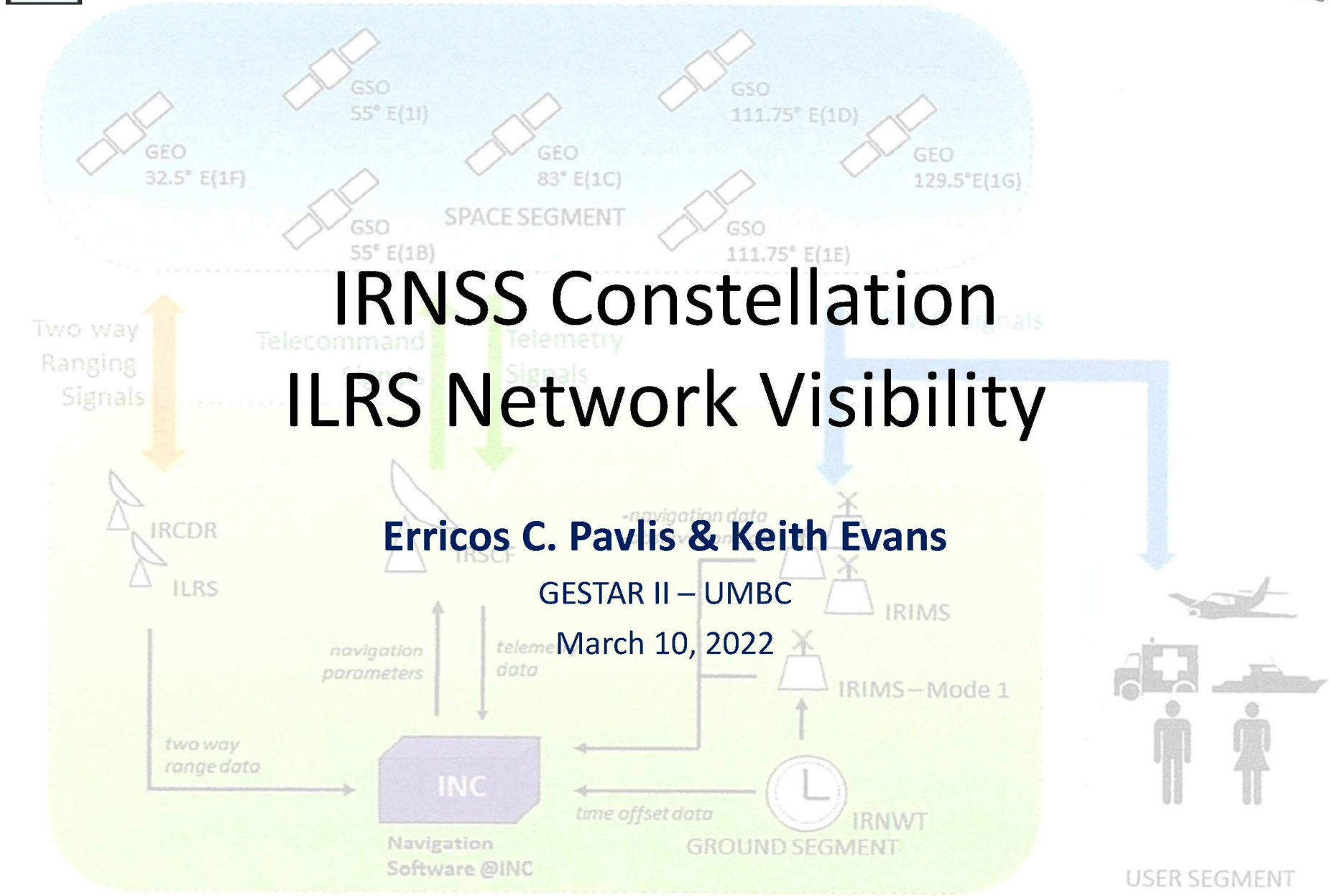


IRNSS Constellation
ILRS Network Visibility

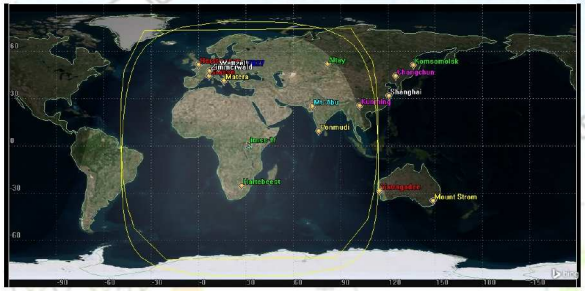
Erricos C. Pavlis & Keith Evans

GESTAR II – UMBC

March 10, 2022

Minimum Elevation: 0°

IRNSS 1F



IRNSS 1C

IRNSS 1G

IRNSS 1I & 1B

IRNSS 1D & 1E

- Area of visibility with a 0° minimum elevation for ILRS stations located within its limits.

Minimum Elevation: 35°

IRNSS 1F

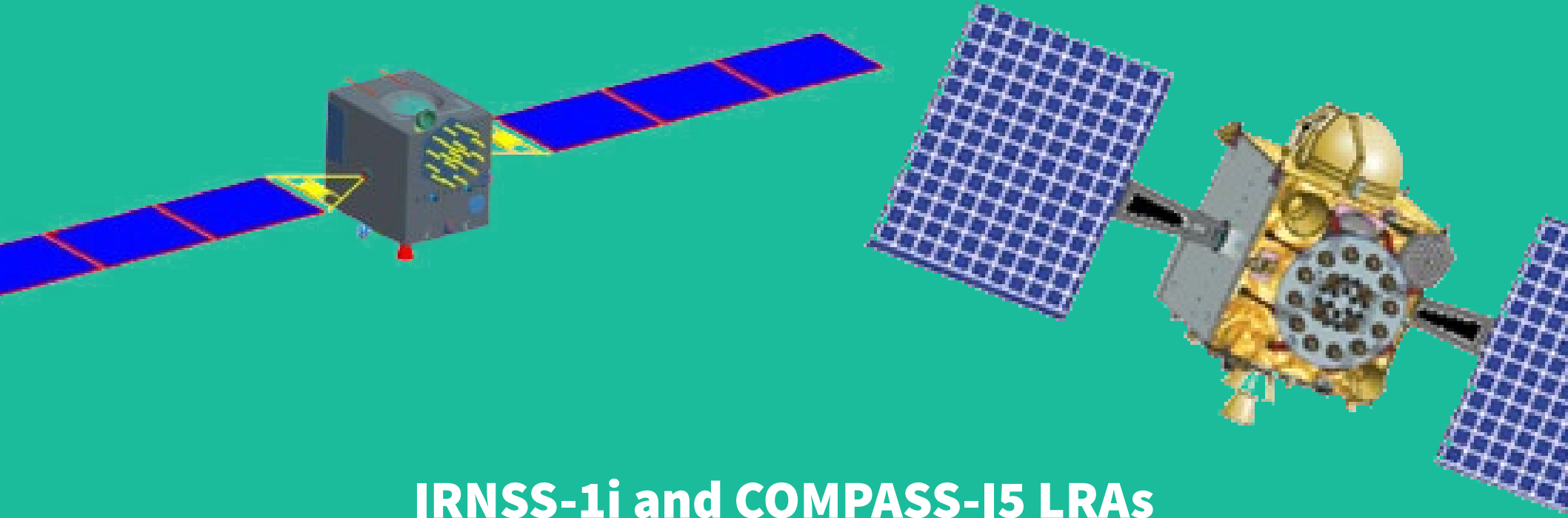
IRNSS 1C

IRNSS 1G

IRNSS 1I & 1B

IRNSS 1D & 1E

- Area of visibility with a 35° minimum elevation for ILRS stations located within its limits.

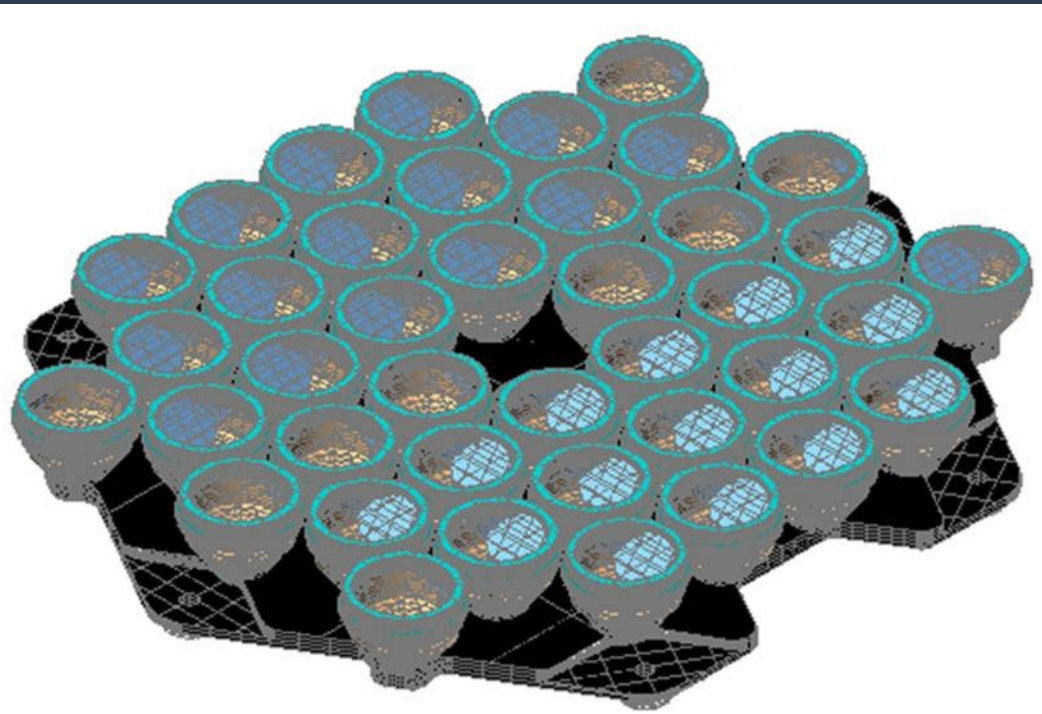


IRNSS-1i and COMPASS-I5 LRAs

Matt Wilkinson
NESC
24th March 2022

Source: ILRS website

IRNSS-1i



- **Altitude 35,786 km**
- **Retro-reflector array**
  - 40 cubes
  - 38mm diameter
  - Total surface area 453.6 cm^2
  - Fused Quartz
  - Uncoated
  - Clocked
  - Dihedral angle of the cube is 0 degrees ± 0.5 arc seconds

Source: ILRS website

COMPASS-I5

- **Altitude 35,786 km**
- **Retro-reflector array**
  - 42 cubes
  - 33mm diameter
  - Total surface area 359.2 cm^2
  - Quartz
  - Uncoated
  - Clocked
  - Dihedral angle of the cube is 0.6 ± 0.3 arc seconds

Comparison

	IRNSS-1i	COMPASS-I5
Altitude	35,786 km	35,786 km
Number of corner cubes	40	42
Cube diameter	38mm	33mm
Total surface area	453.6 cm^2	359.2 cm^2
Material	Fused Quartz	Quartz
Coating	Uncoated	Uncoated
Cube alignment	Clocked	Clocked
Dihedral Angle	0 ± 0.5 arc seconds	0.6 ± 0.3 arc seconds

IRNSS SCF-Test

Thermo-optical vacuum testing of IRNSS laser retroreflector array qualification model

L. Porcelli, A. Boni, E. Ciocci, S. Contessa, S. Dell'Agnello, G. Delle Monache, N. Intaglietta, M. Martini, C. Mondaini, G. Patrizi, L. Salvatori, M. Tibuzzi, C. Lops, C. Cantone, P. Tuscano, M. Maiello, R. Venkateswaran, P. Chakraborty, C.V. Ramana Reddy, K.V. Sriram,

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https://doi.org/10.1016/j.asr.2017.05.012.

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ADVANCES IN SPACE RESEARCH (a COSPAR publication)

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Thermo-optical vacuum testing of IRNSS laser retroreflector array qualification model

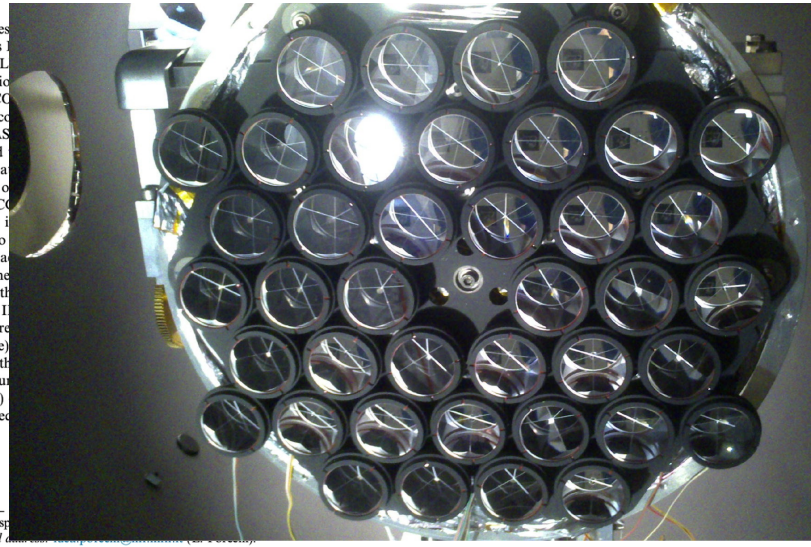
L. Porcelli [a,*], A. Boni [a], E. Ciocci [a], S. Contessa [a], S. Dell'Agnello [a], G. Delle Monache [a], N. Intaglietta [a], M. Martini [a], C. Mondaini [a], G. Patrizi [a], L. Salvatori [a], M. Tibuzzi [a], C. Lops [a], C. Cantone [a], P. Tuscano [a], M. Maiello [a], R. Venkateswaran [b], P. Chakraborty [b], C.V. Ramana Reddy [b], K.V. Sriram [b]

[a] *Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali di Frascati (INFN-LNF), Via E. Fermi 40, 00044 Frascati, Rome, Italy*

[b] *Indian Space Research Organisation – Laboratory for Electro-Optics Systems (ISRO-LEOS), First Cross, First Phase, Peenya Industrial Estate, Bangalore 560 058, India*

Received 5 December 2016; received in revised form 8 May 2017; accepted 10 May 2017
Available online 18 May 2017

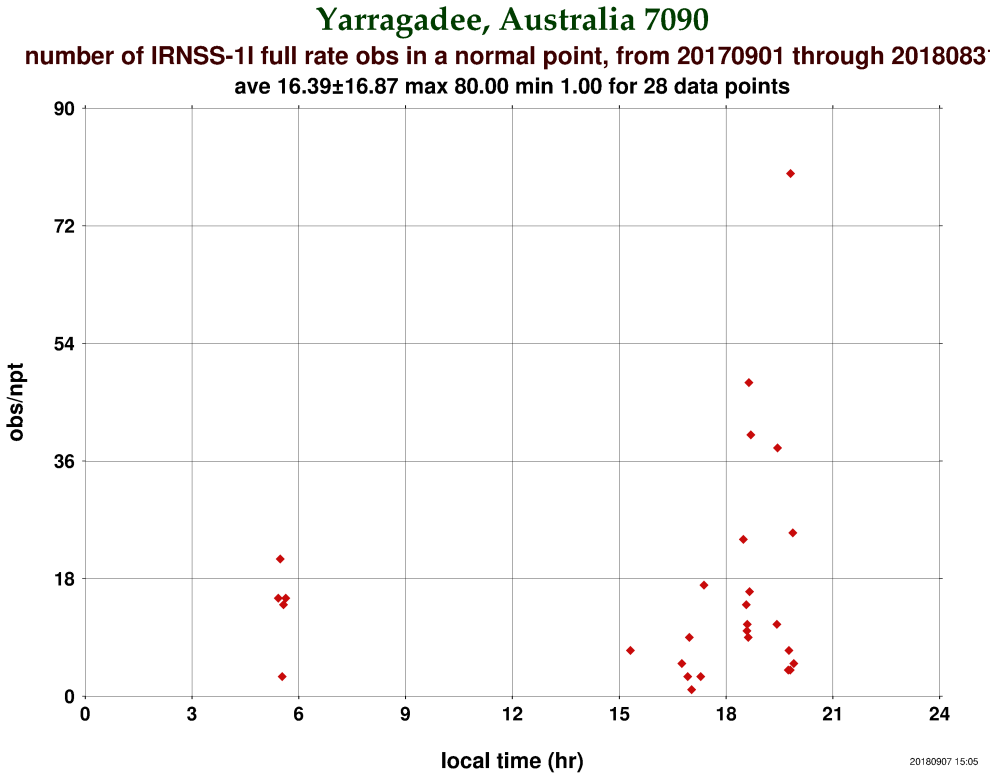
Abstract

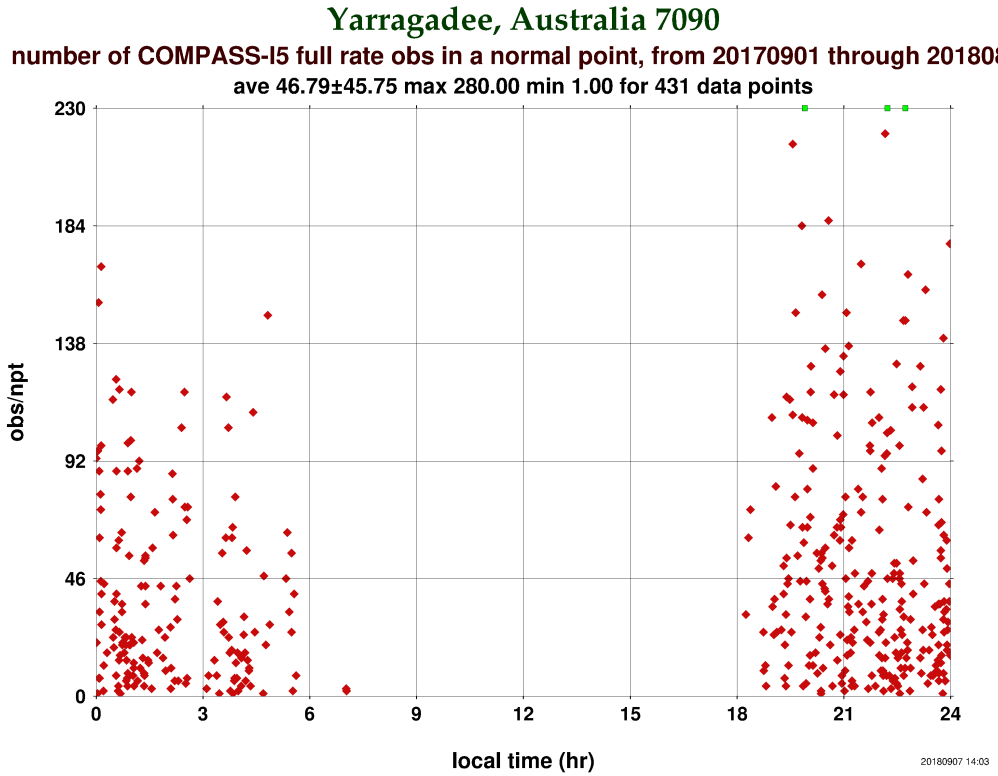


* Corresp
E-mail

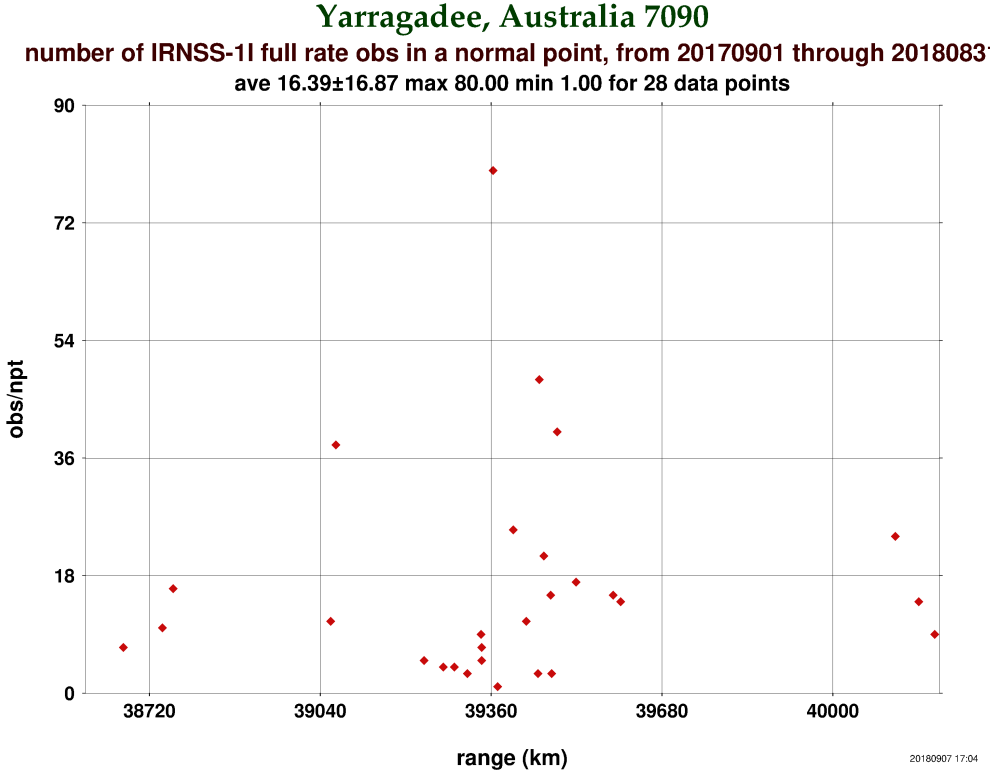
http://dx.doi.org/10.1016/j.asr.2017.05.012

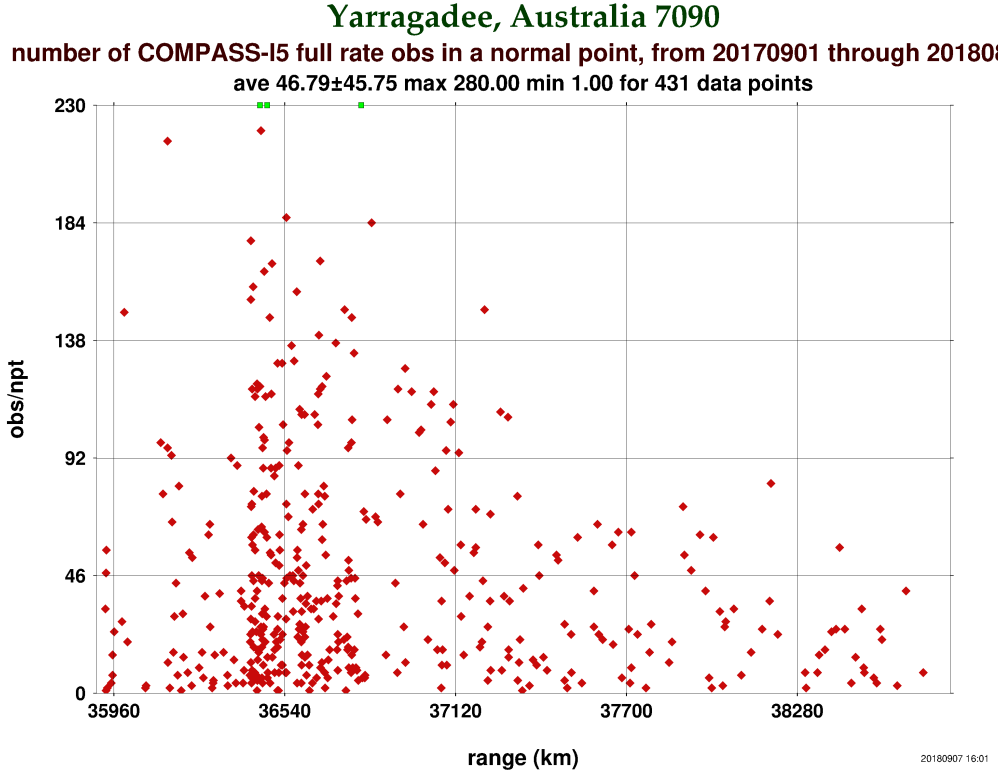
Comparison - Yarragadee





Comparison - Yarragadee

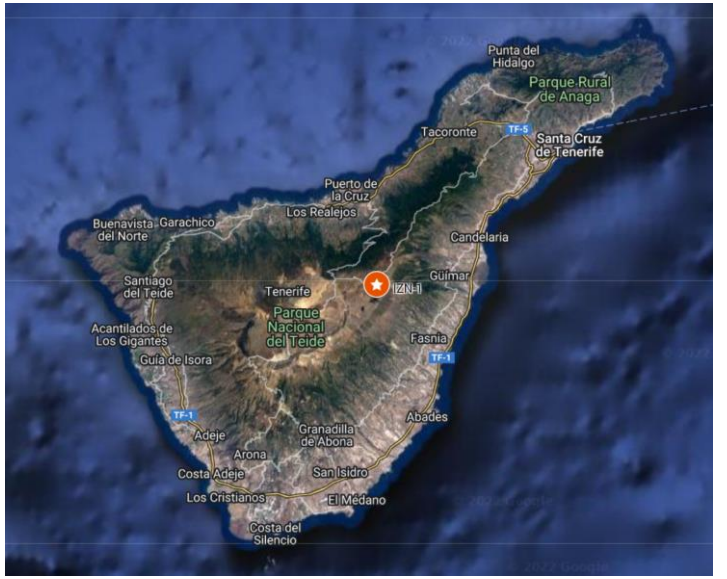




Introducing the ESA Satellite Laser Ranging station IZN-1, Tenerife

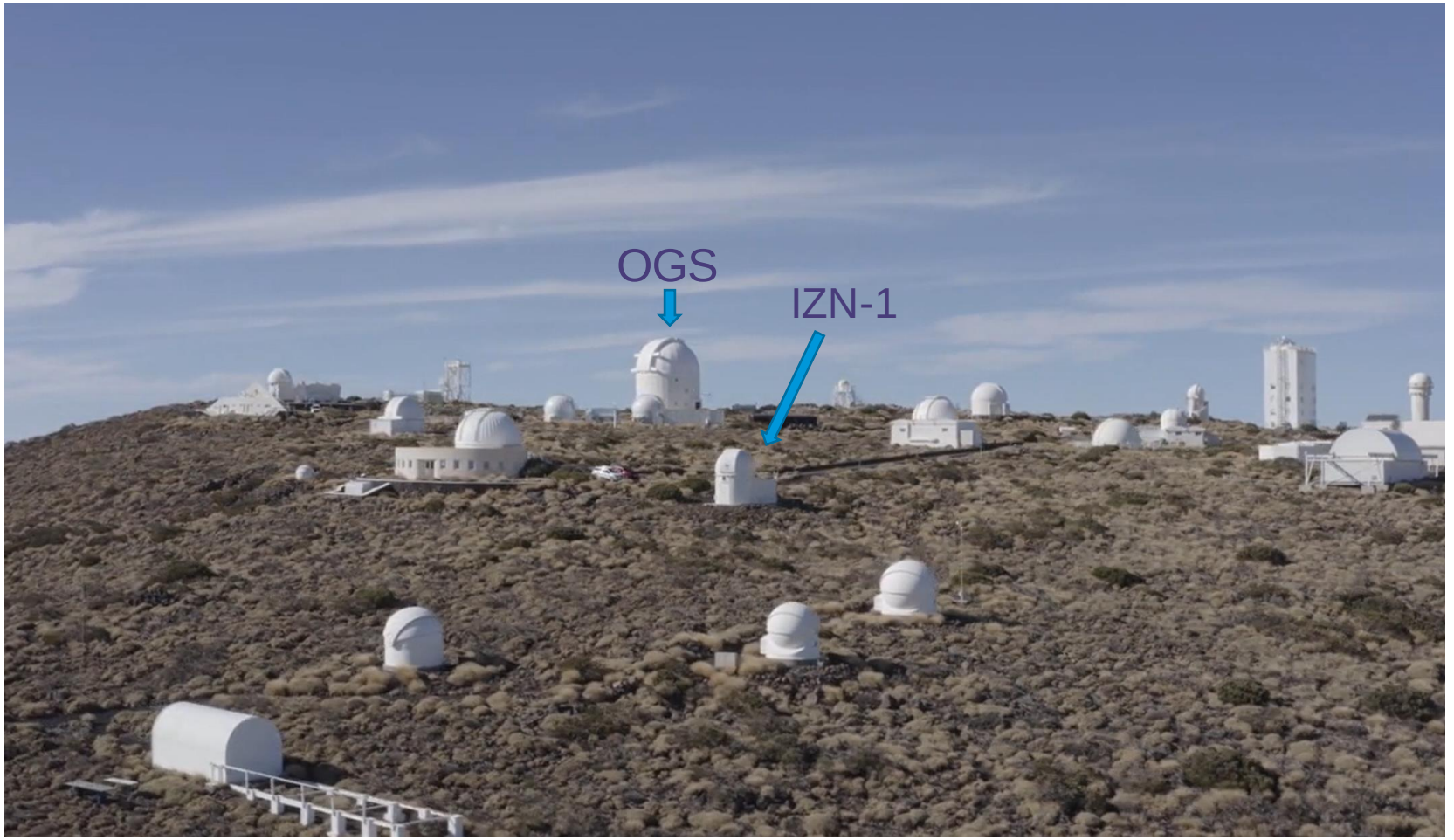
Andrea Di Mira, Jens Steinborn

ESA Laser Ranging Station: IZN-1



- Station site: Teide Observatory (2400 m) in Tenerife
- Turnkey solution based on COTS components
- Remote operations

ESA Laser Ranging Station: IZN-1



ESA Laser Ranging Station: IZN-1

Targeted short term goals:

- Satellite Laser Ranging at 532 nm and 1064 nm
- ILRS engineering station
- On-demand SLR support and support to ESA missions
- LEO-DTE Optical Ground Station
- Space debris passive observations
- Testbed for European Industry
- Autonomous operations

Main station subsystems

Telescope

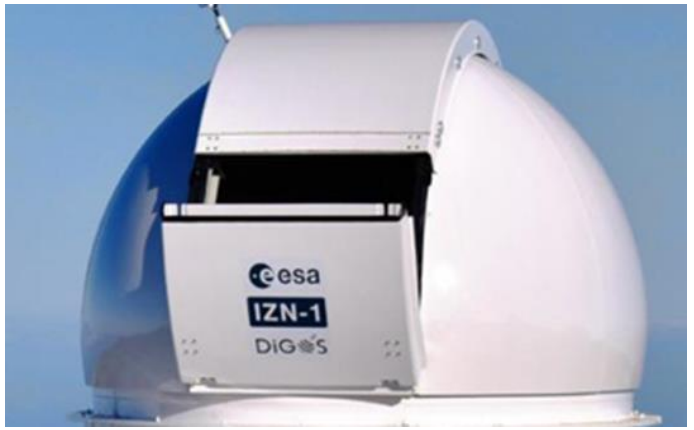
- ASA AZ800
- Ritchey- Chretien 80 cm f/6.8
- Pointing accuracy <5 arcsec

Detector package

- C-SPAD (532 nm)
- IR-SPAD (1064 nm)

Dome

- Baader Planetarium 4.2 m
- Lower flap and rolling shutter



Laser package

- Passat Compiler 532/1064 nm
- Nd:YAG PRF 400 Hz

λ	Pulse width	Pulse Energy
532 nm	7 ps	400 µJ
1064 nm	8.5 ps	500 µJ

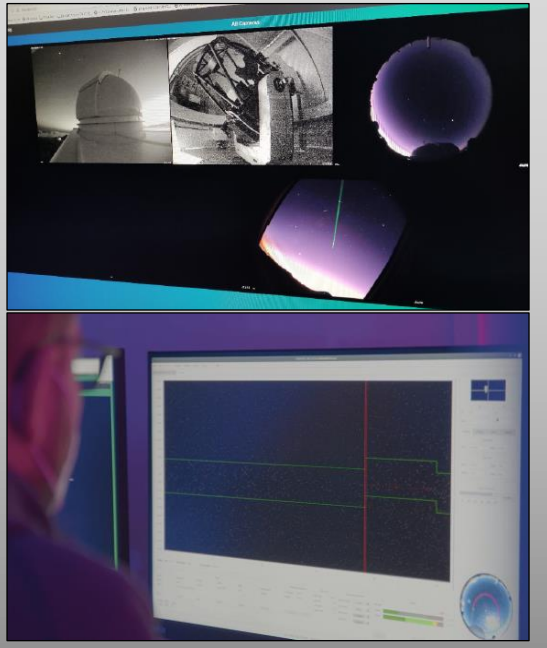
Main station subsystems

Space Debris Camera

- FLI ML 16070
- Pixel size 7.4 µm
- N of pixels: 4864 x 3232

SLR equipment rack

- Range Gate Generator
- Event timer A033-ET
- NTP
- GNSS receiver / OCXO DHQ
- Stability 2E-12 @1s



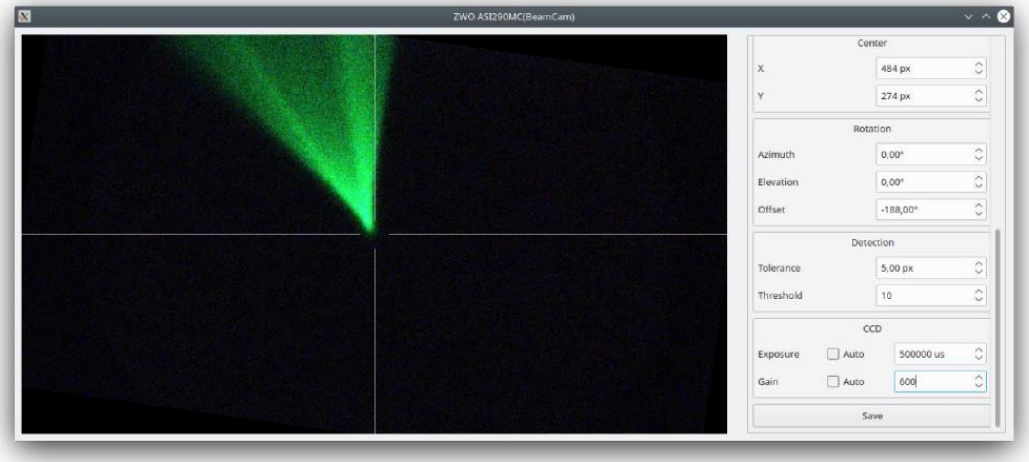
Laser Safety

- Emergency stops
- Interlocks
- ADS-B
- IR cameras

Project Timeline

- ✓ Kick off 2018
- ✓ Design, procurement and pre-integration in 2018-2020
- ✓ FAT in 2020
- ✓ Deployment and SAT 2021
- ✓ **SAT Closeout review** January 2022
- ➢ Formal handover: April 2022

Station Validation and Performance



- Optical alignments and pointing performance verification
- Laser ranging campaigns (day and night-time)
- Tracking since Q3 2021 several LEOs, geodetic and navigation targets
- Also some success with IRNSS 1i at 22° elevation
- Remote operations

TARGET

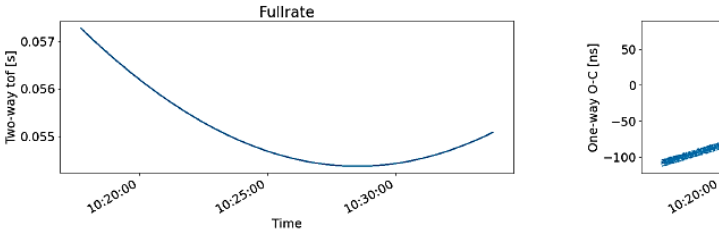
LAGEOS-1

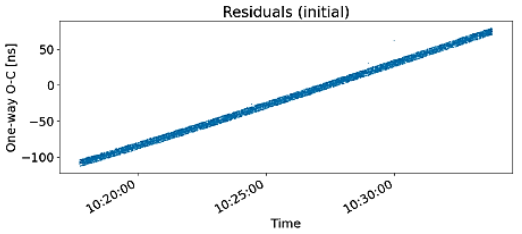
WAVELENGTH (nm)

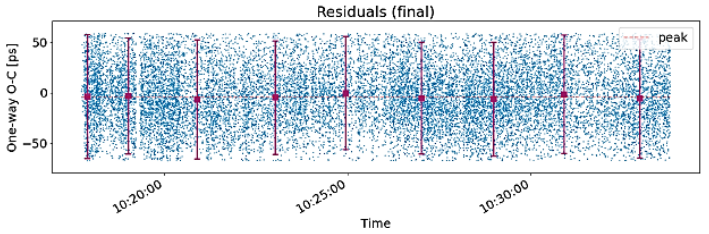
1064.0

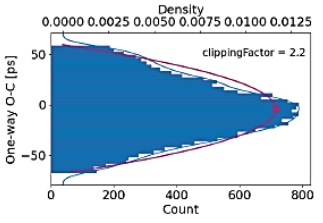
EVALUATION

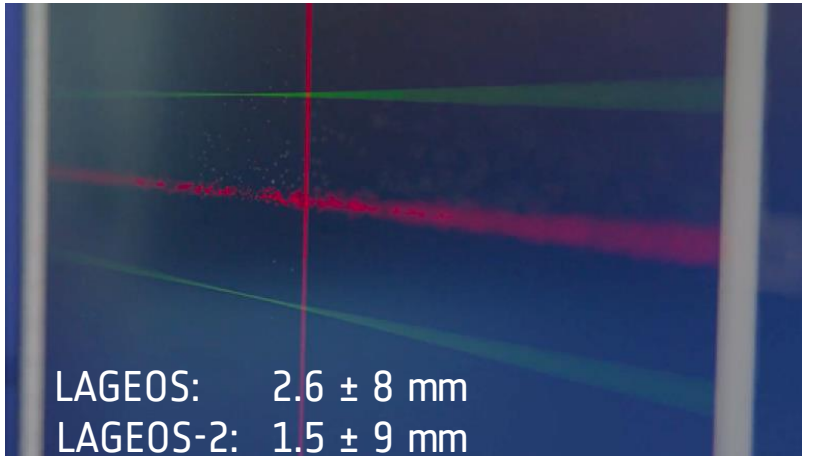
Returns	18951
RMS (1w, mm)	8.66
RMS (2w, ps)	57.74
TB (ms)	0.13
RB (m)	-0.51





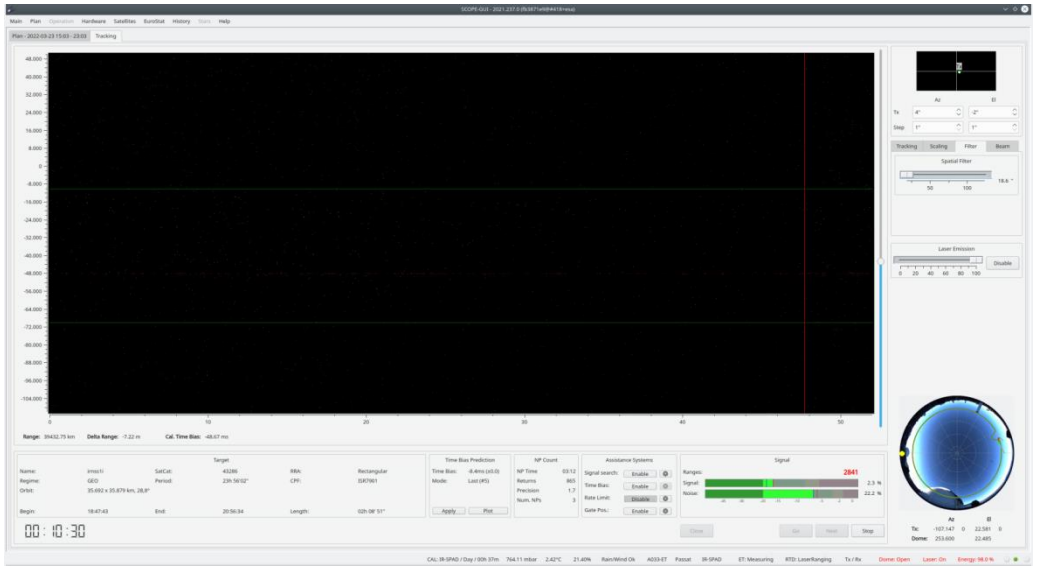






Joining ILRS

- Regular tracking of Lageos 1&2 started September 2021 @532nm
- First quality control and estimation of station coordinates done by Toshi based on 14 Lageos1&2 passes @532nm
- Average RB <10mm (also the data amount is small)



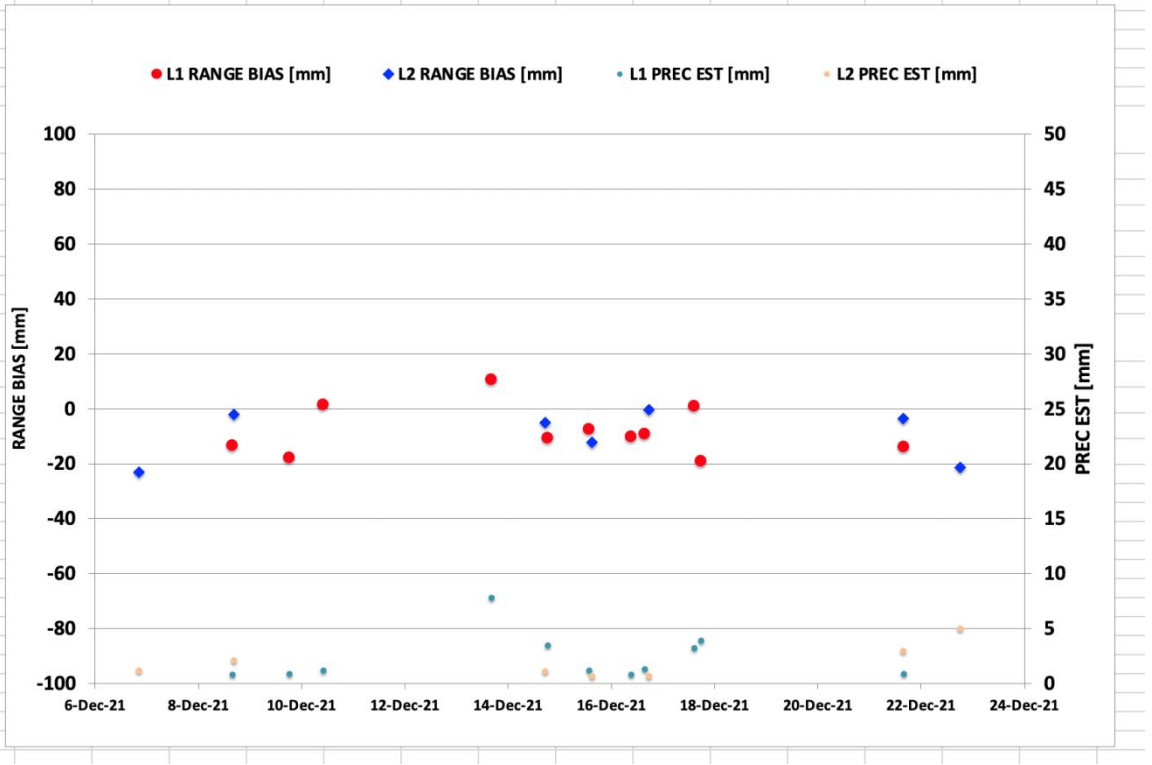
- Since end November stable tracking with 1064nm
- Second quality control and estimation of stations coordinates done by Toshi based on 14 Lageos 1&2 passes @1064nm
- Similar RB and good agreement to 532nm

- Tracking continues completely remotely mainly at 1064nm
- Station ID 7701 assigned by ILRS
- Regular data upload to EDC since January 2022

First QC Report

L1 77015711	PREC EST [mm]	RANGE BIAS [mm]
Mean	2.3	-8.1
STD	2.2	9.0
RMS	3.1	11.8
Point	11	11

L2 77015711	PREC EST [mm]	RANGE BIAS [mm]
Mean	2.0	-9.7
STD	1.6	9.4
RMS	2.5	13.0
Point	7	7



- First QC report provided by Erricos in January with good precision and small RB
- Waiting for more Lares passes to release station out of quarantine

IZN-1 Short-term Upgrades and Future Perspectives

Laser ranging to space debris

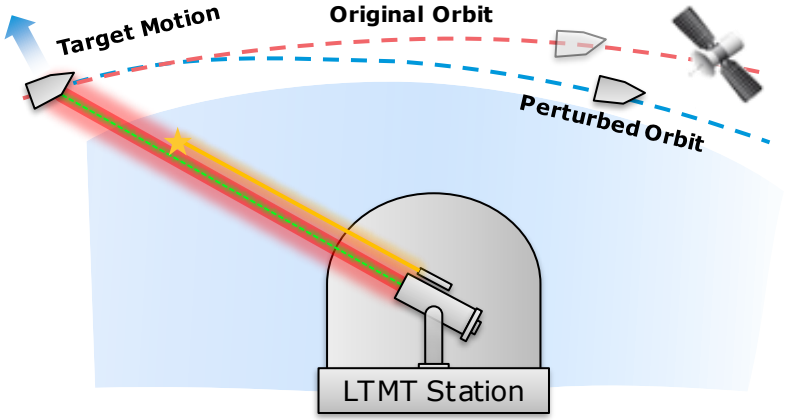
- Average Power 20 - 100 W @1 ns
- Range measurement accuracy ~10s cm
- Optimization for daylight tracking
- Network of space debris tracking stations

LEO-DTE Optical Communications

- Implementation of uplink data transmission and beacon (1590 and 1605 nm)
- 1550 nm downlink capability
- Fiber Laser Technology, Average power > 15W

Development towards:

- Autonomous operations
- Laser Momentum Transfer



Testbed for debris tracking and support to definition of LMT station requirements

- CW 40kW, Yb-doped fiber 1070 nm
- Pre-compensation through high-power Adaptive Optics

Press Release Article:
https://www.esa.int/Safety_Security/Space_Debris/New_laser_station_lights_the_way_to_debris_reduction

Thank you!

We would like to thank the **Istituto de Astrofisica de Canarias** for their support during the installation and **Toshi** for his great contribution in the preliminary evaluation of the station performance.

Some of the images in this presentation were taken by the company 20Zoll

When and How to Update Site Log Section 6: the Receiver System

Van Husson

Vhusson@peraton.com

ILRS Central Bureau

Tertiary Chain
Tertiary Chain
Tertiary Chain

Introduction/History

- **Our colleague and former ILRS Chairman, Werner Gurtner from Zimmerwald, designed the original ILRS Site Log based on the IGS Site Log.**
- **The ILRS Site Log has a section for each major SLR subsystem**
- **Based on reviewing site logs, CRD V2 data, and interactions with the stations over the past few years, there appears to be some confusion on how to complete Section 6: Receiver System of the ILRS Site Log**
- **There are 3 subsections (6.01 Primary Chain, 6.02 Secondary Chain, 6.03 Tertiary Chain) in Section 6 in order to document all the possible receiver configurations being used in parallel**
  - Systems which ranged using multiple wavelengths (e.g. Zimmerwald, Wettzell, Matera);
  - System which used more than one detector (e.g. Zimmerwald, Graz, Potsdam); and/or
  - Systems which used an optional amplifier (e.g. Yarragadee, Monument Peak, Hartebeesthoek, Greenbelt, Tahiti)
- **Many SLR systems only have a single receiver system. In those cases, Sections 6.02 and 6.03 should be blank**
- **The site log was designed to show a complete history of configuration changes. This is accomplished by adding an additional level to each subsection (6.01.01, 6.01.02, 6.01.03, ...)**

Site Log Section 6: Receiver System

6.01.01 Primary Chain
Wavelength [nm]:
Detector Type :
Manufacturer :
Model :
Quantum Efficiency [%]:
Nominal Gain :
Rise Time [ps]:
Jitter (Single PE)[ps]:
Field of View Diam ["]:
Date Installed :
Date Removed :
Amplifier Type :
Manufacturer :
Model :
Gain :
Bandwidth :
Date Installed :
Date Removed :
Additional Information:
Signal Processing :
Manufacturer :
Model :
Date Installed :
Date Removed :
Amplitude Measurement :
Return-Rate Controlled:
Mode of Operation :
Additional Information:
Time of Flight Observ. :
Manufacturer :
Model :
Resolution [ps]:
Precision [ps]:
Date Installed :
Date Removed :
Additional Information :

6.02.01 Secondary Chain
Wavelength [nm]:
Detector Type :
Manufacturer :
Model :
Quantum Efficiency [%]:
Nominal Gain :
Rise Time [ps]:
Jitter (Single PE)[ps]:
Field of View Diam ["]:
Date Installed :
Date Removed :
Amplifier Type :
Manufacturer :
Model :
Gain :
Bandwidth :
Date Installed :
Date Removed :
Additional Information:
Signal Processing :
Manufacturer :
Model :
Date Installed :
Date Removed :
Amplitude Measurement :
Return-Rate Controlled:
Mode of Operation :
Additional Information:
Time of Flight Observ. :
Manufacturer :
Model :
Resolution [ps]:
Precision [ps]:
Date Installed :
Date Removed :
Additional Information :

6.03.01 Tertiary Chain
Wavelength [nm]:
Detector Type :
Manufacturer :
Model :
Quantum Efficiency [%]:
Nominal Gain :
Rise Time [ps]:
Jitter (Single PE)[ps]:
Field of View Diam ["]:
Date Installed :
Date Removed :
Amplifier Type :
Manufacturer :
Model :
Gain :
Bandwidth :
Date Installed :
Date Removed :
Additional Information:
Signal Processing :
Manufacturer :
Model :
Date Installed :
Date Removed :
Amplitude Measurement :
Return-Rate Controlled:
Mode of Operation :
Additional Information:
Time of Flight Observ. :
Manufacturer :
Model :
Resolution [ps]:
Precision [ps]:
Date Installed :
Date Removed :
Additional Information :

- **The three Receiver System subsections (6.01, 6.02 and 6.03) have the same identical fields (See examples on the left).**
- **There is the wavelength plus the four following main components**
  1. Detector Type
  2. Amplifier Type (can be blank if no amplifier is used)
  3. Signal Processing
  4. Time of Flight Observation
- **Installing a new model of one of these 4 components requires a site log update by adding another level (e.g. 6.01.02). See next slide**

Site Log Section 6 Primary Chain Update Example

6.01.01 Primary Chain
Wavelength [nm]: 532
Detector Type : MCP
Manufacturer : ITT
Model : F4129F
Quantum Efficiency [%]: 17.7
Nominal Gain : 1e6
Rise Time [ps]: 350
Jitter (Single PE)[ps]: 100
Field of View Diam ["]: 360
Date Installed : 1986-03-31
Date Removed : 2003-04-30
Amplifier Type :
Manufacturer :
Model :
Gain :
Bandwidth :
Date Installed :
Date Removed :
Additional Information:
Signal Processing : CFD
Manufacturer : Tennelec
Model : TC454
Date Installed : 1986-03-31
Date Removed : 2003-04-30
Amplitude Measurement : YES
Return-Rate Controlled: YES
Mode of Operation : Few to Multiple Photons
Additional Information:
Time of Flight Observ. : INTERVAL
Manufacturer : Hewlett-Packard
Model : 5370B
Resolution [ps]: 20
Precision [ps]: 35
Date Installed : 1986-03-31
Date Removed :
Additional Information :

6.01.02 Primary Chain
Wavelength [nm]: 532
Detector Type : MCP
Manufacturer : Photek
Model : PMT318
Quantum Efficiency [%]: 13.3
Nominal Gain : 1e6
Rise Time [ps]: 250
Jitter (Single PE)[ps]: 100
Field of View Diam ["]: 360
Date Installed : 2003-04-30
Date Removed :
Amplifier Type :
Manufacturer :
Model :
Gain :
Bandwidth :
Date Installed :
Date Removed :
Additional Information:
Signal Processing : CFD
Manufacturer : Tennelec
Model : TC454
Date Installed : 1986-03-31
Date Removed :
Amplitude Measurement : YES
Return-Rate Controlled: YES
Mode of Operation : Few to Multiple Photons
Additional Information:
Time of Flight Observ. : INTERVAL
Manufacturer : Hewlett-Packard
Model : 5370B
Resolution [ps]: 20
Precision [ps]: 35
Date Installed : 1986-03-31
Date Removed :
Additional Information :

- **Here on the left is an example where there was a detector change on 30-April-2003**
- **6.01.02 was added to reflect this change. A date removed was added to the detector type in Section 6.01.01 to indicate that ITT MCP detector was no longer in operational use**
- **If you change a component with the same model NO site log change is required, but an entry in your station change history should be added**
- **If a common component to the primary and secondary chain was changed (e.g. the HP370B time interval unit was replaced with an event timer), two new entries 6.01.02 and 6.02.02 would need to be added**

Site Log Section 6 Example of a station that uses an Amplifier

6.01.01 Primary Chain

Wavelength [nm]: 532
Detector Type : MCP
Manufacturer : ITT
Model : F4129F
Quantum Efficiency [%]: 15.5
Nominal Gain : 1e6
Rise Time [ps]: 350
Jitter (Single PE)[ps]: 100
Field of View Diam ["]: 90 - 540
Date Installed : 1987-04-23
Date Removed : 2009-06-17
Amplifier Type :
Manufacturer :
Model :
Gain :
Bandwidth :
Date Installed :
Date Removed :
Additional Information:
Signal Processing : CFD
Manufacturer : Tennelec
Model : TC454
Date Installed : 1993-04-23
Date Removed :
Amplitude Measurement : YES
Return-Rate Controlled: YES
Mode of Operation : Few to Multi Photons
Additional Information:
Time of Flight Observ. : INTERVAL
Manufacturer : Hewlett-Packard
Model : 5370A
Resolution [ps]: 20
Precision [ps]: 50
Date Installed : 1983-06-01
Date Removed : 1998-01-16
Additional Information :

6.02.01 Secondary Chain

Wavelength [nm]: 532
Detector Type : MCP
Manufacturer : ITT
Model : F4129F
Quantum Efficiency [%]: 15.5
Nominal Gain : 1e6
Rise Time [ps]: 350
Jitter (Single PE)[ps]: 100
Field of View Diam ["]: 90 - 540
Date Installed : 1987-04-23
Date Removed : 2009-06-17
Amplifier Type :
Manufacturer : Honeywell
Model : HSLR
Gain : 24
Bandwidth : 20
Date Installed : 1996-07-04
Date Removed :
Additional Information: for HEO Ranging
Signal Processing : CFD
Manufacturer : Tennelec
Model : TC454
Date Installed : 1993-04-23
Date Removed :
Amplitude Measurement : YES
Return-Rate Controlled: YES
Mode of Operation : Few to Multiple Photons
Additional Information:
Time of Flight Observ. : INTERVAL
Manufacturer : Hewlett-Packard
Model : 5370A
Resolution [ps]: 20
Precision [ps]: 50
Date Installed : 1983-06-01
Date Removed : 1998-01-16
Additional Information :

- **In this example the only difference between Sections 6.01.01 and 6.01.02 is that an amplifier is used to track the High Earth Orbiting (HEO) satellites while the primary receiver chain is used to track LEOs and LAGEOS. In the Secondary Chain, the receive signal is amplified 24 dB before the Tennelec Constant Fraction Discriminator (CFD)**

Site Log Section 6 Example of a station that has three receiver chains

6.01.01 Primary Chain
Wavelength [nm]: 423
Detector Type : PMT
Manufacturer : Hamamatsu
Model : H 6533
Quantum Efficiency [%]: 22
Nominal Gain : 2e6
Rise Time [ps]: 700
Jitter (Single PE)[ps]: 160
Field of View Diam ["]: 10 - 30
Date Installed : 1997-01-01
Date Removed : 2003-03-11
Amplifier Type :
Manufacturer :
Model :
Gain :
Bandwidth :
Date Installed :
Date Removed :
Additional Information:
Signal Processing : CFD
Manufacturer : Tennelec
Model : TC454
Date Installed : 1997-01-01
Date Removed : 2003-03-11
Amplitude Measurement : YES
Return-Rate Controlled: YES
Mode of Operation : Single to Few Photons
Additional Information:
Time of Flight Observ. : INTERVAL
Manufacturer : Stanford
Model : 620 #0236
Resolution [ps]: 4
Precision [ps]: 30
Date Installed : 1997-01-01
Date Removed :
Additional Information :

6.02.01 Secondary Chain
Wavelength [nm]: 423
Detector Type : CSPAD
Manufacturer : PESO Consulting
Model : 0410
Quantum Efficiency [%]: 18
Nominal Gain : 1e10
Rise Time [ps]: N.A.
Jitter (Single PE)[ps]: 30
Field of View Diam ["]: 9
Date Installed : 1997-01-01
Date Removed : 2003-03-11
Amplifier Type :
Manufacturer :
Model :
Gain :
Bandwidth :
Date Installed :
Date Removed :
Additional Information:
Signal Processing : Time Walk Compensated
Manufacturer : Graz
Model :
Date Installed : 1997-01-01
Date Removed : 2003-03-11
Amplitude Measurement : NO
Return-Rate Controlled: YES
Mode of Operation : Single to Few Photons
Additional Information:
Time of Flight Observ. : INTERVAL
Manufacturer : Stanford
Model : 620 #2282
Resolution [ps]: 4
Precision [ps]: 30
Date Installed : 1997-01-01
Date Removed :
Additional Information : use for test only

6.03.01 Tertiary Chain
Wavelength [nm]: 846
Detector Type : CSPAD
Manufacturer : PESO Consulting
Model : Zimmerwald-01
Quantum Efficiency [%]: 15
Nominal Gain : 1e10
Rise Time [ps]: N.A.
Jitter (Single PE)[ps]: 39
Field of View Diam ["]: 8
Date Installed : 1997-01-01
Date Removed : 2002-01-01
Amplifier Type :
Manufacturer :
Model :
Gain :
Bandwidth :
Date Installed :
Date Removed :
Additional Information:
Signal Processing : Time Walk Compensated
Manufacturer : Graz
Model :
Date Installed : 1997-01-01
Date Removed : 2002-01-01
Amplitude Measurement : NO
Return-Rate Controlled: YES
Mode of Operation : Single to Few Photons
Additional Information:
Time of Flight Observ. : INTERVAL
Manufacturer : Stanford
Model : 620 #2282
Resolution [ps]: 4
Precision [ps]: 30
Date Installed : 1997-01-01
Date Removed :
Additional Information :

- **Here is example of a station (Zimmerwald) that had three receiver configurations with different detectors, wavelengths and time of flight devices**
- **Zimmerwald started to provide normal point data from both its primary and tertiary chains in August 2002.**
- **The secondary chain was originally used only for testing, but in 2003, the secondary chain and the primary chain were swapped. See next slide**

Site Log Section 6 Example of a Station has made the Secondary Receiver the Primary Receiver

6.01.01 Primary Chain
- Wavelength [nm]: 423
- Detector Type : PMT
  - Manufacturer : Hamamatsu
  - Model : H 6533
  - Quantum Efficiency [%]: 22
  - Nominal Gain : 2e6
  - Rise Time [ps]: 700
  - Jitter (Single PE)[ps]: 160
  - Field of View Diam ["]: 10 - 30
  - Date Installed : 1997-01-01
  - Date Removed : 2003-03-11
- Amplifier Type :
  - Manufacturer :
  - Model :
  - Gain :
  - Bandwidth :
  - Date Installed :
  - Date Removed :
  - Additional Information:
- Signal Processing : CFD
  - Manufacturer : Tennelec
  - Model : TC454
  - Date Installed : 1997-01-01
  - Date Removed : 2003-03-11
  - Amplitude Measurement : YES
  - Return-Rate Controlled: YES
  - Mode of Operation : Single to Few Photons
  - Additional Information:
- Time of Flight Observ. : INTERVAL
  - Manufacturer : Stanford
  - Model : 620 #0236
  - Resolution [ps]: 4
  - Precision [ps]: 30
  - Date Installed : 1997-01-01
  - Date Removed :
- Additional Information :

6.01.02 Primary Chain
- Wavelength [nm]: 423
- Detector Type : CSPAD
  - Manufacturer : PESO Consulting
  - Model : 0410
  - Quantum Efficiency [%]: 18
  - Nominal Gain : 1e10
  - Rise Time [ps]: N.A.
  - Jitter (Single PE)[ps]: 30
  - Field of View Diam ["]: 9
  - Date Installed : 2003-03-11
  - Date Removed :
- Amplifier Type :
  - Manufacturer :
  - Model :
  - Gain :
  - Bandwidth :
  - Date Installed :
  - Date Removed :
  - Additional Information:
- Signal Processing : Time Walk Compensated
  - Manufacturer : Graz
  - Model :
  - Date Installed : 2003-03-11
  - Date Removed :
  - Amplitude Measurement : NO
  - Return-Rate Controlled: YES
  - Mode of Operation : Single to Few Photons
  - Additional Information:
- Time of Flight Observ. : INTERVAL
  - Manufacturer : Stanford
  - Model : 620 #0236
  - Resolution [ps]: 4
  - Precision [ps]: 30
  - Date Installed : 1997-01-01
  - Date Removed : 2004-12-28
- Additional Information :

6.02.01 Secondary Chain
- Wavelength [nm]: 423
- Detector Type : CSPAD
  - Manufacturer : PESO Consulting
  - Model : 0410
  - Quantum Efficiency [%]: 18
  - Nominal Gain : 1e10
  - Rise Time [ps]: N.A.
  - Jitter (Single PE)[ps]: 30
  - Field of View Diam ["]: 9
  - Date Installed : 1997-01-01
  - Date Removed : 2003-03-11
- Amplifier Type :
  - Manufacturer :
  - Model :
  - Gain :
  - Bandwidth :
  - Date Installed :
  - Date Removed :
  - Additional Information:
- Signal Processing : Time Walk Compensated
  - Manufacturer : Graz
  - Model :
  - Date Installed : 1997-01-01
  - Date Removed : 2003-03-11
  - Amplitude Measurement : NO
  - Return-Rate Controlled: YES
  - Mode of Operation : Single to Few Photons
  - Additional Information:
- Time of Flight Observ. : INTERVAL
  - Manufacturer : Stanford
  - Model : 620 #2282
  - Resolution [ps]: 4
  - Precision [ps]: 30
  - Date Installed : 1997-01-01
  - Date Removed :
- Additional Information : use for test only

6.02.02 Secondary Chain
- Wavelength [nm]: 423
- Detector Type : PMT
  - Manufacturer : Hamamatsu
  - Model : H 6533
  - Quantum Efficiency [%]: 22
  - Nominal Gain : 2e6
  - Rise Time [ps]: 700
  - Jitter (Single PE)[ps]: 160
  - Field of View Diam ["]: 10 - 30
  - Date Installed : 2003-03-11
  - Date Removed :
- Amplifier Type :
  - Manufacturer :
  - Model :
  - Gain :
  - Bandwidth :
  - Date Installed :
  - Date Removed :
  - Additional Information:
- Signal Processing : CFD
  - Manufacturer : Tennelec
  - Model : TC454
  - Date Installed : 1997-01-01
  - Date Removed :
  - Amplitude Measurement : YES
  - Return-Rate Controlled: YES
  - Mode of Operation : Single to Few Photons
  - Additional Information:
- Time of Flight Observ. : INTERVAL
  - Manufacturer : Stanford
  - Model : 620 #0236
  - Resolution [ps]: 4
  - Precision [ps]: 30
  - Date Installed : 2003-03-11
  - Date Removed : 2004-12-28
- Additional Information : use for test only

Conclusions/Reminders/Questions

- ❑ I hope these few examples were helpful in updating Section 6 of the Site Log
- ❑ Any system configuration change requires both an update to your site log and your station change history
- ❑ Replacing a major component with the same model requires a station change history update but NOT a site log update
- ❑ Keep your site log and station change history current
- ❑ Maintain detailed onsite records of system changes, because this information may be invaluable to pinpoint when a change occurred in your range bias
- ❑ Any questions?
- ❑ Thank you for your attention! Clear Skies and Stay Safe!

SLR Campaign on NavIC Constellation

The ISRO Campaign

SLR Campaign on NavIC Constellation

- ILRS network would track Indian Constellation of Navigation Satellites (IRNSS)
- Includes 2 new SLR Stations in India
- Tracking Campaigns last 10 days
- Seven satellites already in Geosynchronous orbit (on the ILRS tracking list)
- Timeframe - late 2022 – 23
- First telecon with ISRO during the week of January 21

Tracking Requirements

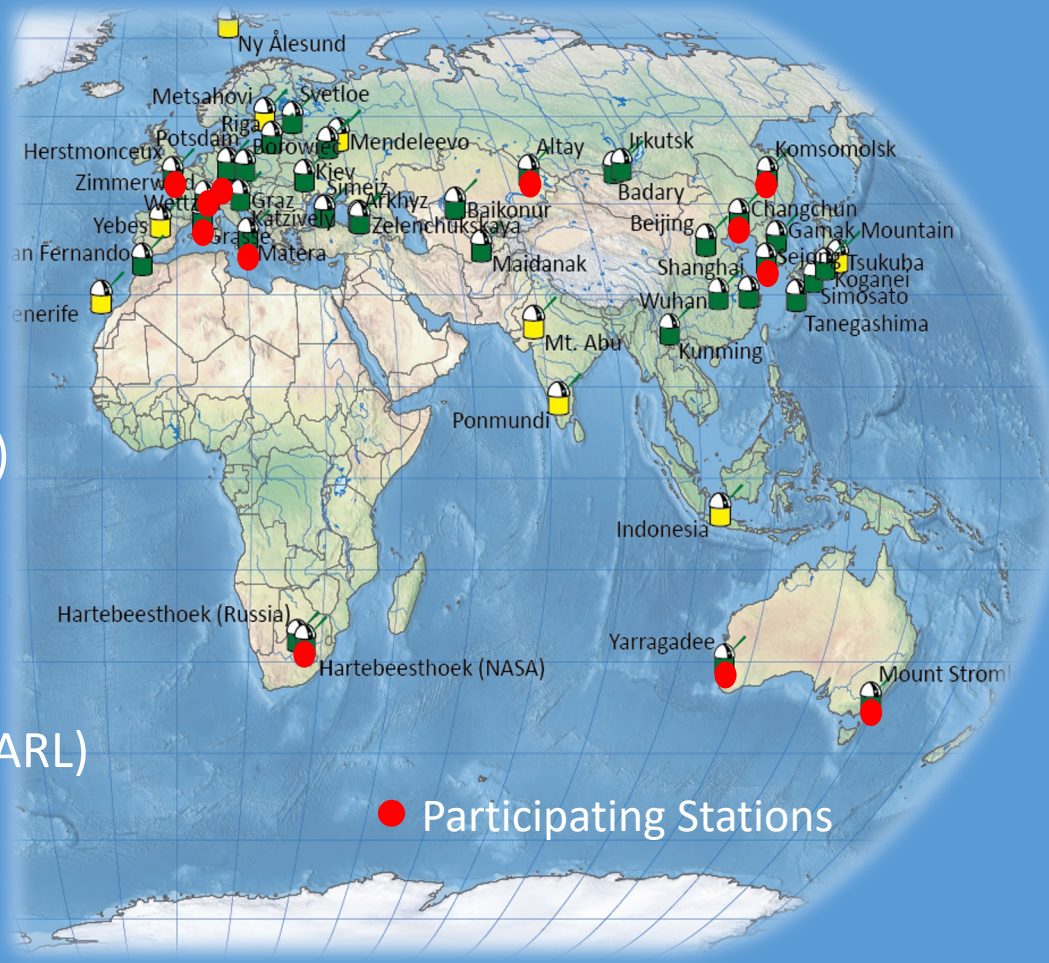
Tracking requirements are summarized below:

1) An IRNSS satellite tracking campaign shall last for at least 10 days.
2) The IRNSS satellite for which the tracking campaign is being undertaken shall be tracked from at least 4 SLR Stations: Each station should track the IRNSS satellite for a minimum of 3 days, generating a minimum of 4 Normal Points every day.
3) The tracking campaign shall ensure that the Normal Points are evenly distributed along the ground trace (see figures for desirable ground trace distribution of NP).
4) A minimum of 65 Normal Points are required to be generated by the tracking network during the campaign.

List of Participating Stations

Stations that may be included in the campaign (Selected to form a wide baseline for the ranging):

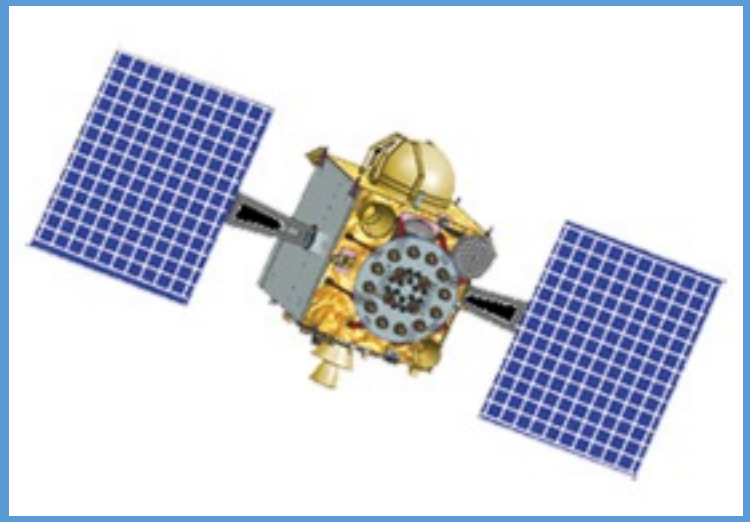
1) Yarragadee, Australia (YARL)
2) Altay, Russia (ALTL)
3) Zimmerwald, Switzerland (ZIML)
4) Shanghai, China (SHA2)
5) Herstmonceux, England (HERL)
6) Wettzell, Germany (SOSW, WETL)
7) Matera, Italy (MATM)
8) Grasse, France (GRSM)
9) Changchun, China (CHAL)
10) Hartebeesthoek, South Africa (HARL)
11) Komsomolskna, Russia (KOML)
12) Mt. Stromlo, Australia (STL3)
13) Mt. Abu and Ponmundi, India



List of IRNSS Satellites

Indian Regional Navigation Satellite System (IRNSS) Constellation:

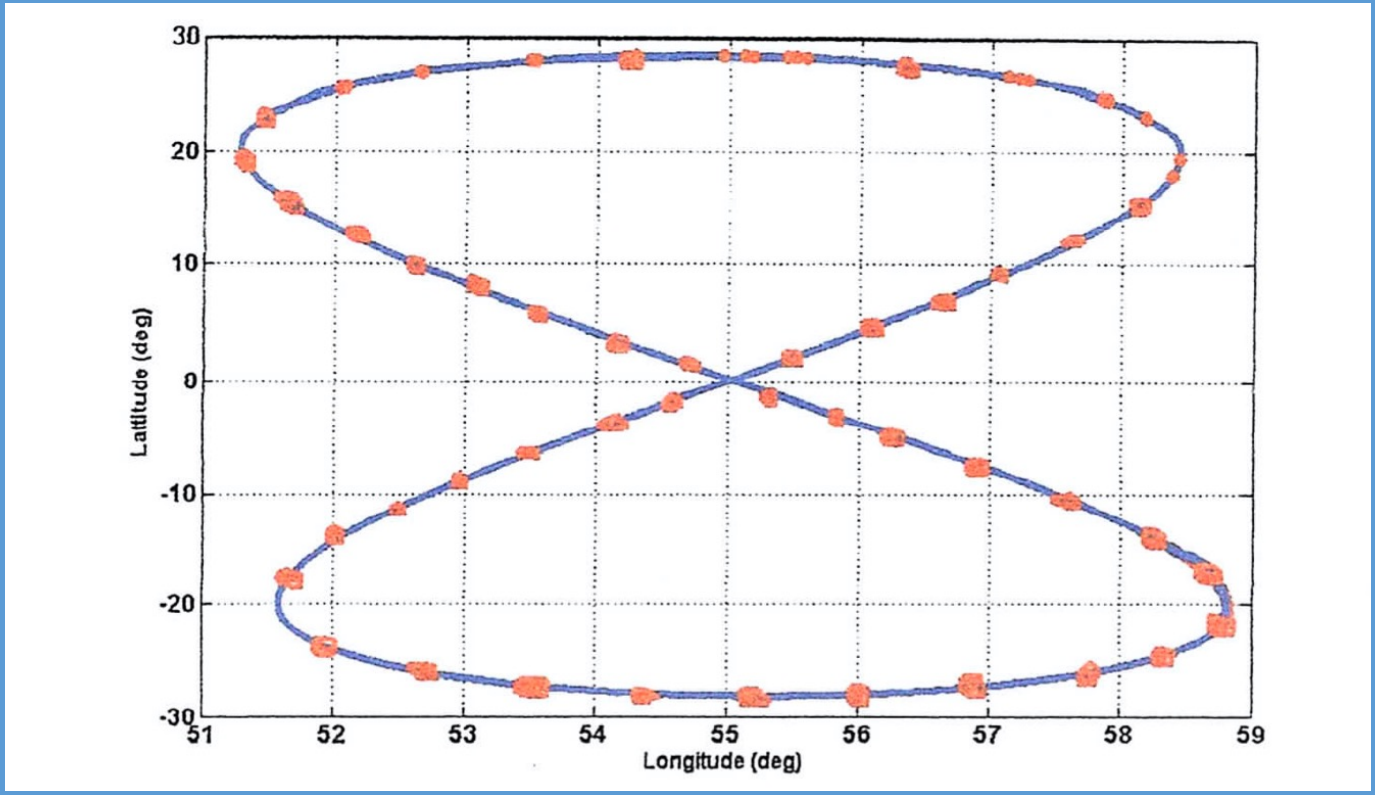
1) IRNSS-1A
2) IRNSS-1B
3) IRNNS-1C
4) IRNSS-1D
5) IRNSS-1E
6) IRNSS-1F
7) IRNSS-1I



Courtesy of ISRO

Desired Distribution of NP during an ILRS Tracking Campaign

Desirable dispersion of Normal Points generated during an ILRS tracking campaign

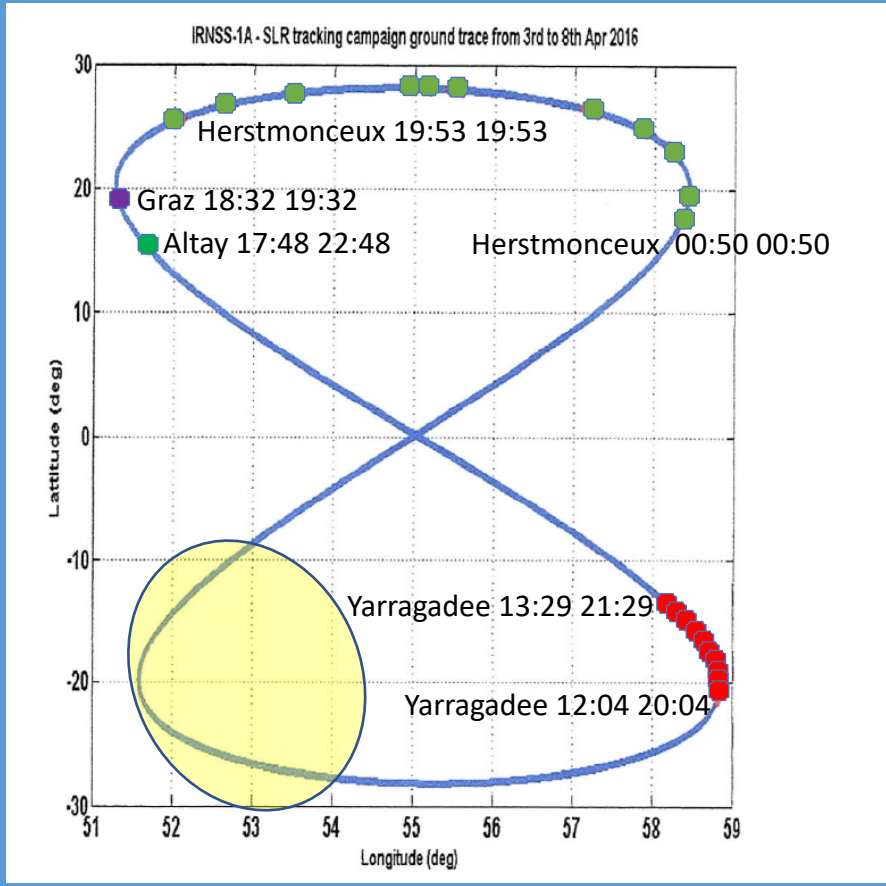


Constraints in achieving this desired distribution of NPs:

- Station distribution not uniform
- Satellites visibility at the station restricted due to ..., etc.

Past Data Experience

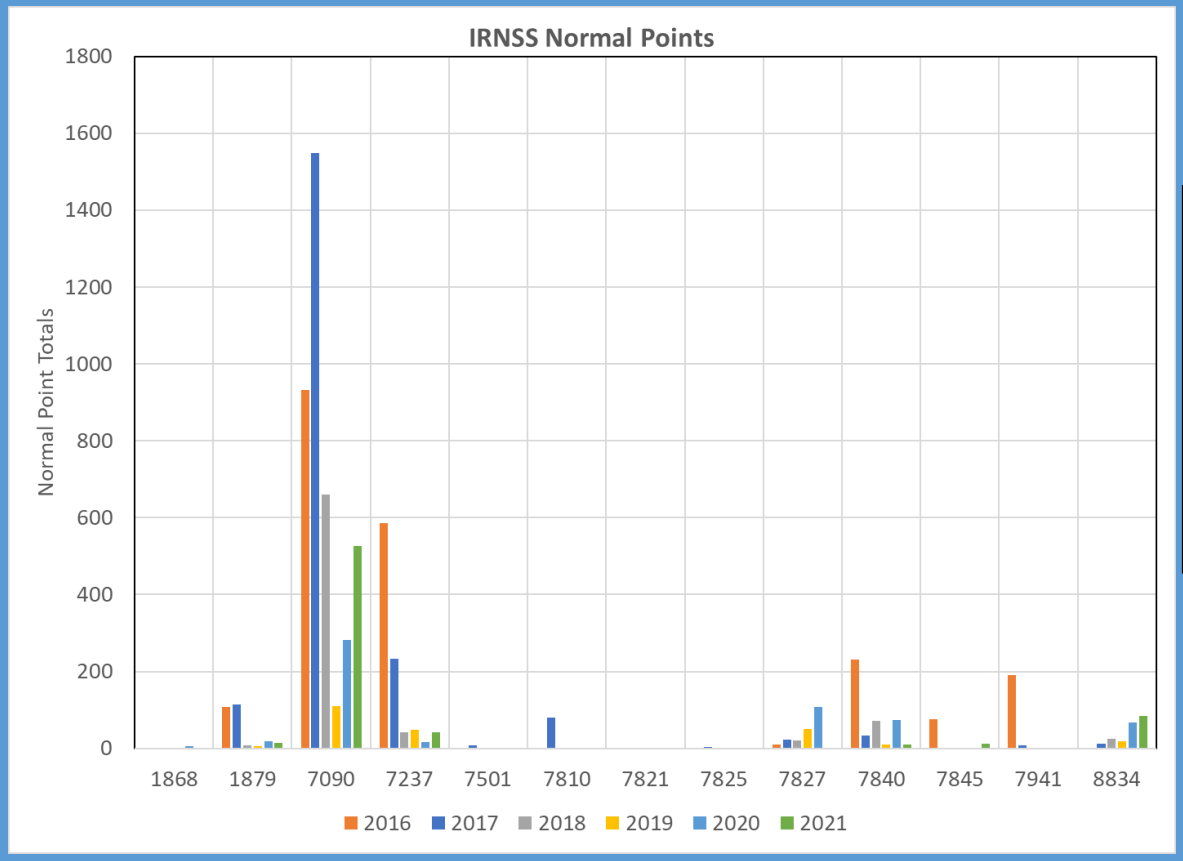
IRNSS-1A Tracking Analysis (Apr 3-8, 2016)



- Night time tracking only;
- Gaps dictated by station geometry and operational limitations;
- Mt Stromlo never tracked IRNSS-1A, -1B, -1F;
- No European Stations ever tracked IRNSS-1C, -1D or -1E;
- Can Yarragadee track IRNSS-1A, -1B or -1F when at or north of the equator?
- It will be impossible to get complete coverage of the IRNSS orbits due to lack of daylight ranging and station locations;
- Try station coordination to minimize gaps in tracking coverage;
- Look at some longer time interval (10 days)

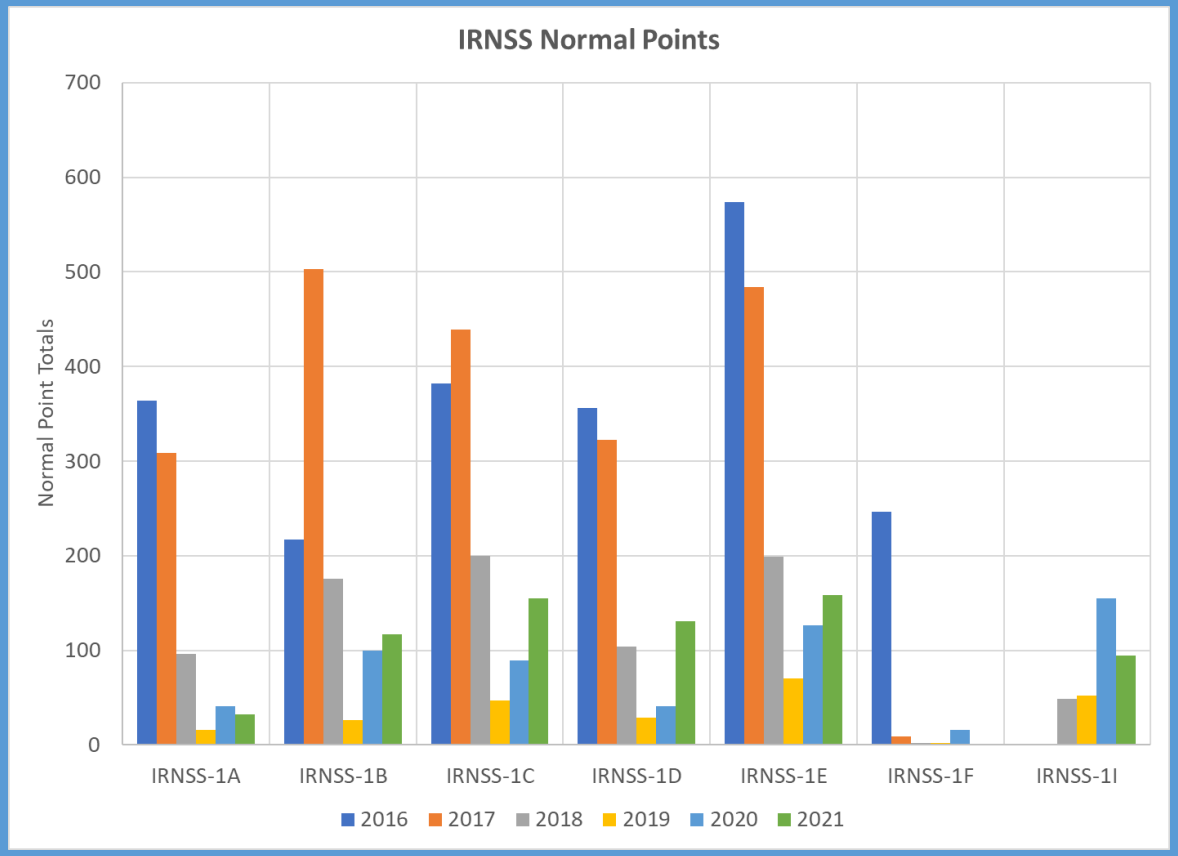
LEGEND
Yarragadee
Altay
Graz
Herstmonceux

IRNSS Normal Points by Year and Station



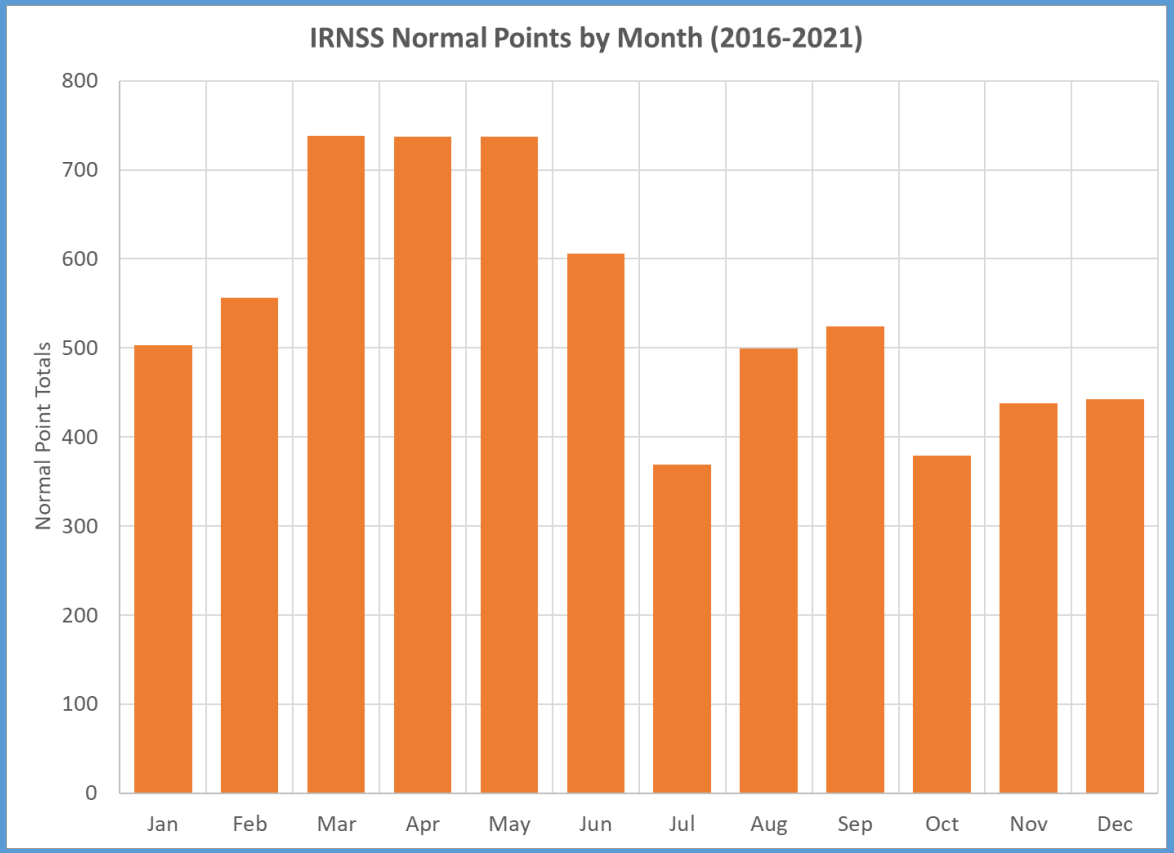
IRNSS Normal Points								
Station	Location	2016	2017	2018	2019	2020	2021	Grand Total
1868	Komsomolsk-Na-Amure, Russia				2	5		7
1879	Altay, Russia	108	115	8	5	19	14	269
7090	Yarragadee, Australia	933	1548	661	110	281	527	4060
7237	Changchun, China	586	234	41	48	16	42	967
7501	Hartebeesthoek, South Africa		8					8
7810	Zimmerwald, Switzerland	2	81	1				84
7821	Shanghai, China	2						2
7825	Mt Stromlo, Australia		3					3
7827	Wettzell, Germany	9	23	20	50	107		209
7840	Herstmonceux, United Kingdom	231	34	71	9	73	9	427
7845	Grasse, France	75					11	86
7941	Matera, Italy	191	7					198
8834	Wettzell, Germany	2	13	24	18	67	84	208
	Totals	2139	2066	826	242	568	687	6528

IRNSS Normal Points by Year and Satellite



IRNSS Normal Points							
Satellite	2016	2017	2018	2019	2020	2021	Total
IRNSS-1A	364	309	96	16	41	32	858
IRNSS-1B	217	503	176	26	100	117	1139
IRNSS-1C	382	439	200	47	89	155	1312
IRNSS-1D	356	322	104	29	41	131	983
IRNSS-1E	574	484	199	70	126	158	1611
IRNSS-1F	246	9	2	2	16		275
IRNSS-1I			49	52	155	94	350
Grand Total	2139	2066	826	242	568	687	6528

IRNSS Normal Points by Month



Month	Normal Points
Jan	503
Feb	556
Mar	738
Apr	737
May	737
Jun	606
Jul	369
Aug	499
Sep	524
Oct	379
Nov	438
Dec	442
Totals	6528