CONFIGURATION MAP

SLR

NASA SLR Operations Scheduling Process

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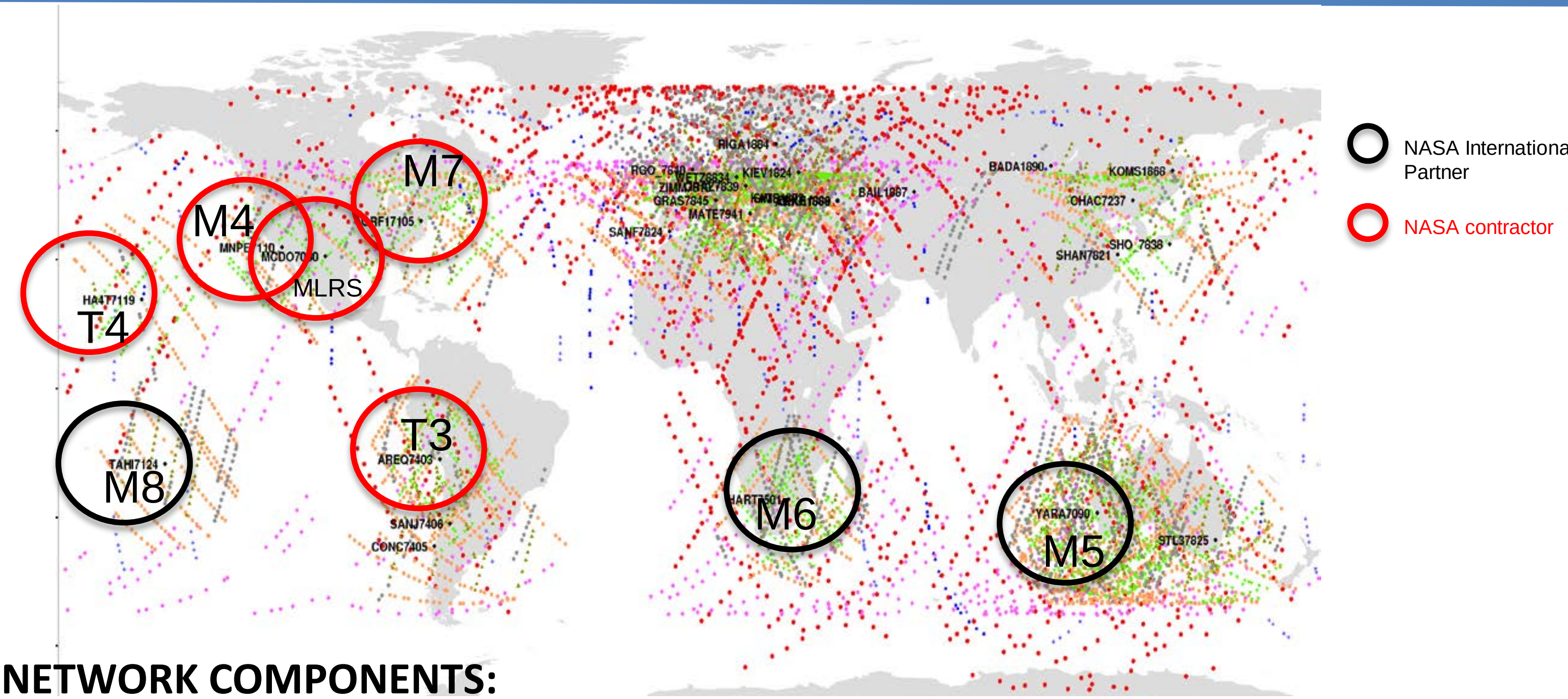
ILRS 20th Workshop
Potsdam, Germany

NASA Network Scheduling and Alternatives

- Review of network characteristics and constraints
- Current tracking statistics
- Alternatives for improvement in:
  - data yield for missions
  - scientific benefit

  (Where budgets prohibit obvious (KHz) system upgrades or crew/labor increase)

NASA SLR Operations



NASA NETWORK COMPONENTS:

<u>Station Operations</u>

TLRS, MOBLAS, MLRS

<u>Network Sustainment</u>

Spares, Engineering, Logistics

<u>Data Operations Center</u>

Data quality checks and prediction/scheduling center

<u>International Laser Ranging Service</u>

Central Bureau

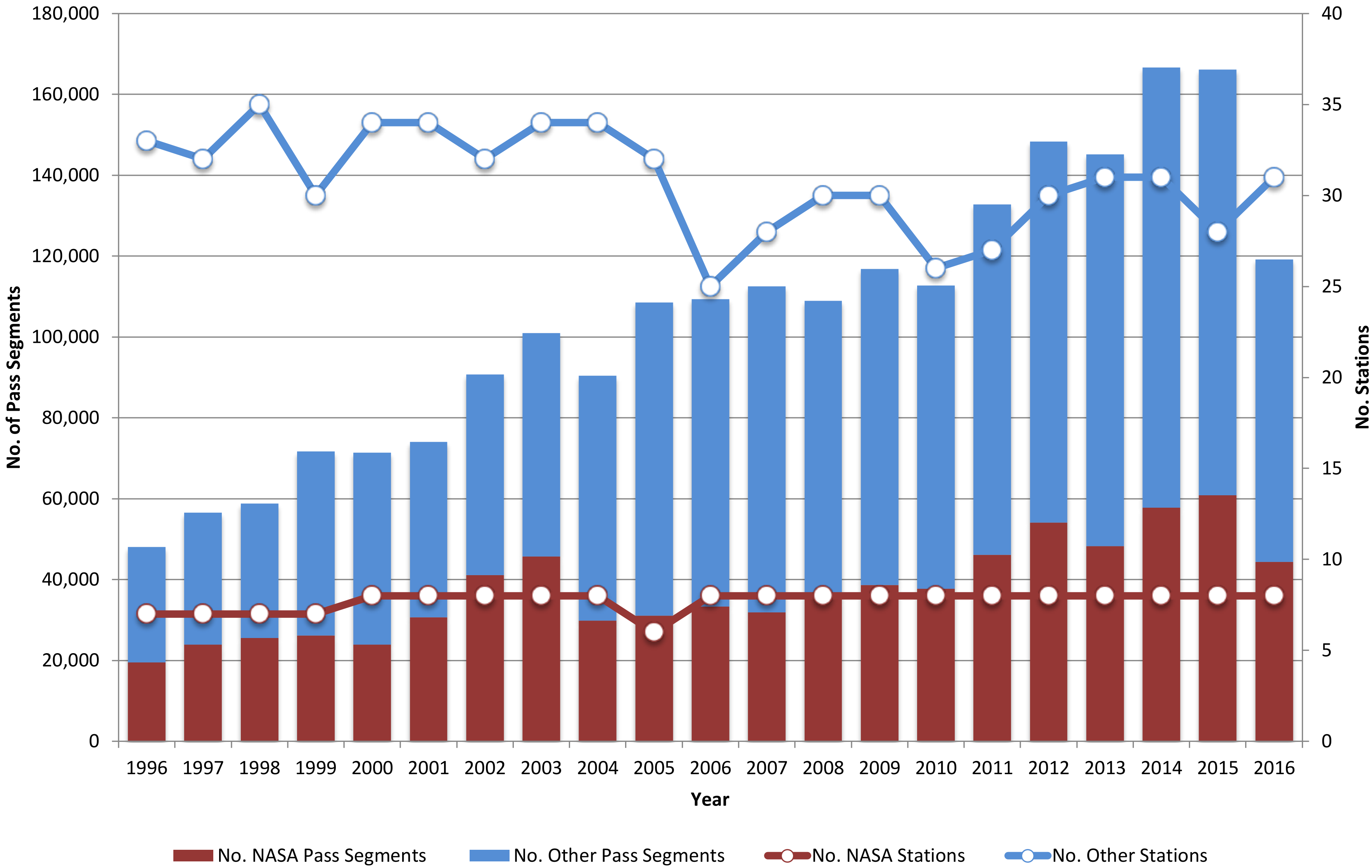
Coordinating Network activities and developing priorities and strategies

Analysis Center

Ensuring standard procedures and coordinating the data product

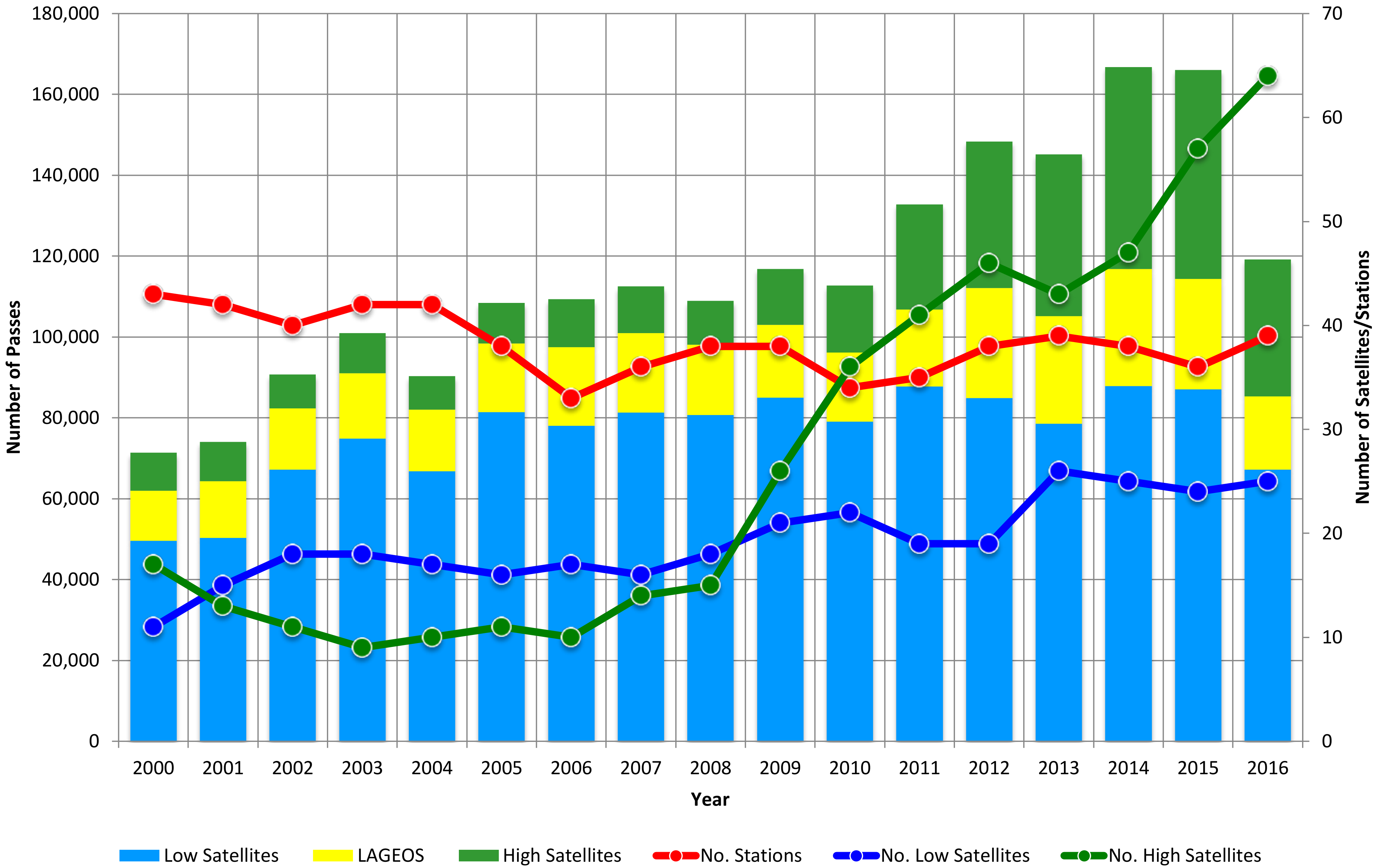
ILRS/NASA Yearly Data Yield

September 20, 2016 Update Graph by Carey Noll



ILRS Yearly Data Yield

September 20, 2016 Update   Graph by Carey Noll

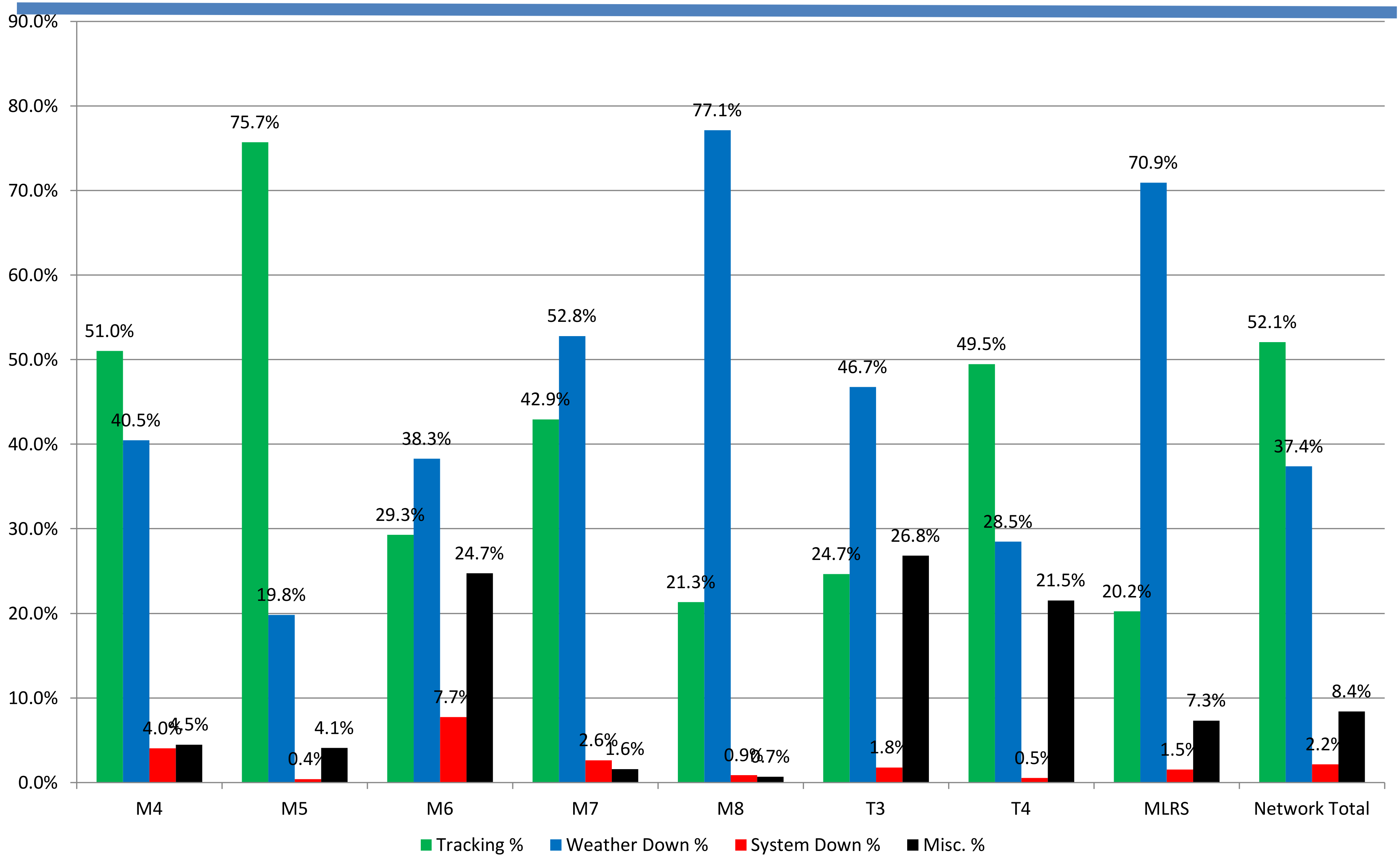


NASA Network Stations Resources

- Australia (MOBLAS 5) 24 hr x 7 days
- South Africa (MOBLAS 6) 24 hr x 5 days + 16 hr x 2 days (weekend)
- Peru (TLRS3) 24 hr x 5 days + some weekend shifts, No HEO
- Maryland (MOBLAS 7) 24 hr x 5 days
- Hawaii (TLRS4) 8 hr x 6 days, 16 hr x 1 day, No HEO
- California (MOBLAS 4) – 16 hr x 5 days
- Tahiti (MOBLAS 8) – 20 hrs x 4 days
- MLRS – 10 hrs x 4 days

NASA SLR Tracking Statistics
June 2015- May 2016

Laser report data manually entered with some weeks omitted (not exact)



NASA Constraints

- External ground calibration 2 hour maximum interval and takes 10 minutes (no internal cal except MLRS)
- Divergence is not adjustable (except MLRS)
- Target acquisition:
  - LEO: initial acquisition can be high as 30 sec-1min
  - LAGEOS > 30 degrees generally
  - HEO - improvement when returning to a satellite from interleave by knowing prior bias

NASA Constraints

- Laser Rep Rate
  - (will increase to 10 Hz for all satellites with full event timer implementation)
  - HEO – 2 Hz
  - LAGEOS – 4/5 Hz
  - LEO – 10Hz
- ILRS NP bin size
  - HEO/GNSS – 5 minutes
  - LAGEOS – 2 minutes
  - LARES – 30 seconds
  - LEO – 5 to 30 seconds
- NASA Station Horizon
  - GODL – 10 degrees
    - with VLBI quadrant mask to 20 degrees
  - YARL – 15 degrees
  - All others – 20 degrees
- Operation Mode
  - Few Photon

NASA Schedule

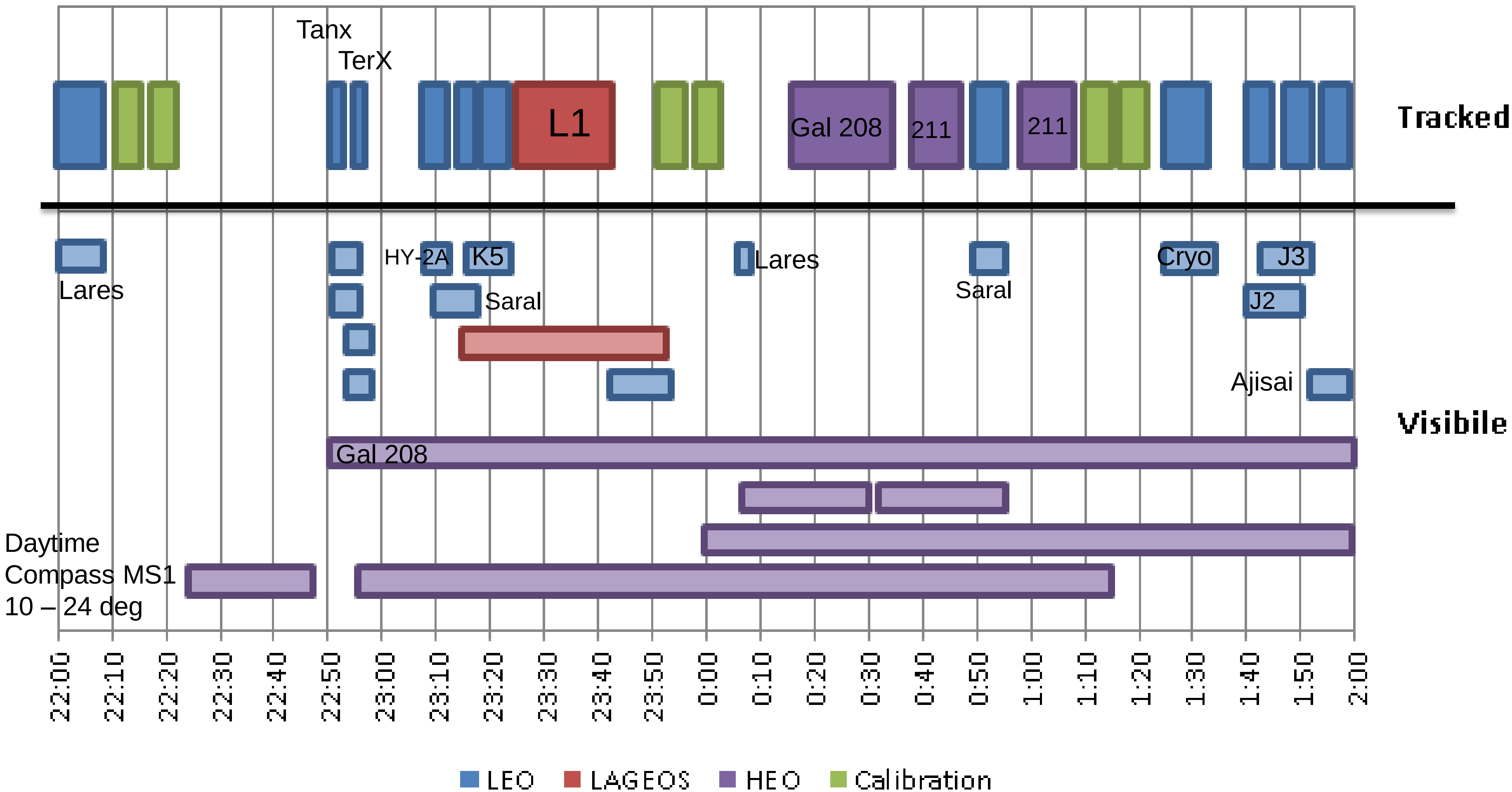
- Schedule based on ILRS priority/altitude
- A schedule is made for each station weekly at the Operations Center and distributed
  - Used only as part of a template for station reports to be returned to Engineering each week
- Actual tracking schedule is simply the chronological sequence of satellite availability and ILRS priority
  - All passes remain available
  - Some stations/managers facilitate/adjust station schedules to maximize data and adjust crew shifts for optimal times
    - Predetermined calibration periods
    - Special reminders included

Schedule Implementation

- Operators go by priority list but exercise real-time flexibility based on local conditions and their experience of success based on the constraints for interleaving or satellite alternatives
  - Focus on low noise data
  - Approximately 25 operators
- Weather awareness and experience
  - influences decisions and pursuit of options/opportunities
- Many LEO passes do not present good interleaving opportunities

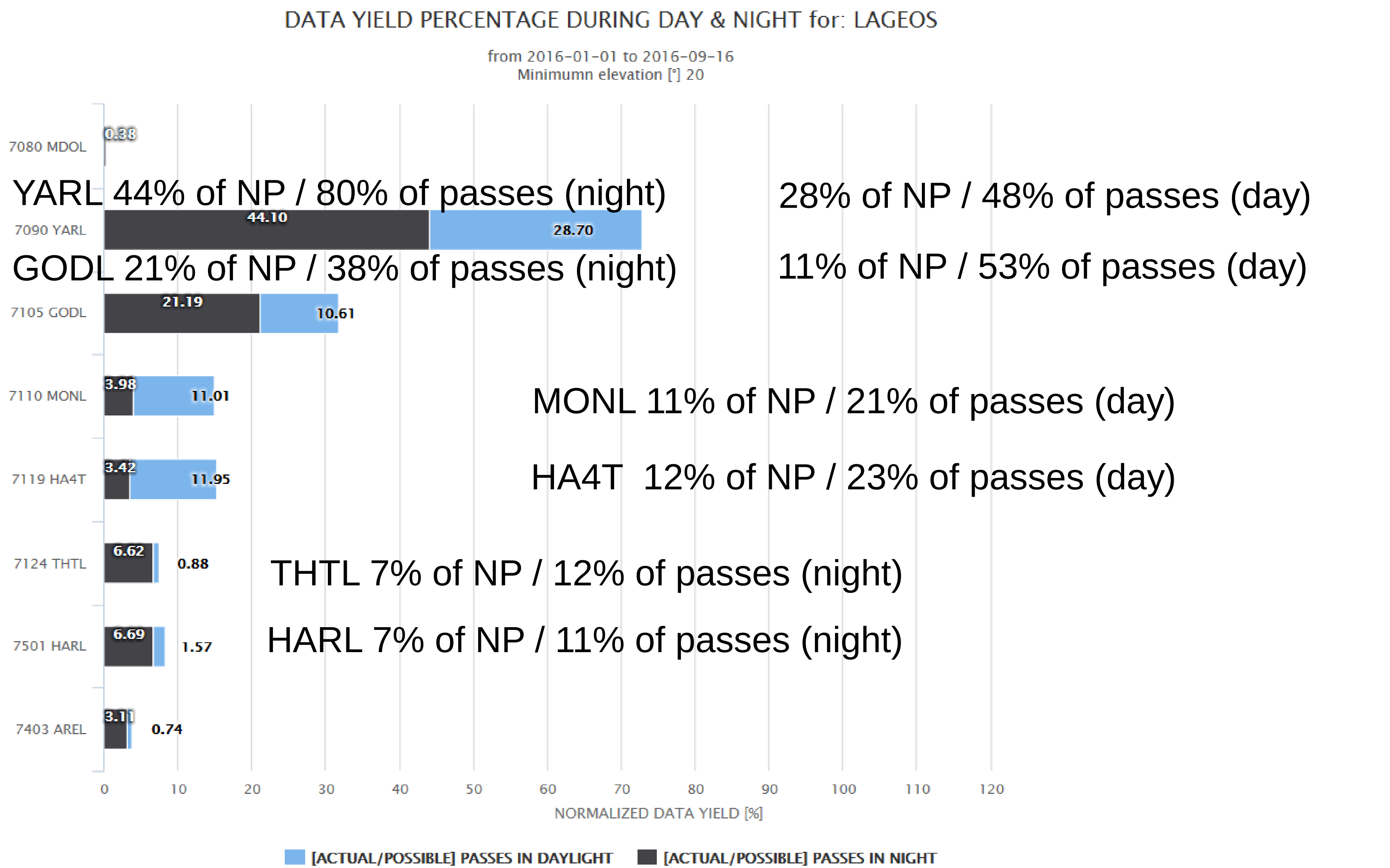
View Periods v. Tracking Periods:

4 Hours: 27-Sep-2016 2200 to 28-Sep-2016 0200



NASA L1 NP Efficiency

2016http://geodesy.jcet.umbc.edu/DATACATS/configuration_W.php



YARL 44% of NP / 80% of passes (night)

28% of NP / 48% of passes (day)

GODL 21% of NP / 38% of passes (night)

11% of NP / 53% of passes (day)

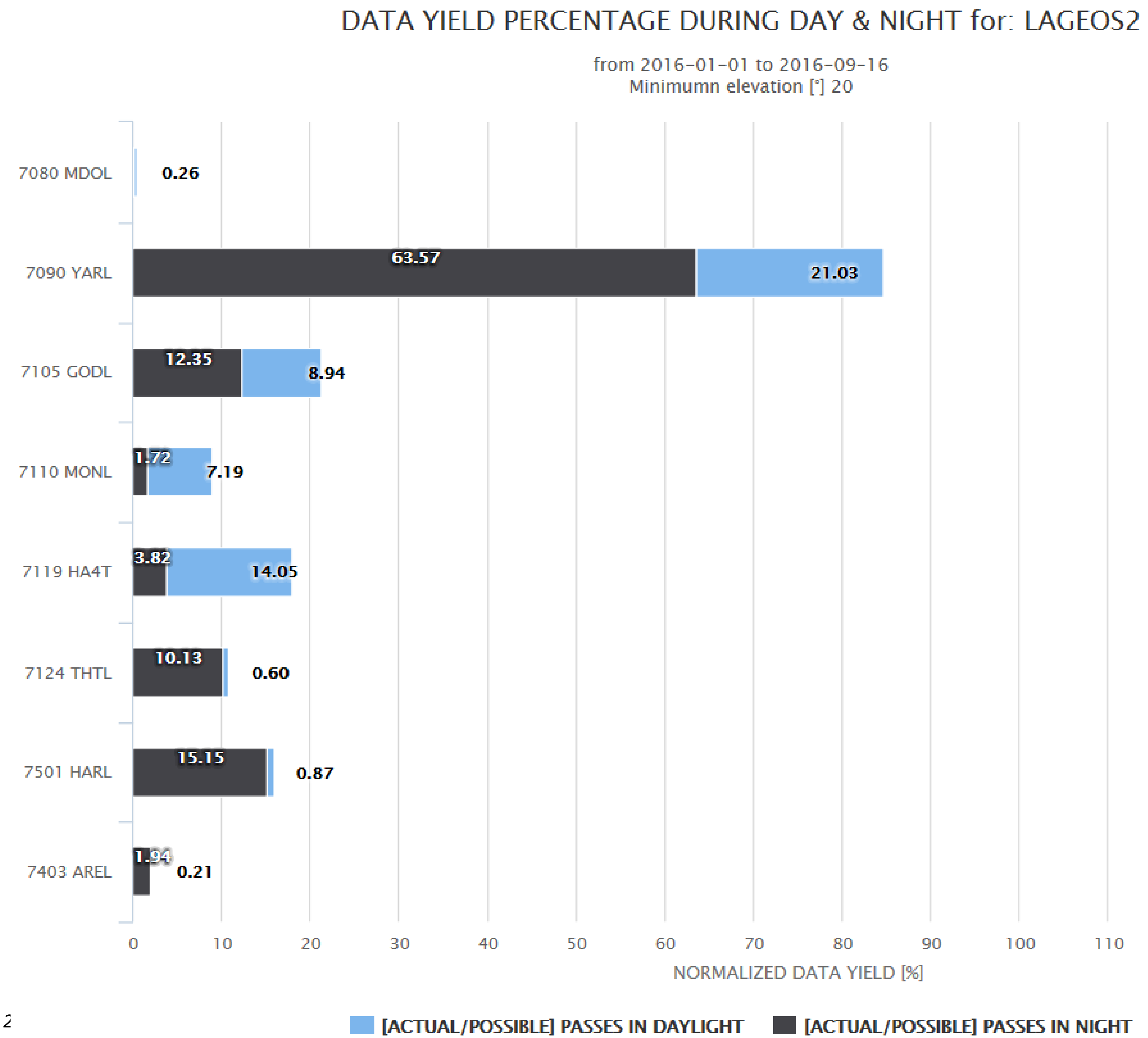
MONL 11% of NP / 21% of passes (day)

HA4T 12% of NP / 23% of passes (day)

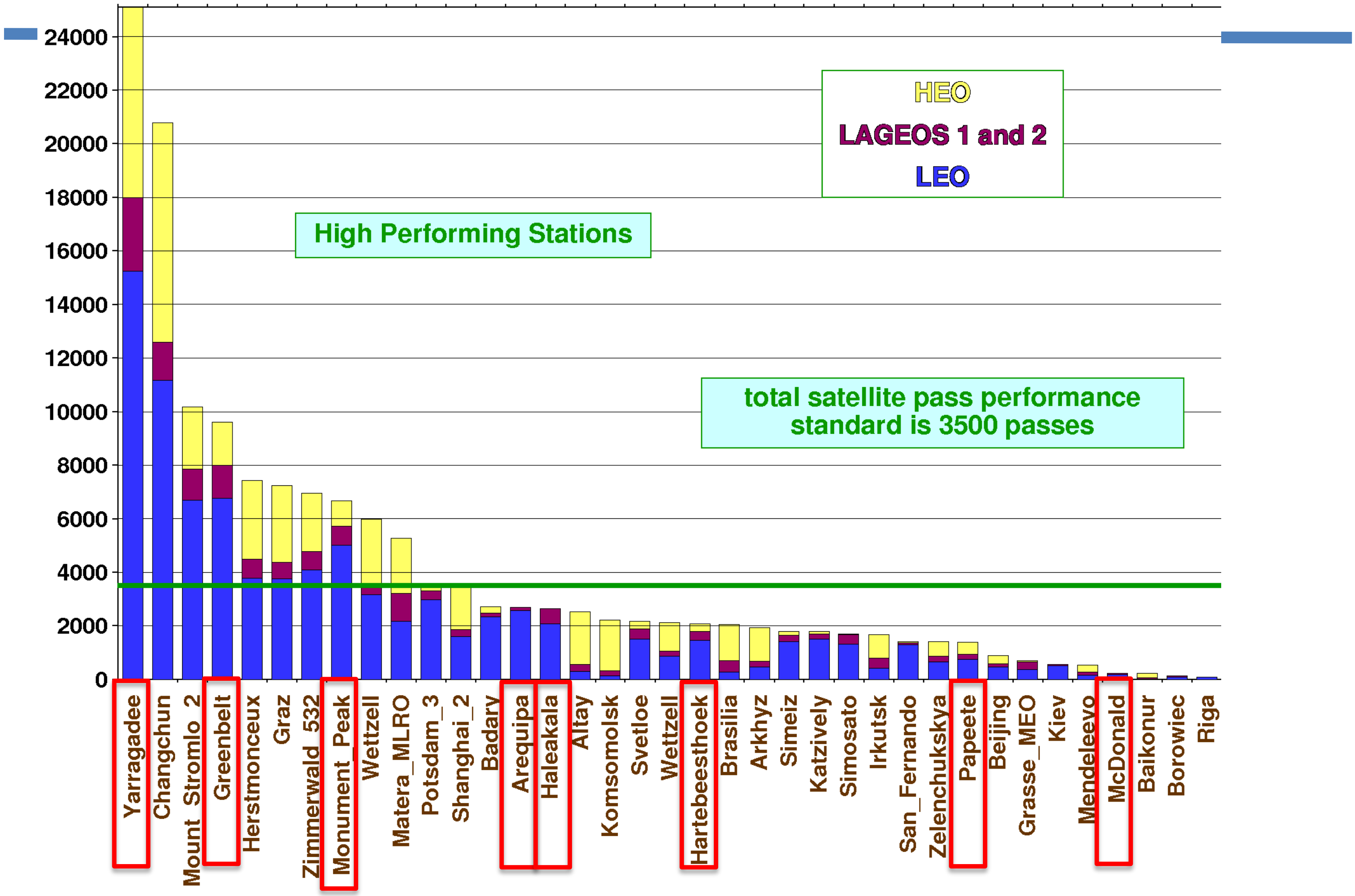
THTL 7% of NP / 12% of passes (night)

HARL 7% of NP / 11% of passes (night)

NASA L2 Efficiency



total passes
from July 1, 2015 through June 30, 2016

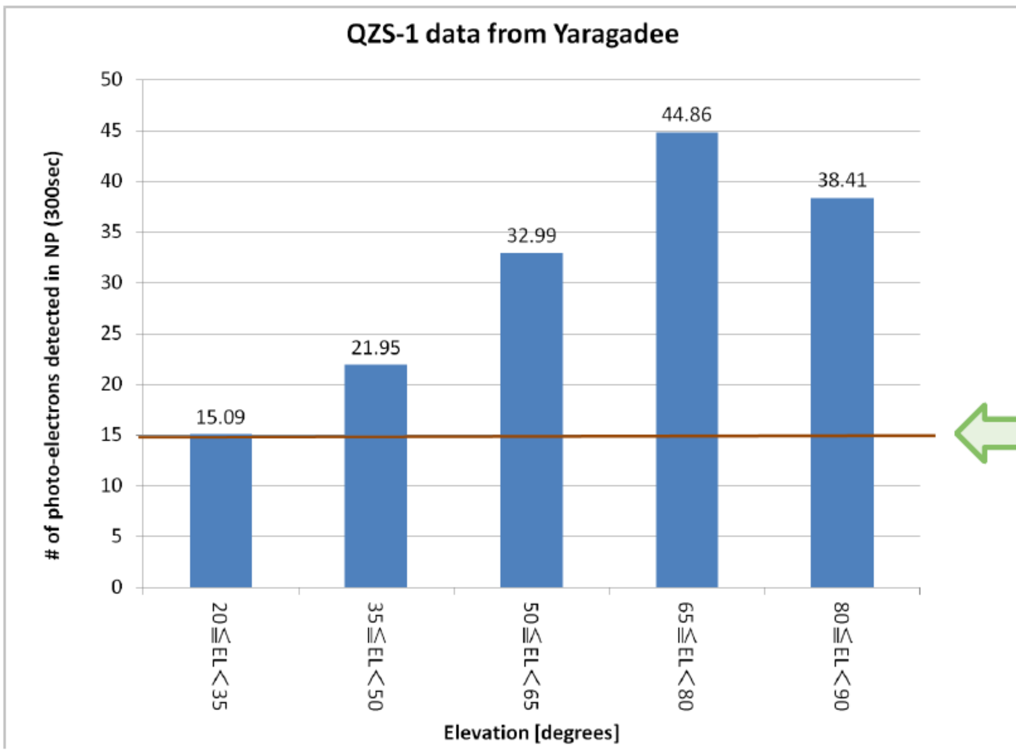


Mission Tracking Needs QZS-1

Ref: Matera
Role of SLR on QZSS operation
Yoshimi Ohshima, Ph.D.
NEC Corporation
y-ohshima@cb.jp.nec.com

Accuracy evaluation using **SLR data has helped modeling** and **parameter tuning** for QZS-1 **Orbit Determination**.

- Data used: 2012 to 2014
- SLR station: Yarragadee (most difficult target station to satisfy requirement)



Satisfies λ >15 requirement!
λ : requirement for # of detected photo-electron detected in NP

Scheduling Alternatives/Improvement

- Goal of a stable terrestrial reference frame
  - Accuracy: ≤ 1 mm (1-Sigma) in X, Y, Z (decadal scale)
  - Stability: ≤ 0.1mm/yr (annual scale)
  - Does this allow any relaxation of ILRS quality requirements or bin size as a way to achieve more yield?
  - How is this translated into station metrics or resource planning?

Potential for Improvement

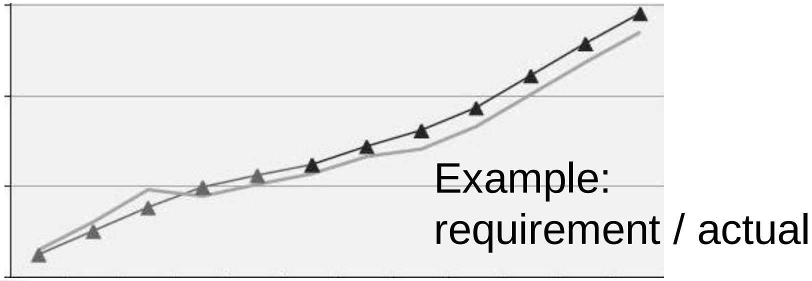
- Improve prediction accuracy and thus acquisition timelines
  - Evaluate an aggregate of prediction / time bias problems and look for improvement opportunities
    - Build efficiency
    - Quantify thresholds and develop processes
- Coordinate some alternating satellite tracking for overlapping stations
  - Selected stations/regions
  - How much simultaneous tracking is desirable?
    - Should we quantify this?
- Maximize night tracking for stations with limited labor and daytime issues
  - HEO/GNSS issue primarily

Potential for Improvement

- Motivate or reward difficult tracking or interleaving with new metrics or recognition
  - Are current metrics promoting any unwanted behavior?
    - NP's vs passes
  - New ILRS yield minimum (3500 passes) is more realistic than previous but
    - This change did not change NASA operations nor could it be translated well into scientific success or failure

Potential for Improvement

- Quantify every mission/user's minimum data/tracking threshold and develop the process of mission/user feedback to the ILRS
  - Translate into clear goals and mission tracking intervals that station operators can understand and implement
    - # NP/pass, etc.
  - Metrics relatable to our sponsors
  - Prepares ILRS for additional satellites/requirements
  - Future:
    - Web-tool display of real time priority change
    - Continued refinement



Back up slides

Mission Tracking Needs

- In Matera we received some mission feedback
- Galileo
  - SLR measurements are of great benefit for:
    - Galileo orbit validation
    - Galileo force model development and validation

year 2015	NPT/Day	% days tracked
GAL 101-104	16	96
GAL 201-204	9	82

  - Points for improvement:
    - “It would be very much appreciated if the position of the Galileo satellites in the ILRS mission priority list could be increased”

Ref: Matera: SLR measurements and their importance for Galileo Werner Enderle, Daniel Navarro-Reyes, Francisco Gonzalez, Erik Schoenemann, René Zandbergen 26/10/2015

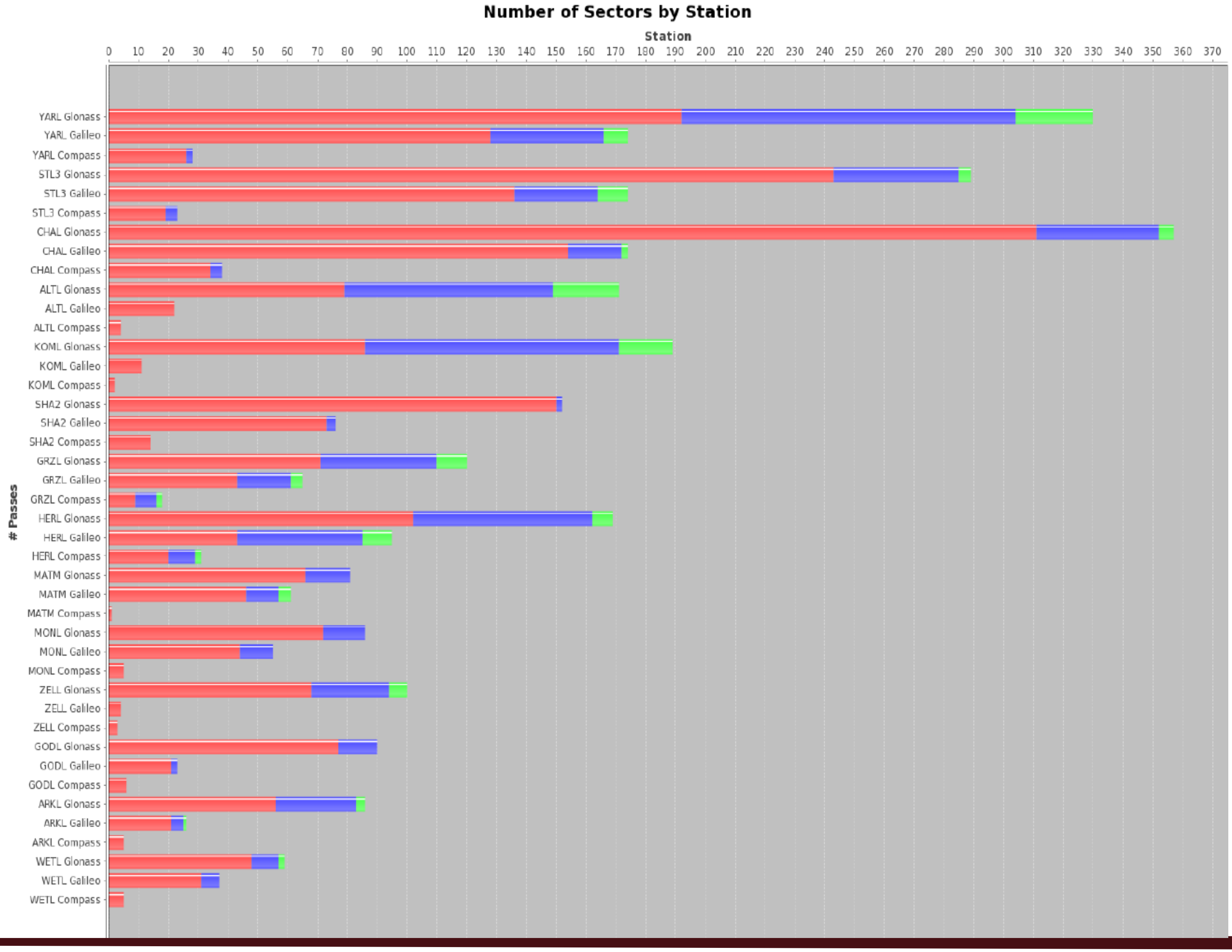
Mission Tracking Needs

- **To achieve the centimeter accuracy of orbits determination for navigation SC equipped with laser retro-reflectors, the performance rates of SLR station must be increased by more than 1 order at the expense of a data collection time reduction and automatic functioning under day conditions and through overcast breaks. In fact ,we mean making SLR stations function in a 24/7 mode of operation.**

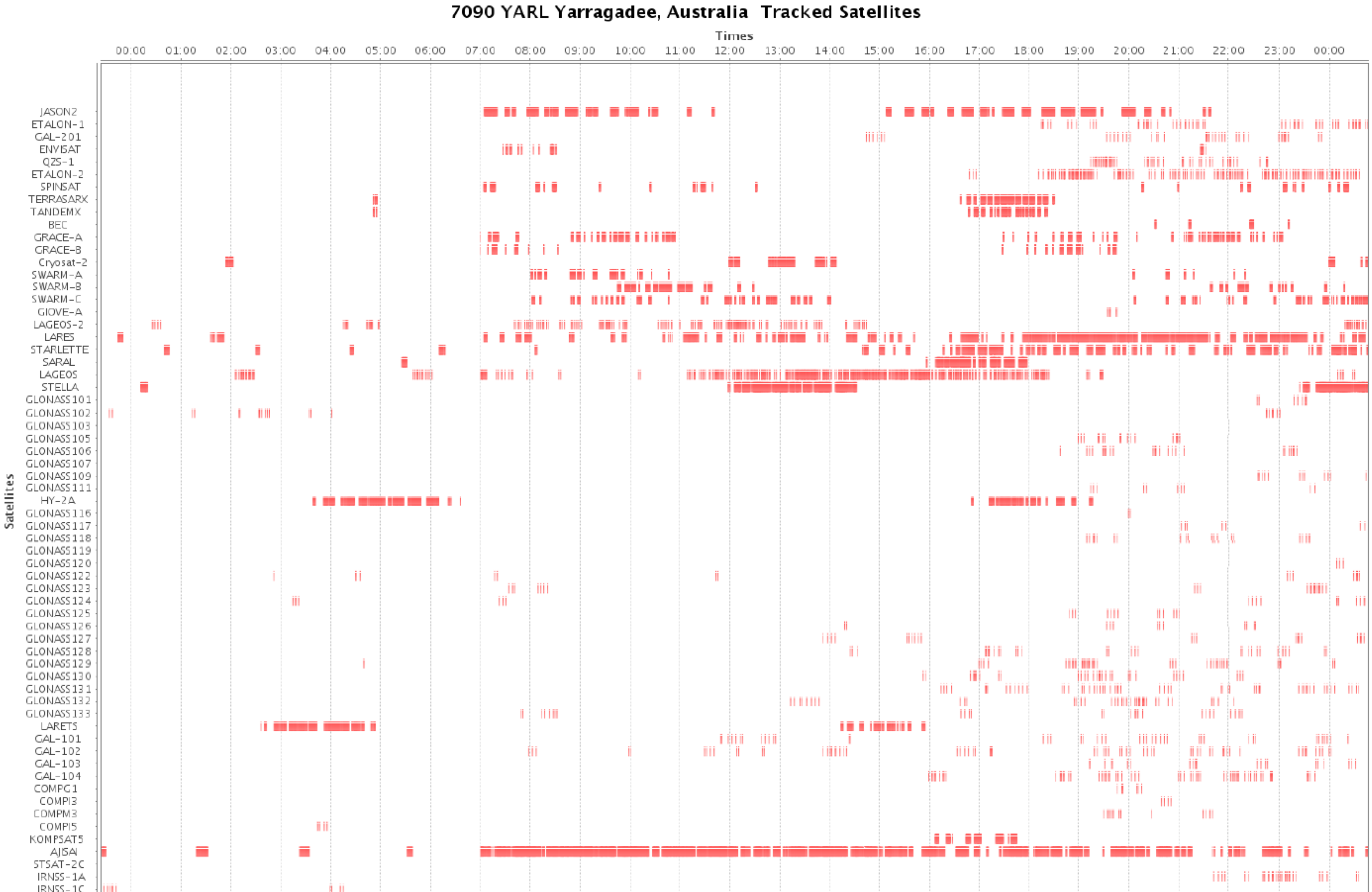
- **Ref Matera: M. A. Sadovnikov, V.D. Shargorodskiy RESEARCH-AND-PRODUCTION CORPORATION «PRECISION SYSTEMS AND INSTRUMENTS»Moscow, Russia**

GNSS Campaign Sector Tracking Actual

Figure 4: Number of Sectors by Station for the Second GNSS Campaign; November 24, 2014 - February 28, 2015



YARL GNSS Actual Tracking 2015/01/25 to 2015/02/07 LOCAL TIME



ILRS Data Constraints

- Nice France 2002 meeting; minimum data requirement
  - Daytime normal points - minimum 6 data points
  - Night time normal points - minimum 3 data points
  - Fewer data points would be acceptable on lower satellites (5-second normal points) from those ranging systems with lower pulse repetition rates where these minimum requirements are not practical.
- Bad Koetzting Germany 2003; stations may exercise their own discretion on setting minimum data criteria per normal point. Nice criteria recommended by ILRS GB for single photoelectron systems with high data yield. Stations with KHz rates may select more stringent criteria (specify in site logs!)