Operational Challenges

of SLR Tracking of GNSS Constellations

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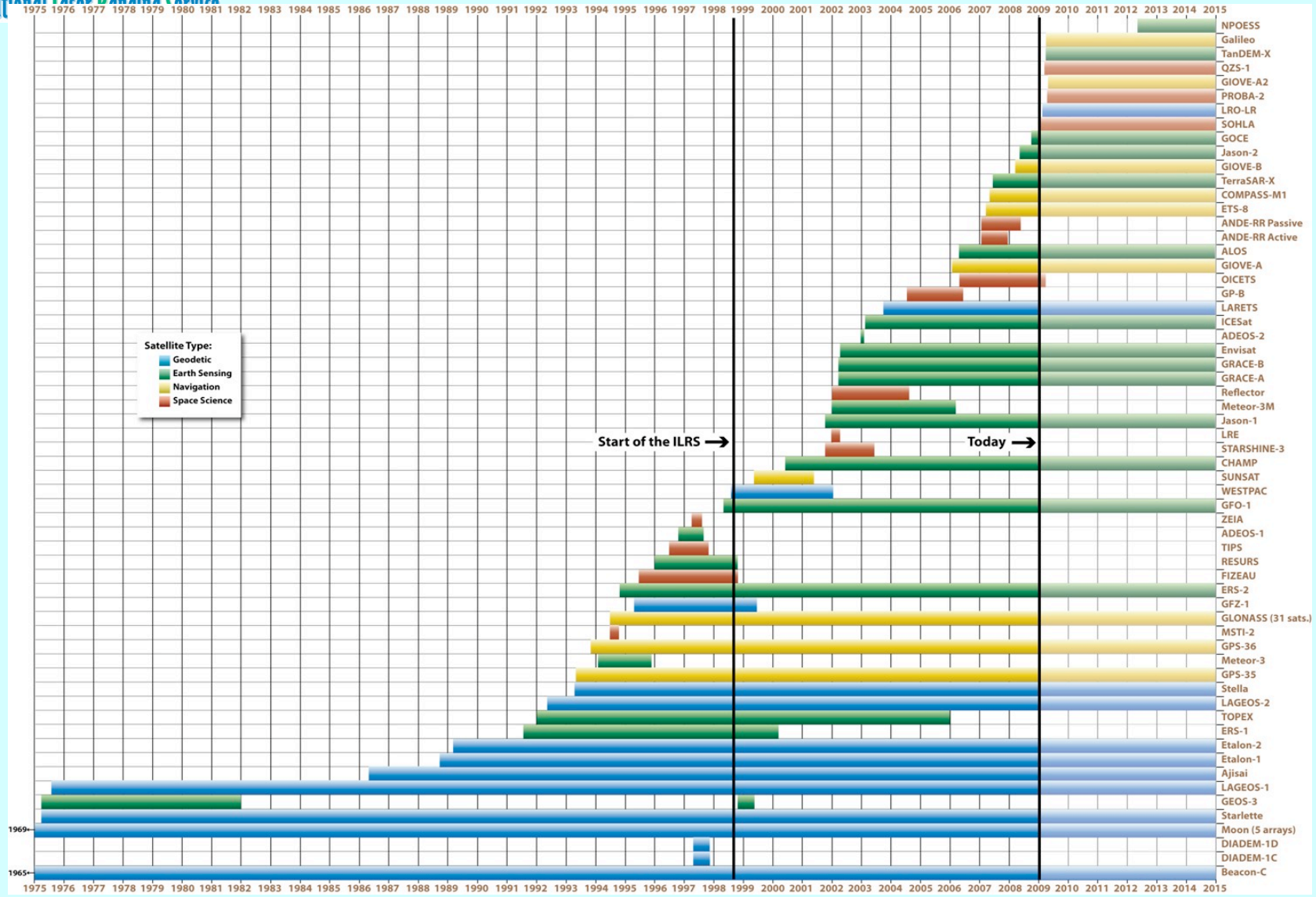
Overview and Introduction

- The stations of the ILRS track a diverse constellation of satellites:
- In turn those missions support a wide range of investigations in the broad area of Earth and planetary research;
- A vital component of the growing Global Geodetic Observing System.
- Satellites include extreme LEO, through MEO and up to GEO
  - and vehicles from all current GNSS missions

Current Situation on GNSS

- Current GNSS missions supported are:

- (1) GPS, (3) GLONASS, (2) GALILEO, (1) COMPASS
- Plus 24 Earth-orbiting, one Lunar orbiting and a number of Lunar targets
- Very efficient operations required


1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Satellite Type:
Geodetic
Earth Sensing
Navigation
Space Science
Start of the ILRS
Today
NPOESS
Galileo
TanDEM-X
QZS-1
GIOVE-A2
PROBA-2
LRO-LR
SOHLA
GOCE
Jason-2
GIOVE-B
TerraSAR-X
COMPASS-M1
ETS-8
ANDE-RR Passive
ANDE-RR Active
ALOS
GIOVE-A
OICETS
GP-B
LARETS
ICESat
ADEOS-2
Envisat
GRACE-B
GRACE-A
Reflector
Meteor-3M
Jason-1
LRE
STARSHINE-3
CHAMP
SUNSAT
WESTPAC
GFO-1
ZEIA
ADEOS-1
TIPS
RESURS
FIZEAU
ERS-2
GFZ-1
GLONASS (31 sats.)
MSTI-2
GPS-36
Meteor-3
GPS-35
Stella
LAGEOS-2
TOPEX
ERS-1
Etalon-2
Etalon-1
Ajisai
LAGEOS-1
GEOS-3
Starlette
Moon (5 arrays)
DIADEM-1D
DIADEM-1C
Beacon-C
1969
1965

Current, ideal tracking strategy

- ILRS assigns priorities to each of the Earth-Orbiters:
  - largely based upon their semi-major axes;
- Most of the highly-productive stations are thus able to interleave their tracking;
  - leaving for example a satellite such as LAGEOS, (pass duration up to 50 minutes), perhaps several times in order to catch passes of for example LEOs such as GRACEs, ENVISAT, JASONs, etc.

So what's the problem?

- All the GNSS systems are expanding:
- 30 GALILEO vehicles, 4 in next two years;
- Quasi Zenith Satellite System vehicles;
- New COMPASS vehicles soon;
- GLONASS mission analysts 'would be happy if all (19) vehicles were tracked'
- Likely that new GPS vehicles will have LRAs

So what's the problem (2)?

- It is also clear (from discussions here and previously) that the missions and analysts are not getting all the data they need even from the current, relatively modest, number of GNSS vehicles:
- The lack of daytime GPS laser tracking;
- Sparse COMPASS tracking;
- Need for more GLONASS vehicles;
- Little hope of SLR-only GNSS orbits
- etc.

Summary of Issues

- The future challenges for the Network will clearly be to continue to serve the existing scientific needs of the community whilst at the same time making sufficient effort to track the growing numbers of GNSS vehicles such that the needs of that, perhaps more technologically-based, community can be met
  - There are of course also good scientific reasons to track GNSS, which must be emphasised

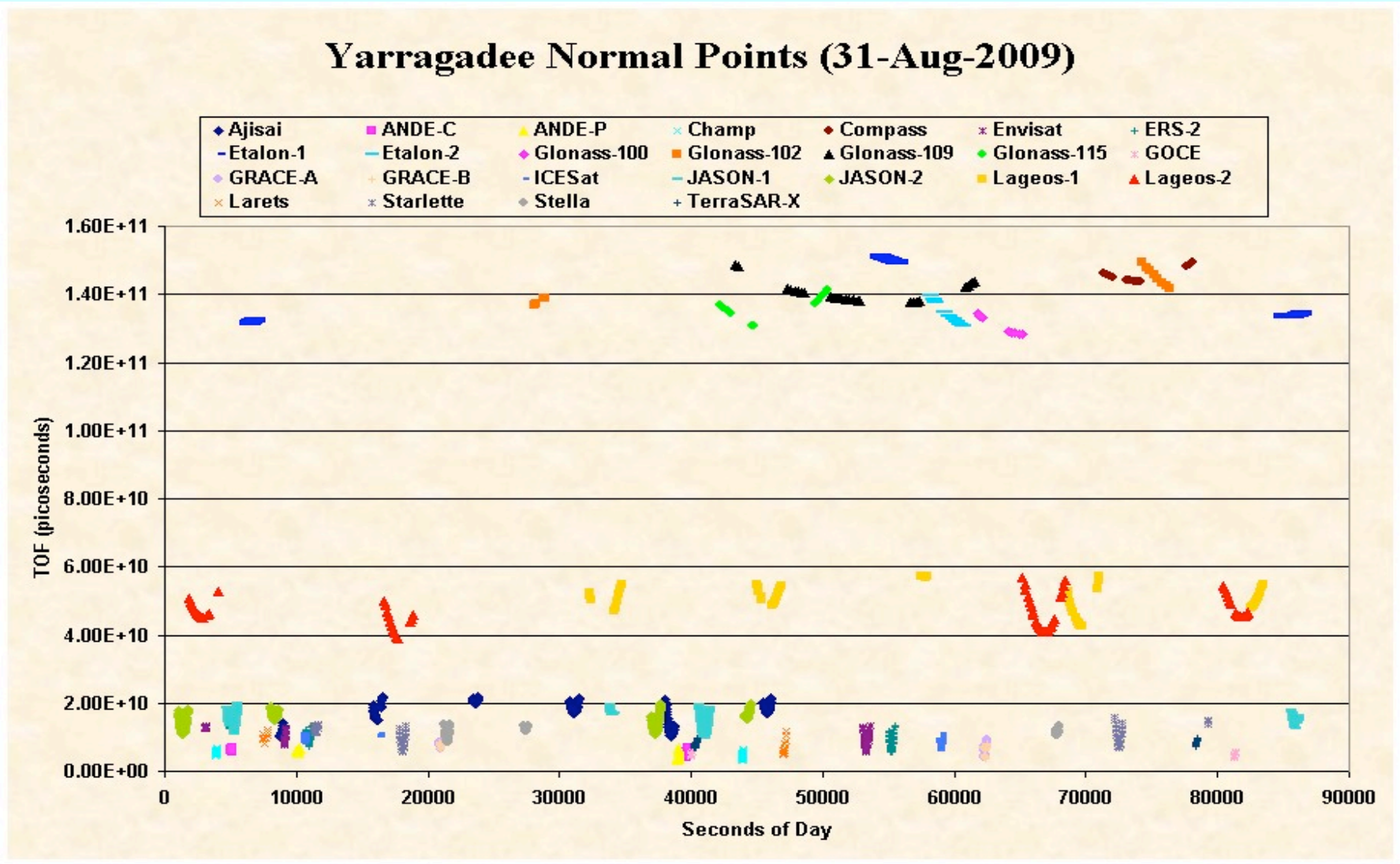
Session Overview

- We now look in a bit more detail at ILRS operations.
- Specific reference to GNSS tracking capacity and capability;
- Presentations following this talk will look in more detail at system optimisation and pass-tracking strategies.
- Technological issues, including array efficiency and design, will be addressed in PP7 on Friday.

Pass Interleaving

- Most of the major ILRS stations operate a pass-interleaving strategy which in effect allows them to multi-task their satellite tracking efforts;
- Assumption is that scientific value of the laser ranging data from a particular pass is not compromised if the tracking data is not continuous throughout the pass;
  - Lessons to be learned from LLR practice

International Laser Ranging Service



Options

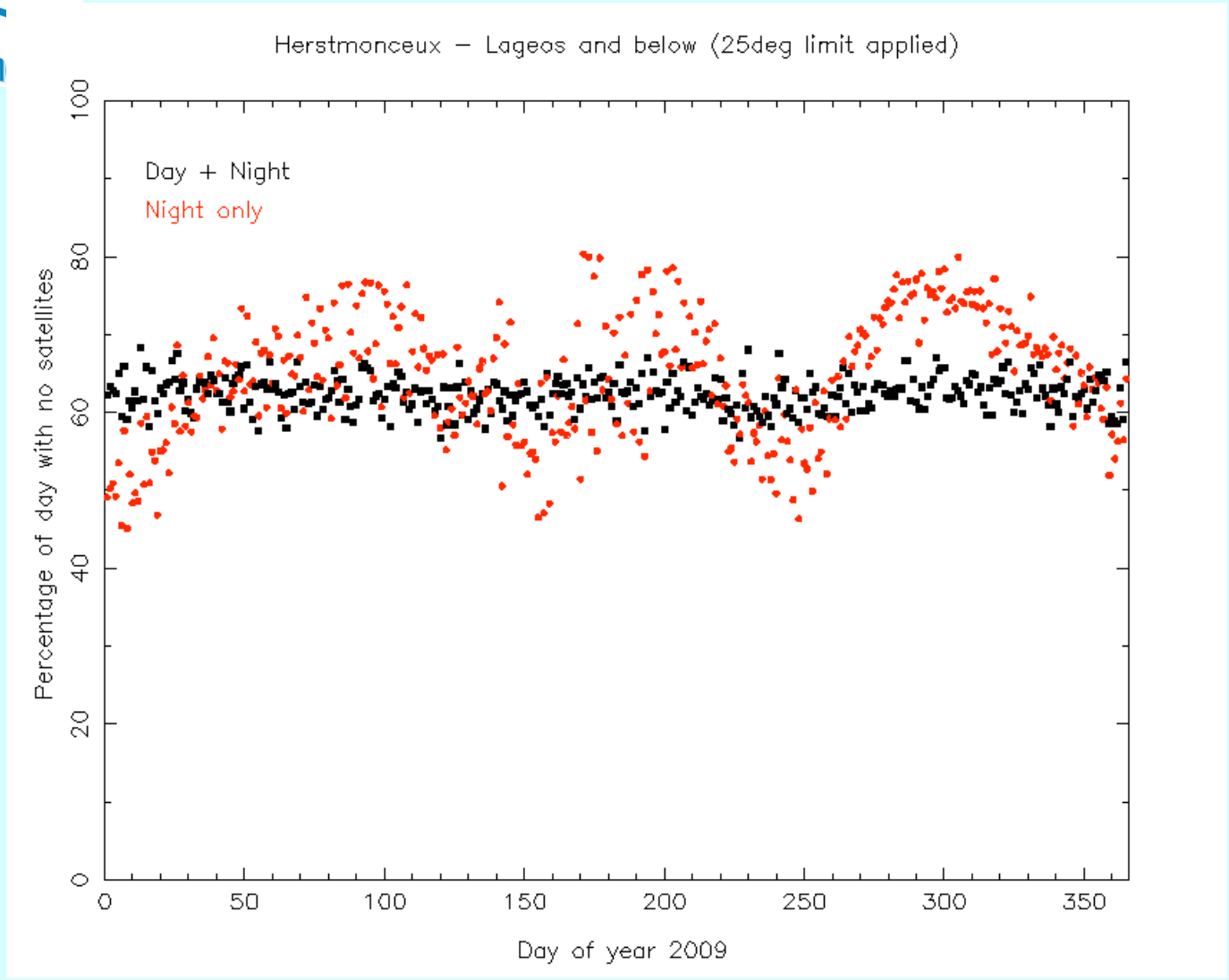
- As the demand for support for more GNSS (and for LEO) vehicles increases, the need for rapid interleaving by the major, high-productivity, stations will increase.
- There must be input from the GNSS community on the best tracking strategy for their needs to inform this policy:
  - Concentrate on all vehicles for short periods;
  - Concentrate on a few vehicles/orbit planes.
- **Subject of further paper in this session**

Network Capacity

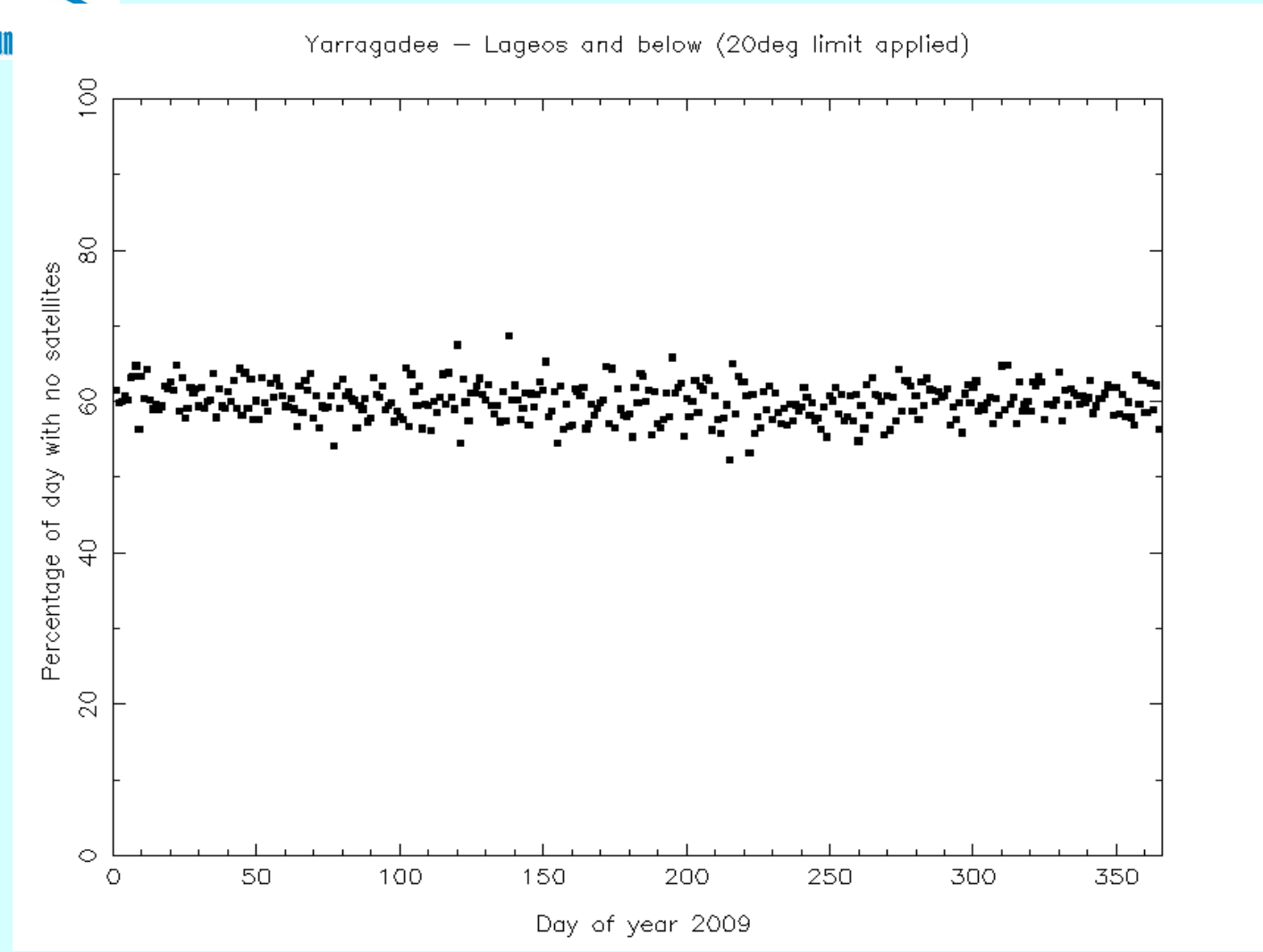
- Is it physically possible for a given station to add more satellites to its schedule;
- how much, if any, spare capacity currently exists in the system?
- Current schedule of typical N and S hemisphere stations from the point of view of all satellites up to the height of the LAGEOS geodetic spheres, with semi-major axes of 12,300km.

Network Capacity

- For a one-year period, we computed the percentage of time during each day when no satellites up to the height of LAGEOS were above the stations' operational elevations of 20° or 25°.
- Results illuminating:



Percentage of time per day when no LEO->LAGEOS satellites are available – Northern Europe



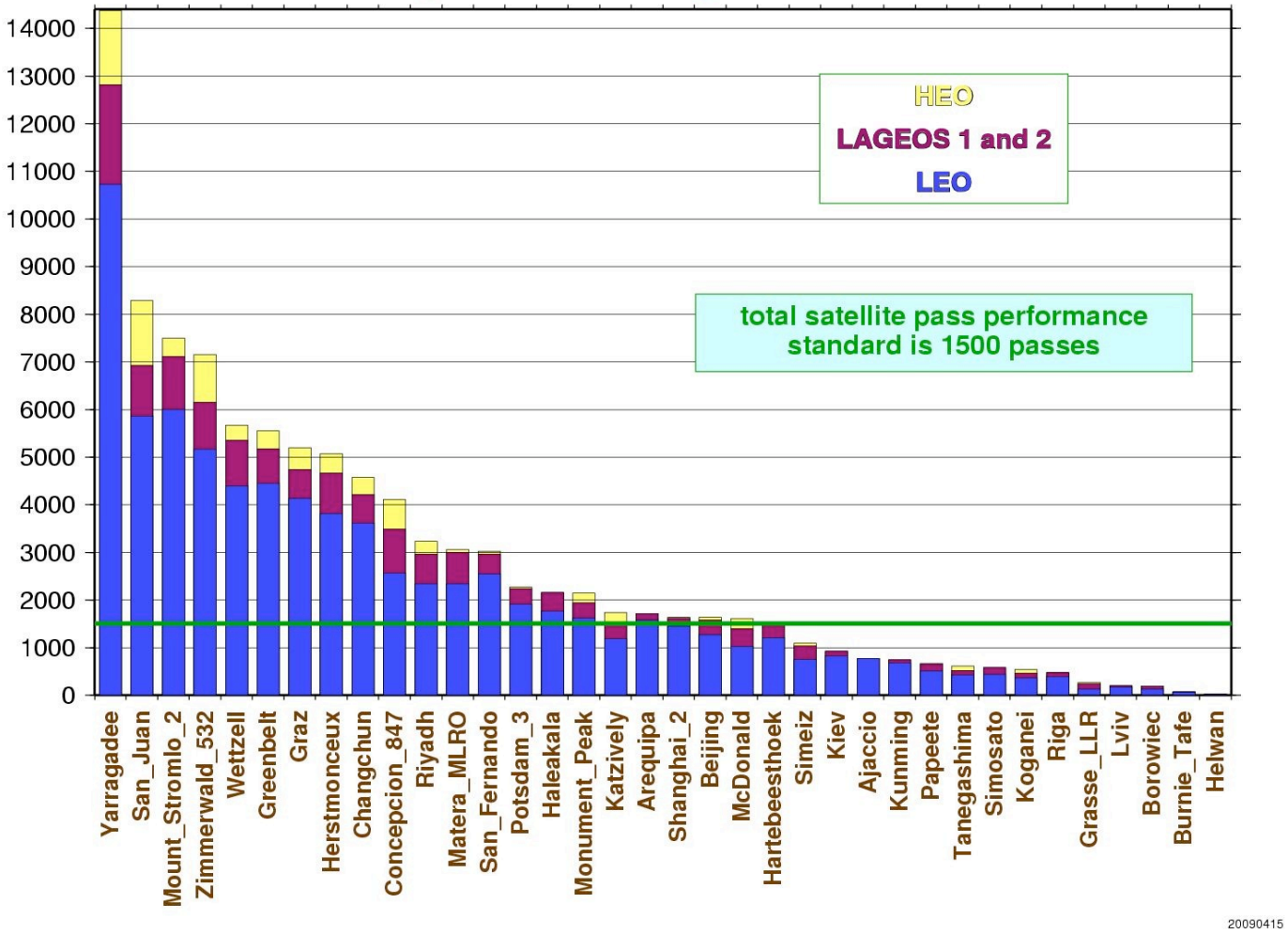
Percentage of time per day when no LEO->LAGEOS satellites are available -Western Australia

Capacity-for HEOs?

- So, provided that the scheduling and funding models permit, some 40 to 60% of each 24-hour period is potentially available for high-satellite tracking, including the GNSS vehicles.
- this computation does not take account of time required for ground-target calibration ranging, which may take several minutes each hour depending on each station's operational practice.

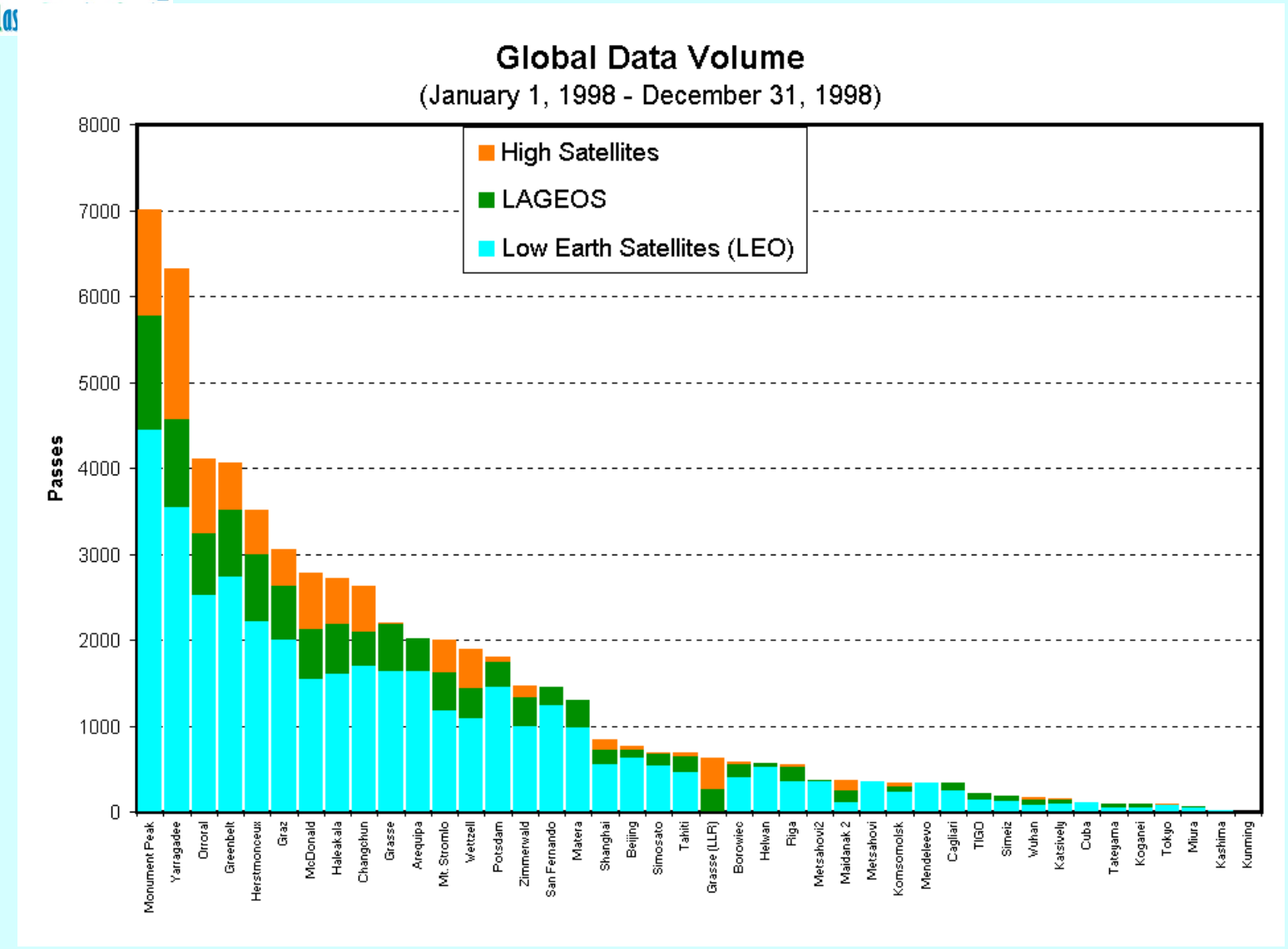
Current tracking records for HEO/GNSS

- Only the most capable of the network stations add significantly to the tracking data for the more difficult, high-orbiting GNSS satellites;
- current capability of each ILRS station is obtained from the ILRS-generated tracking-record plots for the year up to the end of March 2009
- 15 or so 'top' stations that contribute most to tracking the LEO and MEO missions also contribute most to HEO/GNSS tracking


total passes
from April 1, 2008 through March 31, 2009
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
HEO
LAGEOS 1 and 2
LEO
total satellite pass performance standard is 1500 passes
Yarragadee
San_Juan
Mount_Stromlo_2
Zimmerwald_532
Wettzell
Greenbelt
Graz
Herstmonceux
Changchun
Concepcion_847
Riyadh
Matera_MLRO
San_Fernando
Potsdam_3
Haleakala
Monument_Peak
Katzively
Arequipa
Shanghai_2
Beijing
McDonald
Hartebeesthoek
Simeiz
Kiev
Ajaccio
Kunming
Papeete
Tanegashima
Simosato
Koganei
Riga
Grasse_LLR
Lviv
Borowiec
Burnie_Tafe
Helwan
20090415

Past Capacity

- The situation ten years ago, at a time when the stations were tracking the-then full constellation of nine GLONASS vehicles:
- Suggestion that relatively speaking, more effort on HEO tracking
  - Even though less LEO
- indicates that the network can respond positively to greater HEO demands.


Global Data Volume
(January 1, 1998 - December 31, 1998)
High Satellites
LAGEOS
Low Earth Satellites (LEO)
Passes
8000
7000
6000
5000
4000
3000
2000
1000
0
Monument Peak
Yarragadee
Orroral
Greenbelt
Herstmonceux
Graz
McDonald
Haleakala
Changchun
Grasse
Arequipa
Mt.Stromlo
Wettzell
Potsdam
Zimmerwald
San Fernando
Matera
Shanghai
Beijing
Simosato
Tahiti
Grasse (LLR)
Borowiec
Helwan
Riga
Metsahovi2
Maidanak 2
Metsahovi
Komsomolsk
Mendeleevo
Cagliari
TIGO
Simeiz
Wuhan
Katsively
Cuba
Tateyama
Koganei
Tokyo
Miura
Kashima
Kunming

Data Availability

- All ranging data made available rapidly in normal-point form via Data Centres
- Currently 5-minute NP for HEO, even if not full 5-minute tracking 'bursts'
- Should seriously consider 1-minute NP to better reflect tracking practices;
- Problem for missions?

Restricted Tracking

- All ILRS stations agree to adhere to any applicable ILRS Restricted Tracking Procedures:
  - by-station authorization by the Mission;
  - time and viewing angle constraints;
  - energy/power constraints;
  - ftp-based go/no-go switch
- Successfully applied to a number of current missions
- Thus infrastructure in place if new GNSS have time, attitude, other constraints.

Station maintenance/upgrades

- Always important that the laser ranging systems are working to specification in terms of optical and mechanical efficiency.
  - especially so for the relatively low-energy return signals from the high GNSS vehicles
- Therefore stations should adhere to 'best practice' guidelines, for example the current NASA-station upgrade programme
- Details in PP8 text, and to be presented

Collaborative/dynamic scheduling

- With increasing GNSS and other tracking, makes sense for stations to realtime-schedule according to current Network data-yield
- Some infrastructure in place by ILRS to support this dynamic scheduling
- Needs more adherence to existing system, or development of better one.

Conclusion

- Operationally, ILRS Network in reasonable shape to track more GNSS!
- Will respond to extra demands, with some provisos:
- Needs Mission 'interest' feedback of current results, idea of value of data, etc.
  - Excellent Workshop here is great start
- Some difficult per-station funding issues may have to be addressed.

Conclusion (2)

- Must re-asses tracking priority recommendations for each station;
  - e.g. more GLONASS satellites, more time on GIOVEs, etc. ?
- Response to this will depend on station funding models, local science priorities enthusiasm of missions, etc.