International Laser Ranging Service

ILRS: What's New?

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ILRS Central Bureau

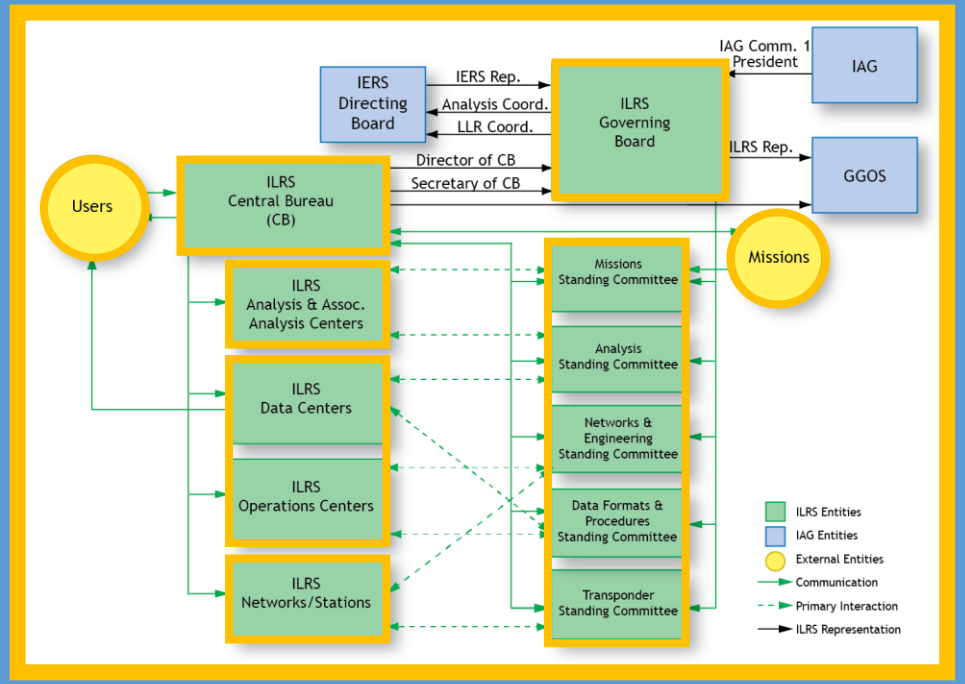
2019 ILRS Technical Workshop
October 21, 2019
Stuttgart, Germany

Outline

- Intro
- News
- Recent developments/ future plans
  - General
  - Network
  - Mission support
  - Operations
  - Analysis
- Challenges

ILRS: large community participation

- Operation through cooperation of organizations leveraging resources to all levels of service functionality
- Components:
  - Network: 40+ stations
  - Data Centers:
    - 2 Operations Centers
    - 2 Data Archive Centers
  - Analysis Centers:
    - 7 Analysis Centers
    - 2 Combination Centers
    - 21 Associate Analysis Centers
    - 6 Lunar Analysis Centers
  - Standing Committees: 5
  - Central Bureau: 25+ members
  - Governing Board: 18 members
  - Membership
    - Associates: 400+
    - Organizations: 110+
    - Countries: 30+
    - Correspondents: 200+
  - Supporting:
    - Users: 1000's
    - Missions: 110+



https://ilrs.gsfc.nasa.gov/about/organization/index.html

ILRS Governing Board: 2019-2020 term

- Elected positions:
  - EUROLAS Network Representatives:
    Pippo Bianco, Georg Kirchner
  - NASA Network Representatives:
    Jan McGarry, Stephen Merkowitz
  - WPLTN Representatives:
    James Bennett, Zhang Zhongping
  - Data Center Representative:
    Christian Schwatke
  - LLR Representative:
    Jean-Marie Torre
  - Analysis Representatives:
    Cinzia Luceri, Erricos Pavlis
  - At-Large Representatives:
    Toshi Otsubo (Chair), Matt Wilkinson
- Ex-officio/appointed positions:
  - Director of the Central Bureau:
    Mike Pearlman
  - Secretary of the Central Bureau:
    Carey Noll
  - Representative of IAG Commission 1:
    Urs Hugentobler
  - IERS Representative:
    Daniela Thaller
- Appointed by the Governing Board:
  - **Ulli Schreiber**
  - **Krzysztof Sośnica**

Recent news

- Proceedings, presentations, posters, summary information, and papers from 21st International Workshop in Canberra (November 2018) available on workshop website: *https://cddis.nasa.gov/lw21*
- First "SLR School" held before this workshop
  - Feedback welcome
  - Video to be made available
- NASA celebrated the 50th anniversary of the Apollo 11 moon landing and the start of LLR
- Finalizing Journal of Geodesy Special Issue on Laser Ranging
- Collecting input and editing 2016-2018 ILRS report

International Workshops on Laser Ranging

- International Workshops on Laser Ranging typically held every two years
  - Program includes sessions on science, infrastructure, operations, technology, software, and mission design
  - Access to presentations, proceedings, papers, summaries available through ILRS website
  - Clinics focus on small group interactions with station personnel

Over 150 participants in the 21st International Workshop on Laser Ranging, Canberra Australia https://cddis.nasa.gov/lw21/

Number	Year	Location
1st	1973	Lagonissi, Greece
2nd	1975	Prague, Czechoslovakia
3rd	1978	Lagonissi, Greece
4th	1981	Austin, TX, USA
5th	1984	Herstmonceux, UK
6th	1986	Antibes, France
7th	1989	Matera, Italy
8th	1992	Annapolis, MD, USA
9th	1994	Canberra, Australia
10th	1996	Shanghai, China
11th	1998	Deggendorf, Germany
12th	2000	Matera, Italy
13th	2002	Washington, D.C., USA
14th	2004	San Fernando, Spain
15th	2006	Canberra, Australia
16th	2008	Poznan, Poland
17th	2011	Bad Koetzting, Germany
18th	2013	Fujiyoshida, Japan
19th	2014	Annapolis, MD, USA
20th	2016	Potsdam, Germany
21st	2018	Canberra, Australia
22nd	2020	Kunming, China

ILRS Technical Workshops

- ILRS also organizes smaller, focused workshops in years between the International Workshops on Laser Ranging
  - *"Laser ranging: To improve economy, performance, and adoption for new applications"*
  - Included one-day "SLR School" providing tutorials on SLR and the ILRS

Topic	Year	Location
SLR System Calibration Issues	September 1999	Florence, Italy
Working Toward the Full Potential of the SLR Capability	October 2003	Kötzting, Germany
Observations Toward mm Accuracy	October 2005	Eastbourne, UK
Challenges for Laser Ranging in the 21st Century	September 2007	Grasse, France
SLR Tracking of GNSS Constellations	September 2009	Metsovo, Greece
Satellite, Lunar and Planetary Laser Ranging: Characterizing the Space Segment	November 2012	Frascati, Italy
Network Performance and Future Expectations for ILRS Support of GNSS, Time Transfer, and Space Debris Tracking	October 2015	Matera, Italy
Improving ILRS Performance to Meet Future GGOS Requirements	October 2017	Riga, Latvia
Laser ranging: To improve economy, performance, and adoption for new applications	October 2019	Stuttgart, Germany

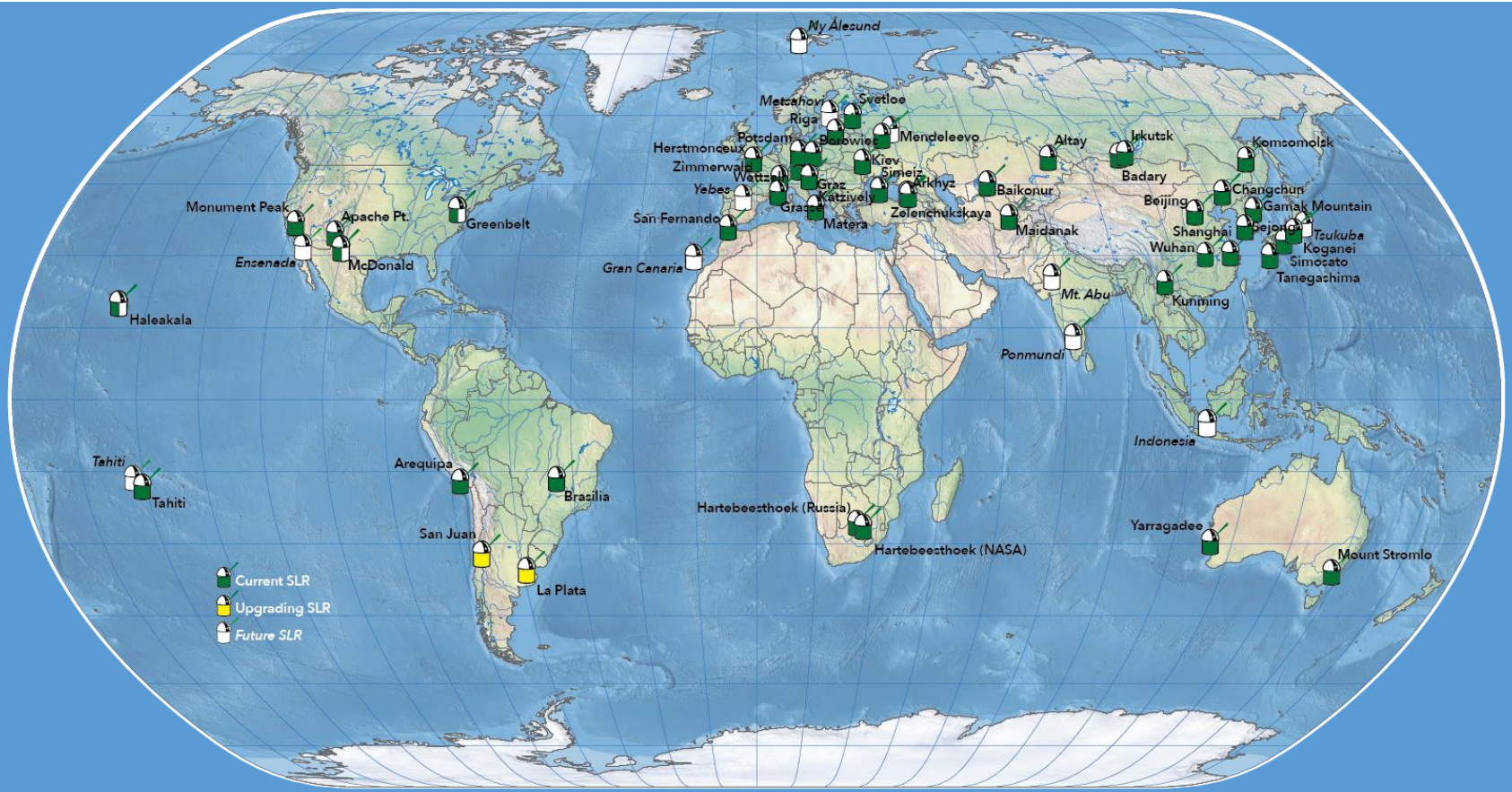
https://ilrs.gsfc.nasa.gov/about/reports/workshop/index.html

Journal of Geodesy Special Issue on Laser Ranging

The ILRS: Approaching twenty years and planning for the future
Geodetic Satellites: A High Accuracy Positioning Tool
Satellite Laser Ranging to Low Earth Orbiters - Orbit and Network Validation
Version of a glass retroreflector satellite with a sub-millimeter "target error"
Laser and Radio Tracking for Planetary Science Missions - A Comparison
Assessment of the impact of one-way laser ranging on orbit determination of the Lunar Reconnaissance Orbiter
Overview of Applications of Satellite Laser Ranging and Laser Time Transfer in BeiDou Navigation Satellite System
Lunar Laser Ranging - A Tool for General Relativity, Lunar Geophysics and Earth Science
NASA's Satellite Laser Ranging Systems for the 21st Century
Time and laser ranging: A window of opportunity for geodesy, navigation and metrology
The Next Generation of Satellite Laser Ranging Systems
Rapid Response Quality Control Service for the Laser Ranging Tracking Network
Solar orbital thermo-optical characterization of an innovative GNSS retroreflector array
Operating two SLR Systems at the Geodetic Observatory Wettzell - from local survey to space ties
Future SLR station networks in the framework of simulated multi-technique terrestrial reference frames
Information Resources Supporting Scientific Research for the International Laser Ranging Service
Modernizing and Expanding the NASA Space Geodesy Network to Meet Future Geodetic Requirements
Time Bias Service: Analysis and Monitoring of Satellite Orbit Prediction Quality

30+ papers submitted;
18 papers published online;
4 papers in final review stage.

ILRS network



Recent developments: network

- Station closings:
  - MLRS, McDonald, TX: lightening strike; to be replaced by SGSLR
- Upgraded stations:
  - Simosato (Japan): kHz operations late 2018
  - Wuhan (China): submitting data (in quarantine)
  - BKG AGGO: continuing setup La Plata Observatory (Argentina); TIGO relocation
  - San Juan (Argentina): kHz, operations planned for 2020
- Co-locating stations:
  - Russia implementing co-location concept at select stations to expand temporal coverage of satellites
  - Hartebeesthoek (South Africa) operational; Mendeleevo (Russia) soon; Tahiti (French Polynesia) future
- New station installations underway/planned

Future developments: network

Site	Type	Agency	Timeframe
La Plata, Argentina	Upgraded core site	BKG, Germany	2019 – 2020
San Juan, Argentina	Upgraded SLR system	NAOC, China	2019 – 2020
Metsähovi, Finland	New SLR system	FGRI, Finland	2019 – 2020
Greenbelt, MD, USA	Replacement core site	NASA, USA	2020 – 2022
Haleakala, HI, USA	Replacement core site	NASA, USA	2020 – 2022
McDonald, TX, USA	Replacement core site	NASA, USA	2020 – 2022
Ny Ålesund, Norway	New core site	NMA, Norway/NASA, USA	2020 – 2022
Ensenada, Mexico	New SLR site	IPIE, Russian Federation	2022 – 2026
Java, Indonesia	New SLR site	IPIE, Russian Federation	2022 – 2026
Gran Canaria, Spain	New SLR in core site	IPIE, Russian Federation	2022 – 2026
Tahiti, French Polynesia	New SLR system	IPIE, Russian Federation	2022 – 2026
Mt Abu, India	New SLR site	ISRO, India	2020 – 2022
Ponmundi, India	New SLR site	ISRO, India	2020 – 2022
Tsukuba, Japan	New SLR site	JAXA, Japan	2021
Yebes, Spain	New SLR site	IGS, Spain	2022

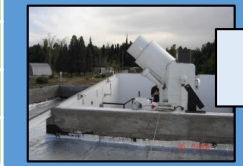
Tochka, Mendeleevo, Russia

ISRO, India

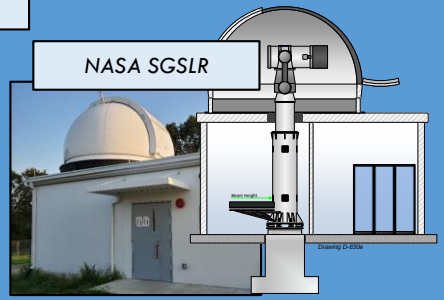
Sazhen-TM, Brasilia, Brazil

Metsähovi, Finland

Wuhan, China



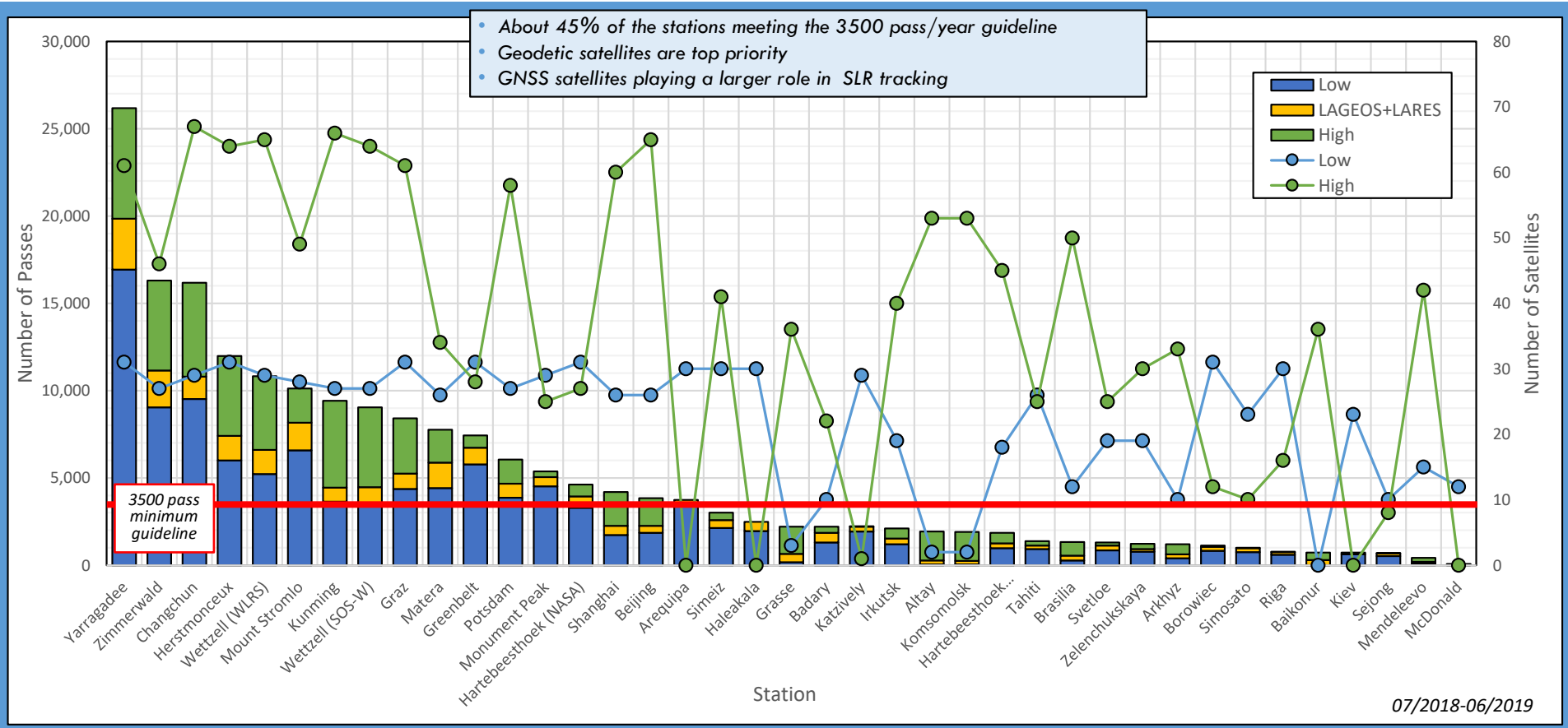
San Juan, Argentina



NASA SGSLR

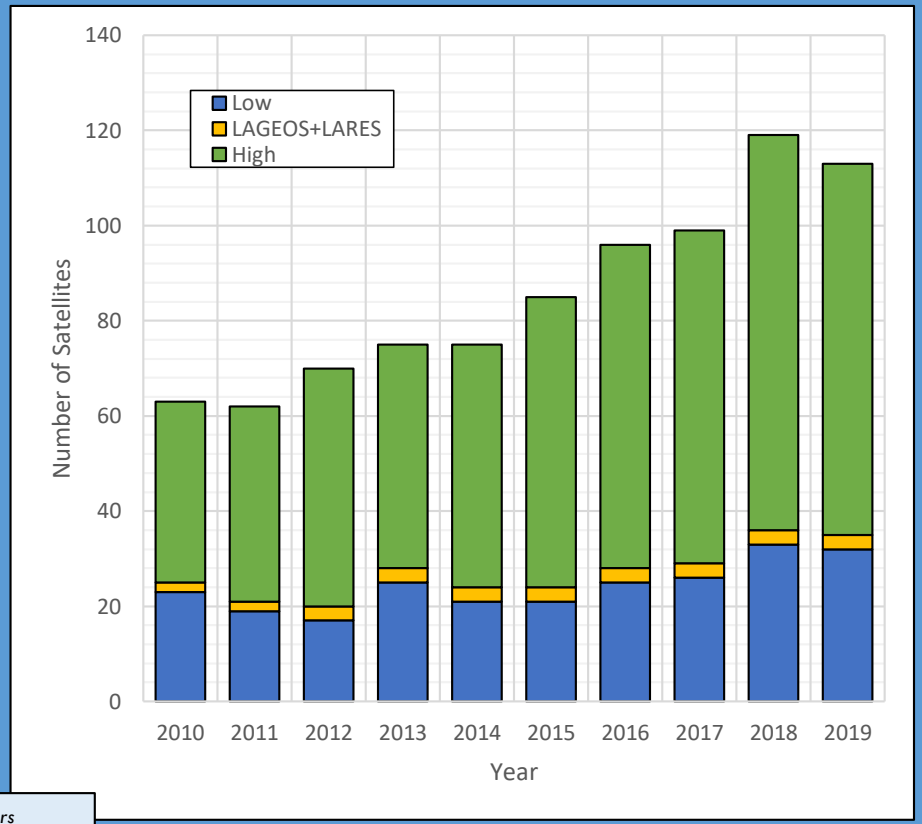
Ny Ålesund, Norway

Station performance: passes



Recent developments: missions

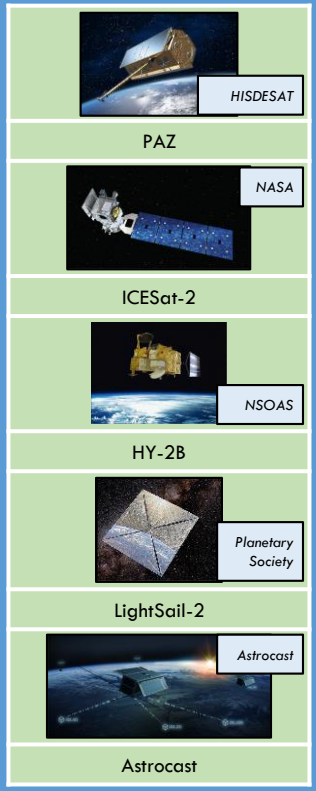
- Tracked 110+ satellites in 2019
- Formulated new GNSS tracking strategy
- Completed 3-month Etalon campaign
- Updated mission support request guidelines (e.g., 6 month advance notice)
- Missions Standing Committee
  - New chair (Stephen Merkowitz) and co-chair (Toshi Otsubo)
  - MSC meeting: October 22@17:00



Number of satellites tracked over the years

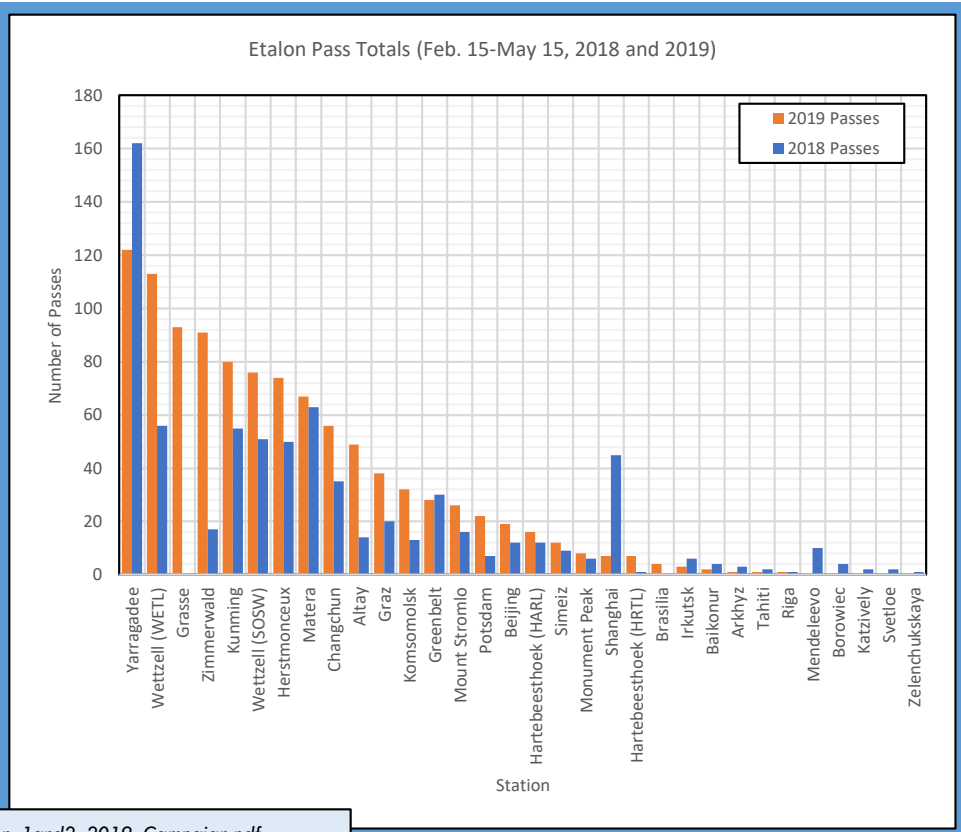
Recent developments: missions

- Recent additions to the ILRS priority list:
  - PAZ (SAR mission)
  - ICESat-2 (laser altimetry mission/restricted tracking)
  - Beidou-3M (4 GNSS satellites)
  - Galileo (4 GNSS satellites)
  - HY-2B (altimetry mission)
  - LightSail-2 (solar sail)
- Future missions requesting ILRS support:
  - Astrocast Precursor (2 cubesats/engineering testing)
  - Additional GNSS: BeiDou/Compass, Galileo, etc.
  - COSMIC-2, HY-2C, SWOT, NISAR
- More requests for restricted tracking, which is time consuming to implement



Etalon campaign: results

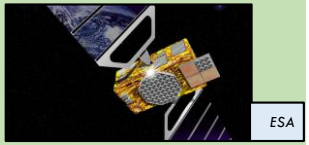
- February 15 through May 15, 2019
- Evaluate increased role of Etalon data in computation of ILRS products contributing to the ITRF, particularly EOP
- Successful campaign:
  in general, stations collected more Etalon data overall and added geometry to data yield
- Data makes significant difference in ILRS EOP product
- Summary report available on ILRS website



https://ilrs.gsfc.nasa.gov/docs/2019/Etalon_1and2_2019_Campaign.pdf

GNSS tracking strategy

- Large number of GNSS satellites
  - GNSS agencies have different requirements for ILRS tracking support
  - More satellites coming with GPS-III
  - GNSS tracking strategy put in place after consultation with missions, IGS, and the ICG
- Strategy:
  - Each constellation selects 4 satellites for higher priority tracking (3 segments of tracking requested per pass)
  - All of the remaining GNSS satellites are tracked at lower priority on a non-interference basis with all of the other ILRS requirements (sampling approach)
- Concentrated tracking in special campaigns (e.g., eclipsing)



Galileo

GLONASS

BeiDou

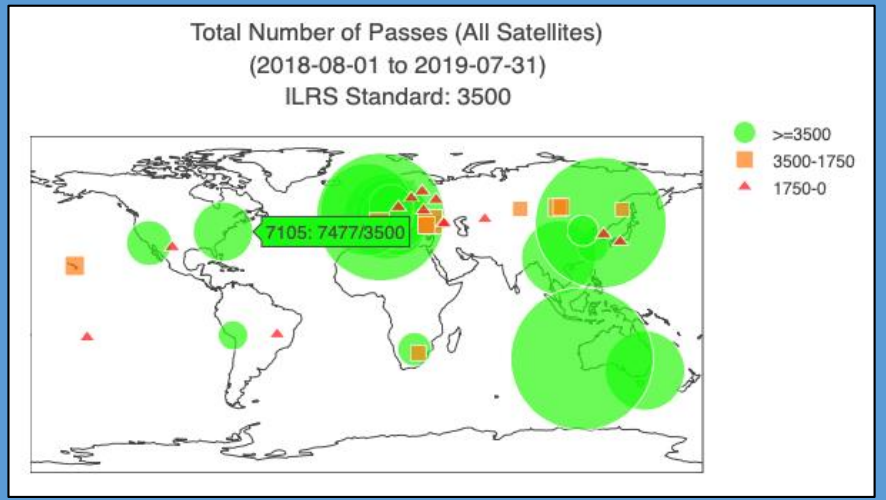
GPS-III

Recent developments: operations

- Site log format and submission/update process
  - Added more information about station configuration and operations
  - Implemented improved procedures (web-based) for submitting/updating station site logs
  - New procedure should help stations keep site logs current
- CRD and CPF formats
  - Issued version 2 of both formats; testing underway
  - Updated versions will facilitate support of future missions and applications (e.g., ELT, space debris)
- Data screening/QC at operations centers
  - Implemented more thorough QC procedures to improve ILRS data product for the user community
  - Harmonized process between EDC and NASA OCs

Station performance assessment tool

- Allows station personnel, analysts to view network capabilities (e.g., #passes, #normal points, adherence to ILRS guidelines, etc.) by category
  - Overall
  - Satellite type (geodetic, altimetry, GNSS)
  - Adherence to priority list
- Report features
  - Emphasize value of station performance to the user community and to the creation of science products
  - Show areas of improvement to support ILRS goals
- Generated monthly, reflects data assessed over the previous 12 months



Size of the bubble reflects the extent the parameter is met, not the geographical coverage tracked

https://ilrs.gsfc.nasa.gov/network/system_performance/monthly_station_performance_maps/index.html

Recent developments: analysis (ASC)

- Working on development of ITRF2020 series; production starts late 2019
- Currently testing new models for gravity, tides, TVG, and target signature (CoM) models, and the inclusion of LARES data
- New operational approach to handling error sources in our current modeling standards
  - Allowance for estimation of systematic errors simultaneously with all other parameters to eliminate biases in station positions (mainly height)
  - Improved corrections in the current model for the CoM target signatures; such errors can affect the SLR-VLBI scale difference at the 0.25 ppb level
- Next steps:
  - Low degree/low order gravity field terms (data product)
  - Include LARES satellite to the operational data products and ITRF2020
  - Add atmospheric loading to the operational data products (at observation level)

Issues and challenges

- Many geographic gaps, primarily in Latin America, Africa, and Oceania
- Mix of new and old technologies, levels of financial support, weather
- Lack of standardization in system hardware and operations
- Marginal operation at many stations, making little or no contribution to the ILRS data products
- Addressing data quality issues; still some systematics
- Continued increase in number of target satellites as new missions use SLR for orbit determination and other applications (110+ satellites)