperture

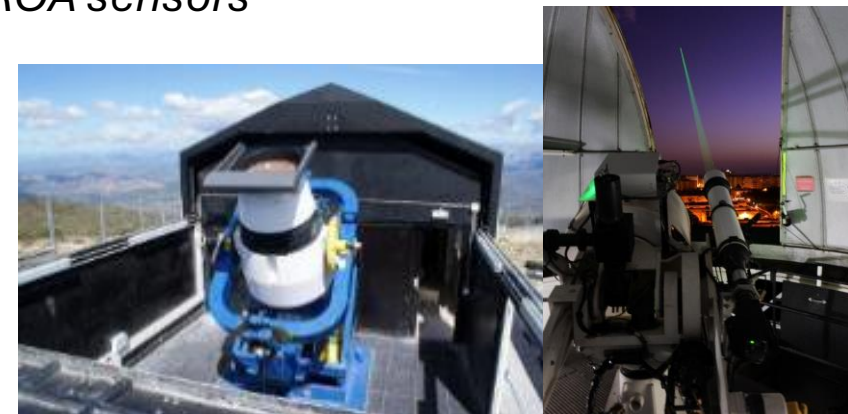
Integrated in station control SW

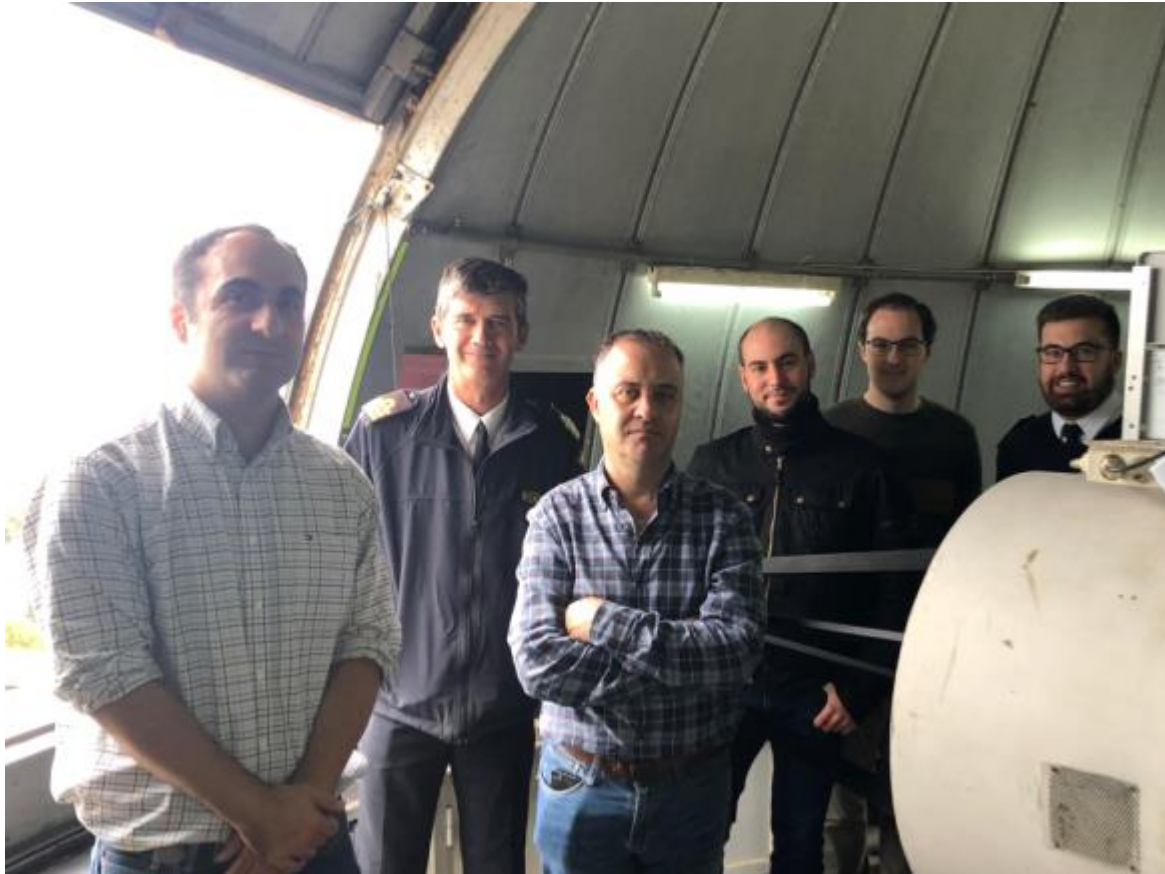


CORA

Operation Center to Control simultaneously

ROA sensors





Staff is the most valuable resource

- *Cohesive group that works with enthusiasm to carry out all the projects we face.*
- *2 observers*
- *4 engineers (multi-discipline)*
- *1 Navy officer (PhD student)*



Tentative schedule

- *Finish current GMV campaign (12/24)*
- *Finish current improvement tasks (12/24)*
- *Evaluation period ILRS Quarentine (TBC with ILRS)*
- *Possible participation in DLR - EU SST Call (01/25)*





Conclusions

- *ROA is making efforts to achieve the state-of-the-art IOT be a **reliable member of ILRS***
- *Several improvements have been developed (i.e. new mount) in a very short period of time*
- *Ready to face new challenges: multistatic observations, blind and daylight tracking,...*

¡Thanks for your attention!



QVS

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