Operational Support by ESOC's GRAS Ground Support Network
-
Status and Outlook

R. Zandbergen, F.Wollenweber, C.Marquardt, W. Enderle

and the ESOC and EUMETSAT teams

(see last slide)

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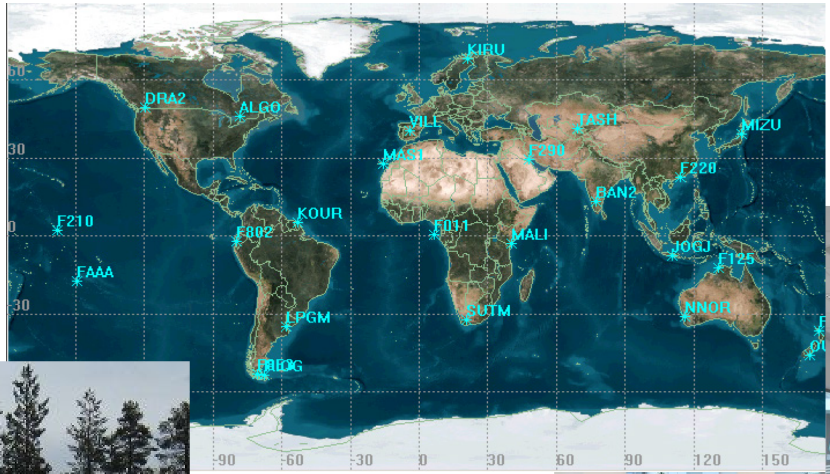
Melbourne, 20/04/2015

Presentation Overview

1. GRAS GSN brief introduction
2. Status:
   a. Evolution history
   b. Present performance
3. Evolution perspectives

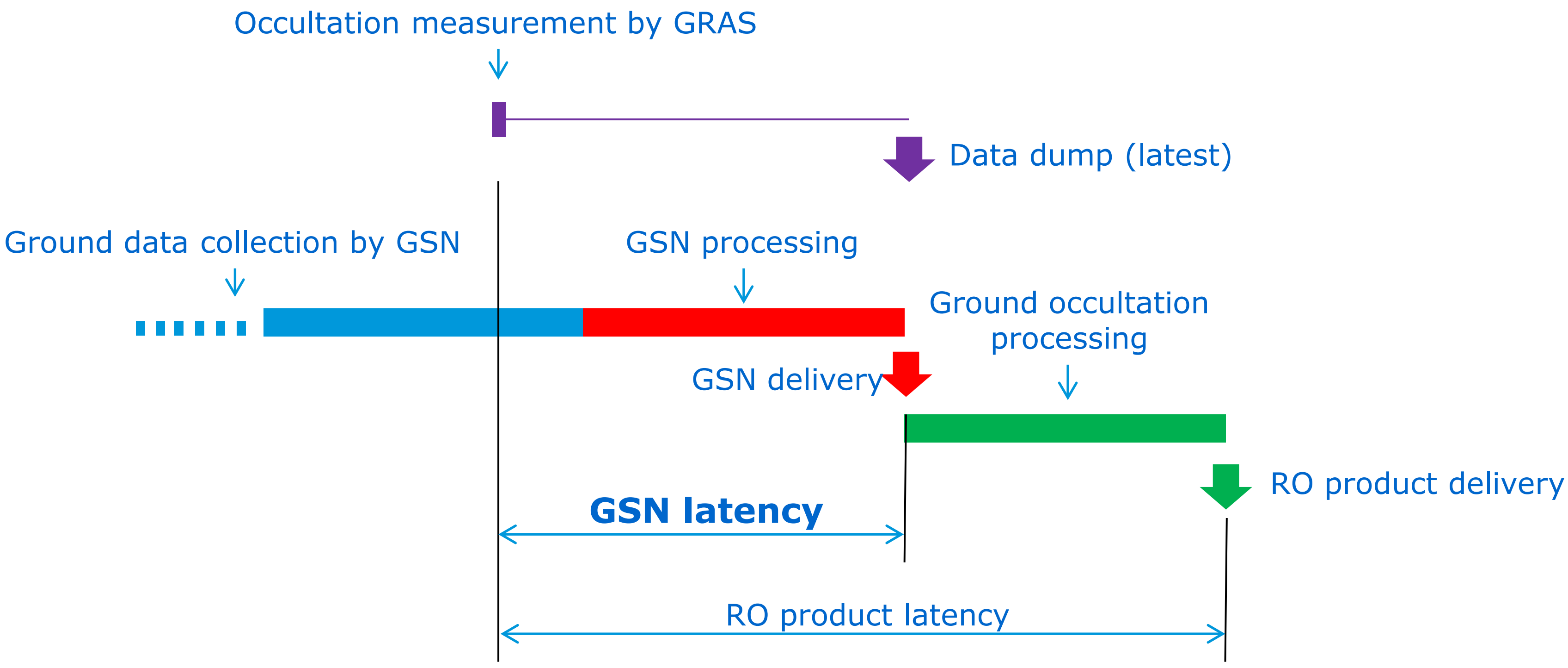
1. GRAS GSN - Introduction

- The GRAS Ground Support Network has been presented at several recent OPAC and IROWG events



1. GRAS GSN - Purpose

- GSN provides all GPS-based inputs needed for operational near-real time RO processing



1. GRAS GSN - Requirements

- Requirements derived from:
  - Needs for RO processing
  - Needs for Metop Precise Orbit Determination

- Primary requirements are on:
  - Timeliness of products (“GSN latency”)
  - High reliability and availability
  - Orbit and clock accuracy sufficient for the purpose
  - Reporting

1. GRAS GSN – Operational setup

- Started operations in 2007 (Metop-A)
- Station network, includes ESOC sites and external providers under contract (GFZ, Fugro, NRCan)
- Processing centre, fully automated operations
  - 24/7 support by team through on-call service
- Delivery of near-real time and offline products
- Precise GPS orbit and clock solutions, and auxiliary data:
  - EOP, (Troposphere), Meteo, Nav.Messages, configuration data
  - Navigation bit stream data

1. GRAS GSN – Daily NRT products

- 24 orbit product deliveries (8766 per year)
  - Inertial orbit file
  - Earth-fixed orbit file
  - Earth Orientation Parameters
- 96 “clock” product deliveries (35,064 per year)
  - Satellite clock offset file
  - Station clock offset file
  - NBS product
- All other products at significantly lower rate.

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2a. GSN evolution (1 of 2)

- Computer centre and data servers were moved to support a geographical separation (redundancy), without service interruption
- Communication to station data suppliers changed
- Core software (orbit and clock determination): from legacy to state of the art software (same as in IGS)
    - Several additional changes improving the performance
- All GNSS receivers at GSN stations were replaced by multi-frequency, multi-system receivers
- Overall GSN latency reduced from 60 to 45 min.

2a. GSN evolution (2 of 2)

- 2013: Implementation of new service to deliver Navigation Bit Stream data in NRT (45 min latency)
  - Some additional receivers
  - High redundancy and data merged from several receivers
  - Allows processing of open-loop tracking of GRAS instrument
- 2014: Installation of fast Intel-based servers, and move to Linux
  - Significant processing time improvement
  - Has been running successfully in parallel for many months
  - Waiting for final validation of dedicated data servers

2b. GSN Status summary

- GRAS GSN has been fully operational since Metop-A launch (2007), presently supporting Metop-A and Metop-B
- Availability requirement (99%) met with a large margin (demonstrated ~ 99.95 %)
- Performance reported to EUMETSAT in Monthly and Yearly Reports, covering all performance indicators
- Accuracy performance increased clearly since the start
- Latency now clearly below 45 min.

2b. Monthly reporting

European Space Ag
Directorate of Human Spaceflight and Operations

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Service Status Report - February 201

GRS-MGT-RP-111-HSO-GN

1.0

15/03/2015

ESOC European Space Opera

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3 SERVICE LEVEL INDICATORS

The SLI presented in this report have been adapted from [RD-1] as agreed
reflect the GSN requirements and results in the metrics usually employed i
Once the definition of the new SLI is completed, [RD-1] will be adapted acc

3.1 SLI for February 2015

SLI Id	SLI Title	SLI value
Completeness of the Delivered Data for current month		
SLI-1	Completeness of the GSN NRT product transmission	100.00 %
Timeliness of the Delivered Data for current month		
SLI-2	NRT GPS Clock products delivery performance	100.00 %
SLI-3	NRT Station TZD products delivery performance	No TZD prod
SLI-4	NRT Station Clock products delivery performance	100.00 %
SLI-6	SSD products delivery performance	No SSD prod
SLI-7	GPS Navigation file generation	100.00 %
SLI-8	GPS Almanac file generation	100.00 %
SLI-9	Status and Configuration file delivery performance	100.00 %
Timeliness of the Delivered Data for the enhanced products		
SLI-5	Enhanced products generation	100,0 %
Accuracy of the Delivered Data for current month		
SLI-10	NRT GPS Position accuracy performance	4.08 cm
SLI-11	NRT GPS Velocity accuracy performance	0.006 mm/s
SLI-12	NRT GPS Clock accuracy performance	SIGMA: 0.26 RMS: 0.52
SLI-13	NRT GPS Clock overlap performance	0.04 ns
SLI-14	NRT Station TZD accuracy performance	No TZD prod

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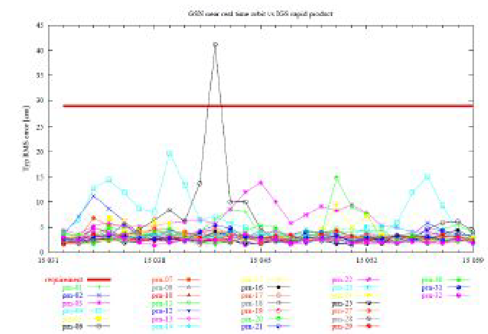


Figure 1: GRAS GSN NRT GPS Orbit performance per day in February 2015

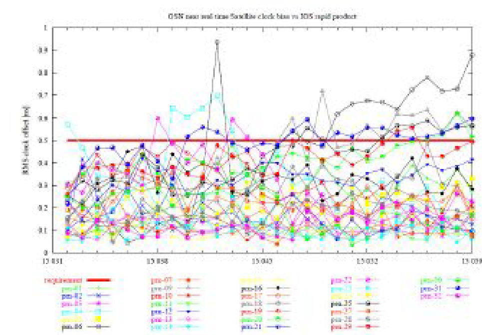
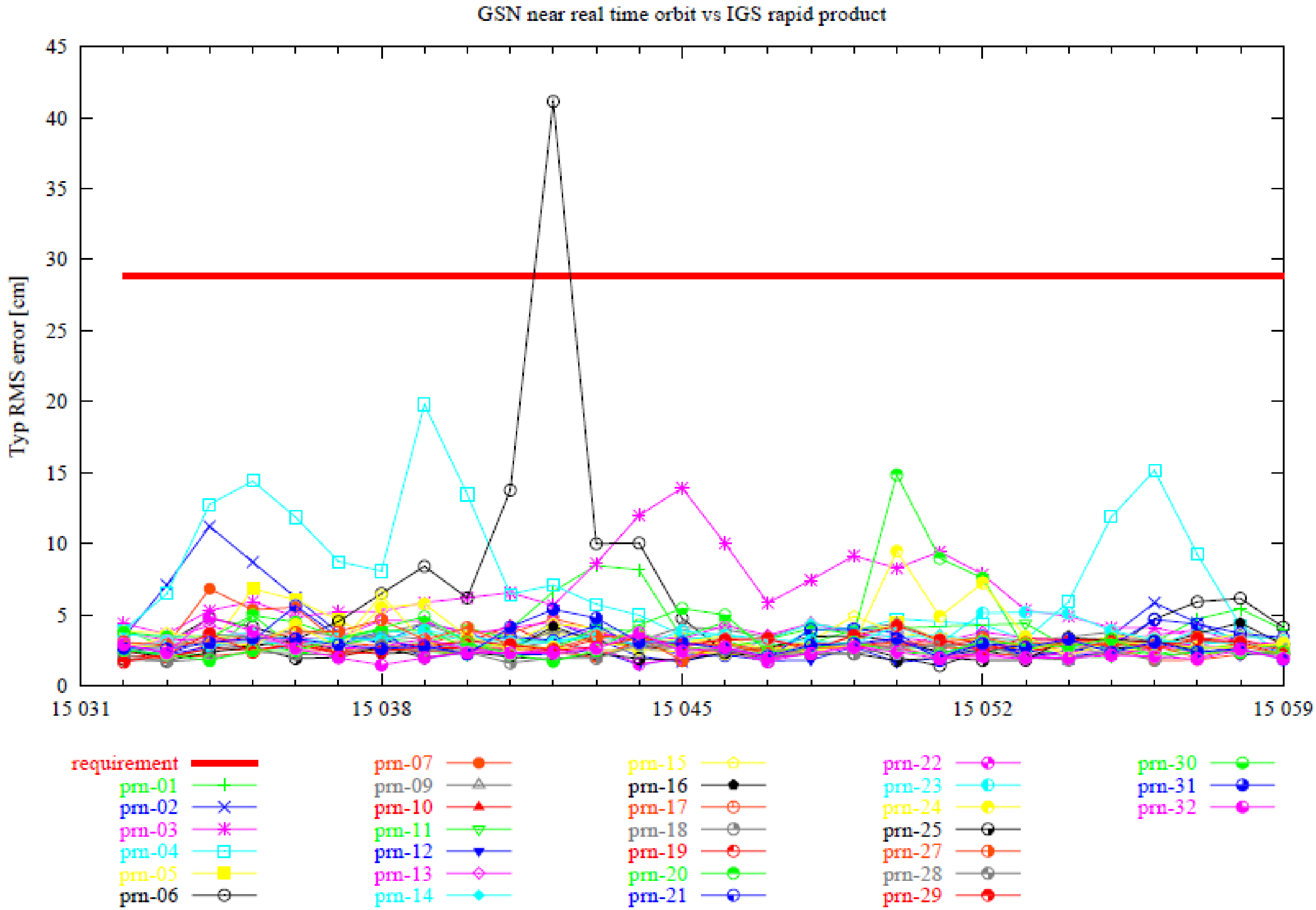


Figure 2: GRAS GSN NRT GPS RMS Clock performance per day in February 2015

2b. Orbit accuracy (cm, ‘typical RMS’)

October ’14	3.91
November ‘14	3.43
December ‘14	5.05
January ‘15	3.59
February ‘15	4.08
Overall	**4.05 cm**

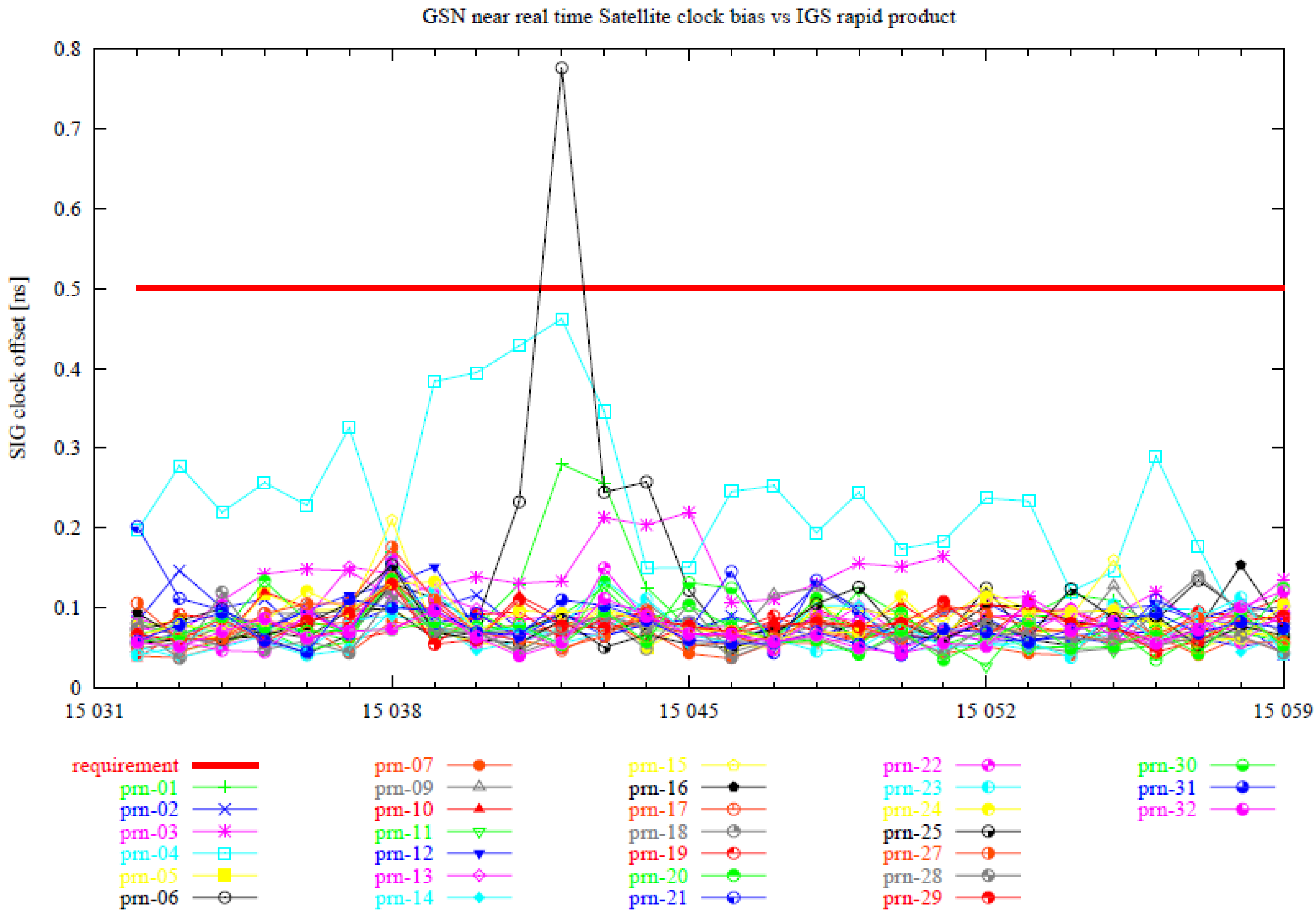
2b. Orbit accuracy (February 2015)



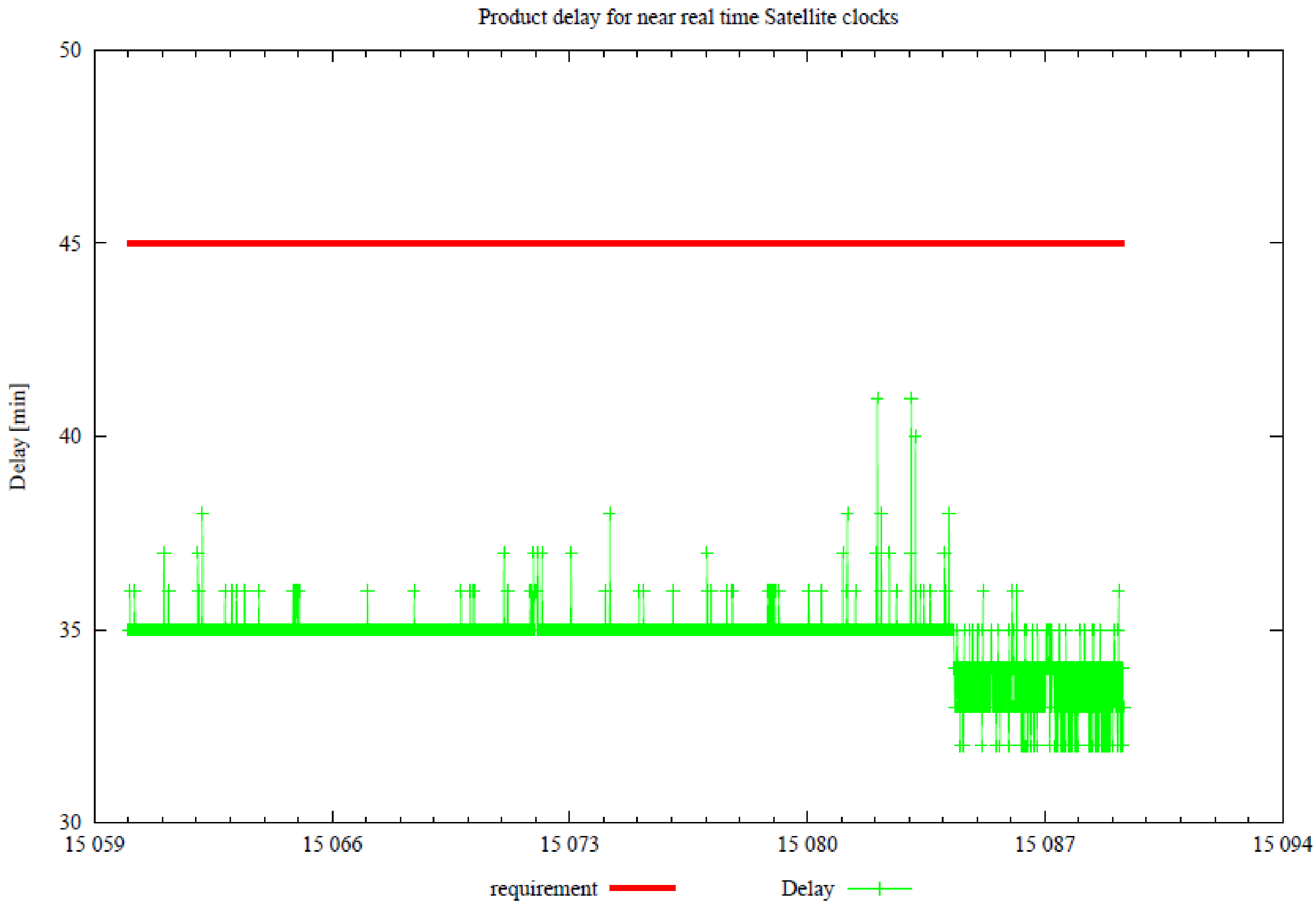
2b. Clock accuracy (ns), RMS & Sigma

	Overall RMS constellation	Overall Sigma constellation
October ’14	0.46	0.26
November ‘14	0.43	0.12
December ‘14	0.38	0.34
January ‘15	0.42	0.13
February ‘15	0.52	0.26
Overall	**0.44 ns**	**0.24 ns**

2b. Clock accuracy (Feb. 2015) - Sigma



2b. Timeliness of clock products (min)



2b. Handling of issues - GPS

- Changing configurations require constant attention
- Commissioning / de-commissioning of satellites, changes to stations
- GPS Block-2F satellites:
  - Unusual behaviour during eclipses
  - Very occasional attitude manoeuvres (not announced)
  - These affect all POD centres including IGS – effects can be more than 1 m in position

2b. Handling of anomalies

- System status is checked every working day
- All issues affecting any performance parameter are tracked in an 'Anomaly Reporting and Tracking System'
  - power, computers, communications, very occasional software issues, …
- To date, 75 anomalies were opened
  - 5 in 2013, 1 in 2014
  - 3 pending closure
  - Of these, 2 waiting for start of Linux operations
  - Many led to improvements (robustness)

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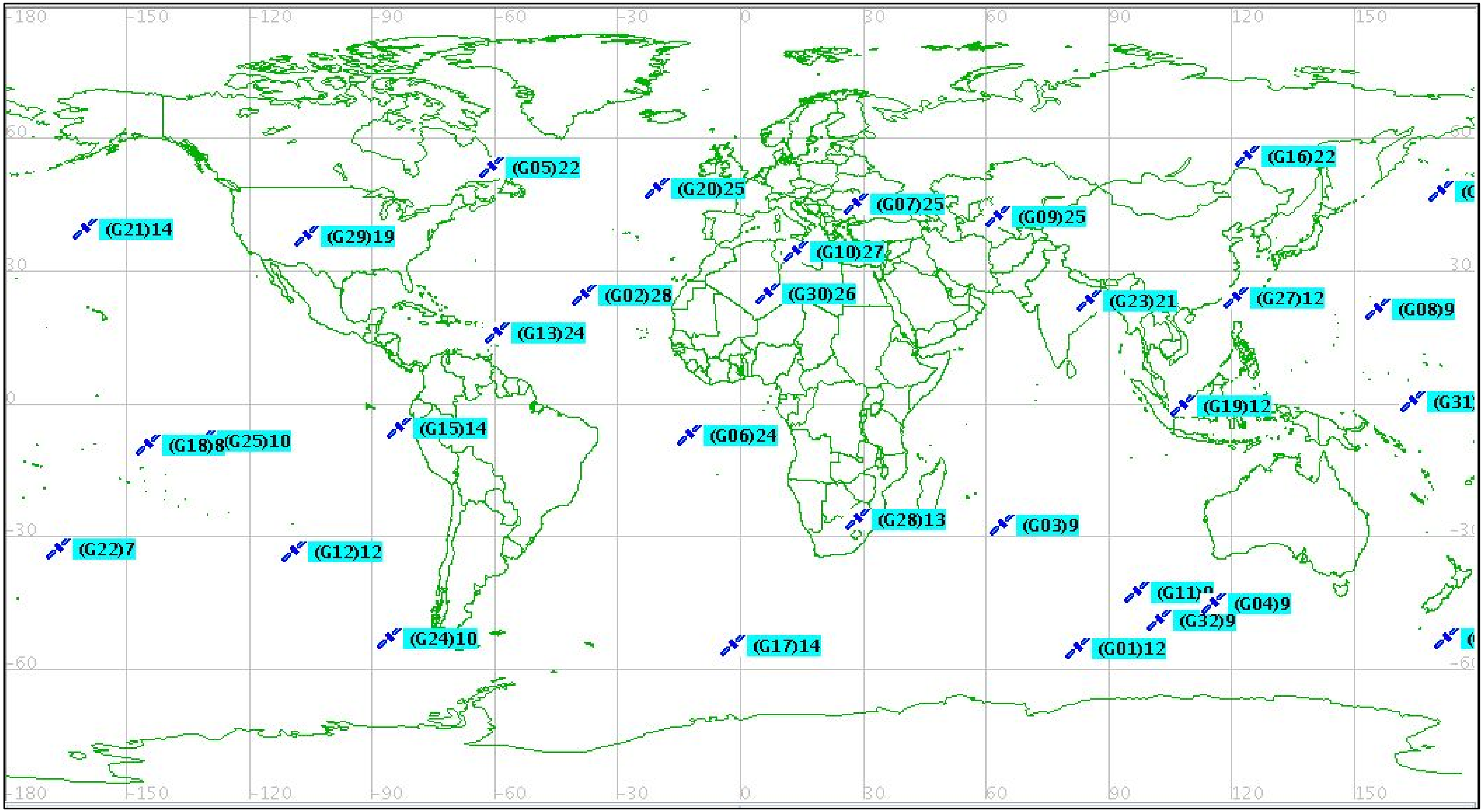
3. Evolution perspectives - overview

- For evolution of radio occultation and POD support, the ESOC Navigation Support Office can draw from expertise and new opportunities in several areas
  - Opportunities from new constellations, new frequencies and new signals
  - Additional ground stations
  - Opportunities from better hardware performance
  - <u>Synergy with other activities</u>
  - Real-time
  - Other

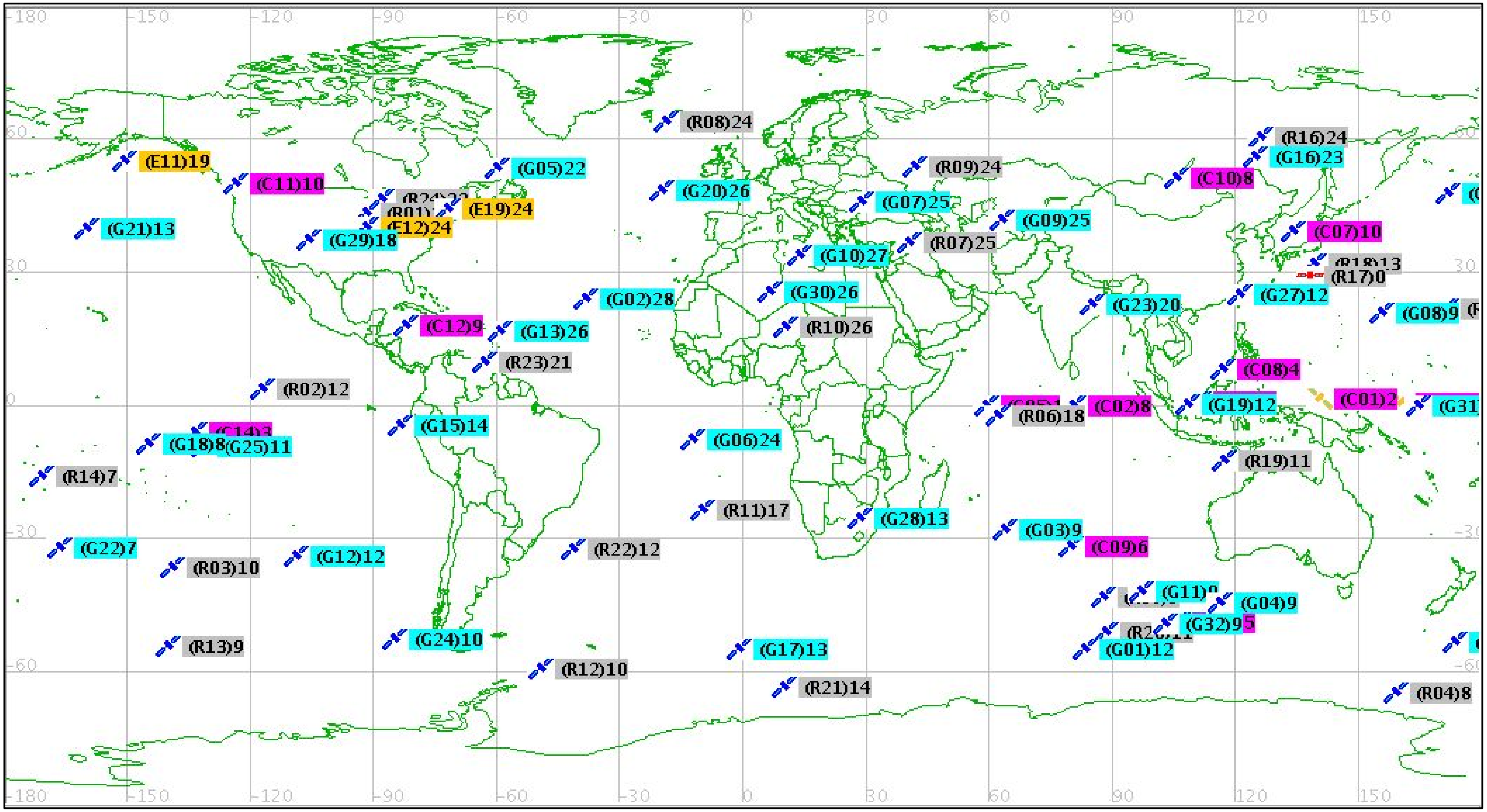
3. GPS constellation

- Majority of present LEO satellites use GPS only

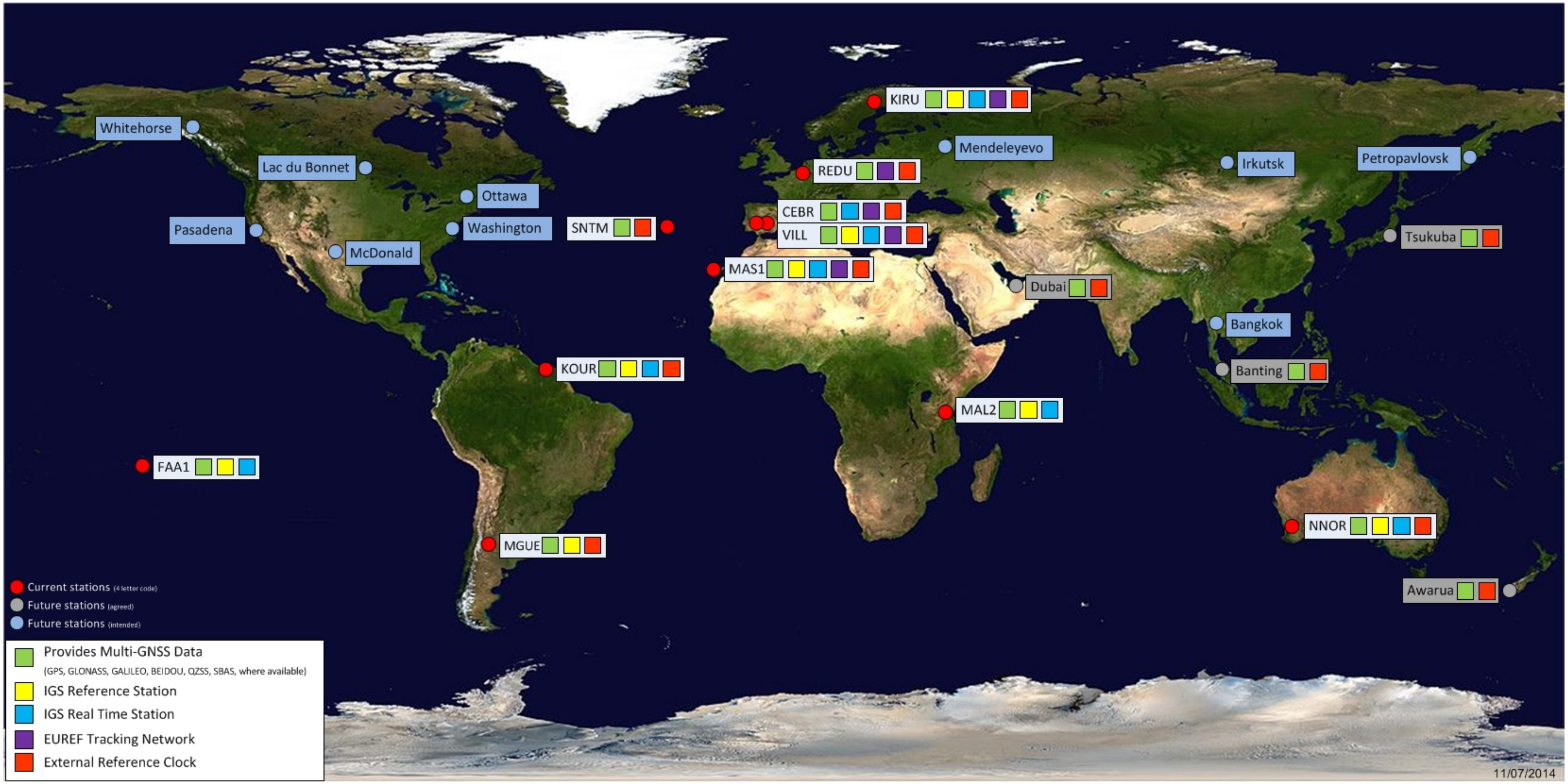


3. New constellations (still under development)

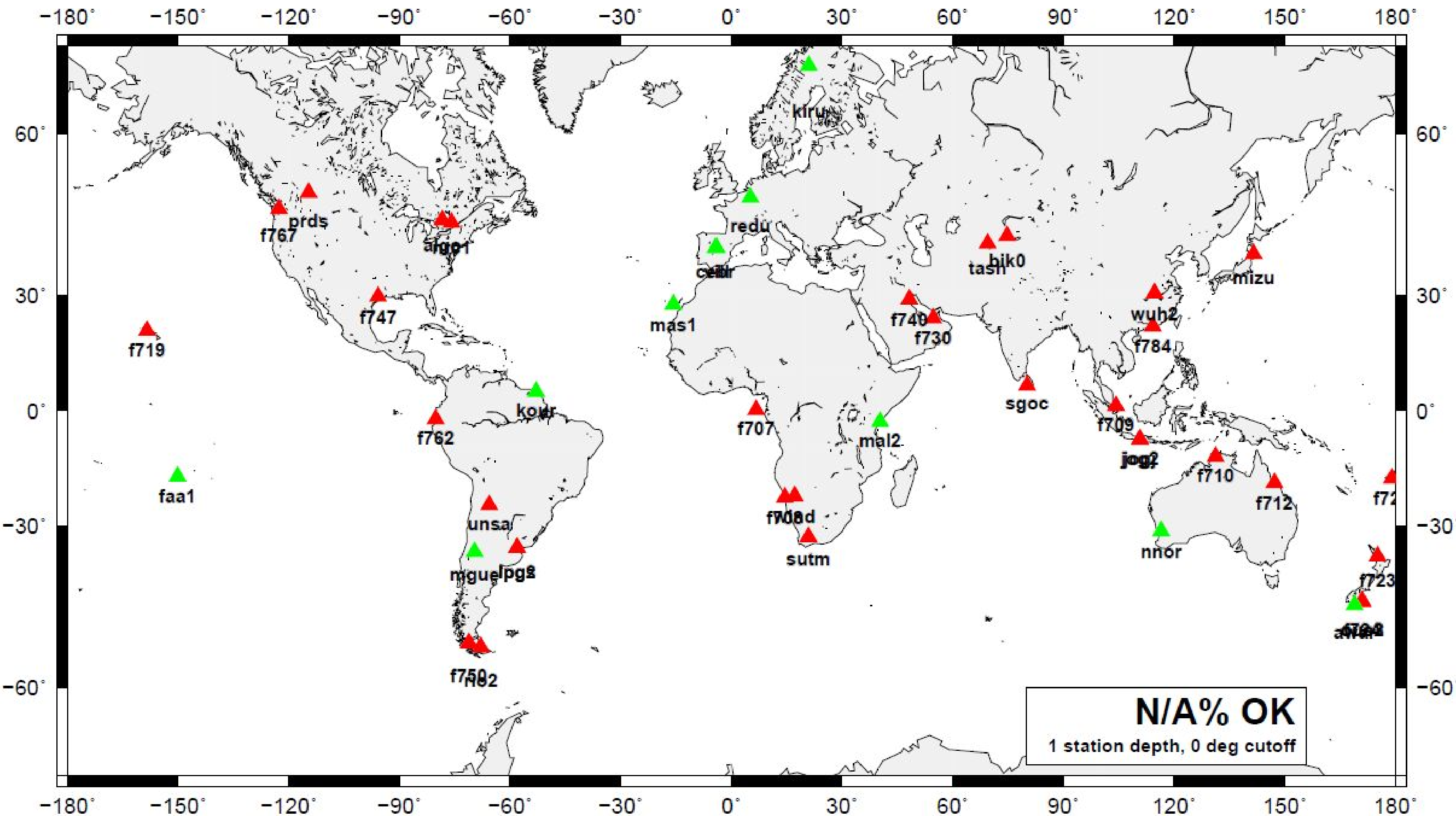
- Two full and two partial constellations available



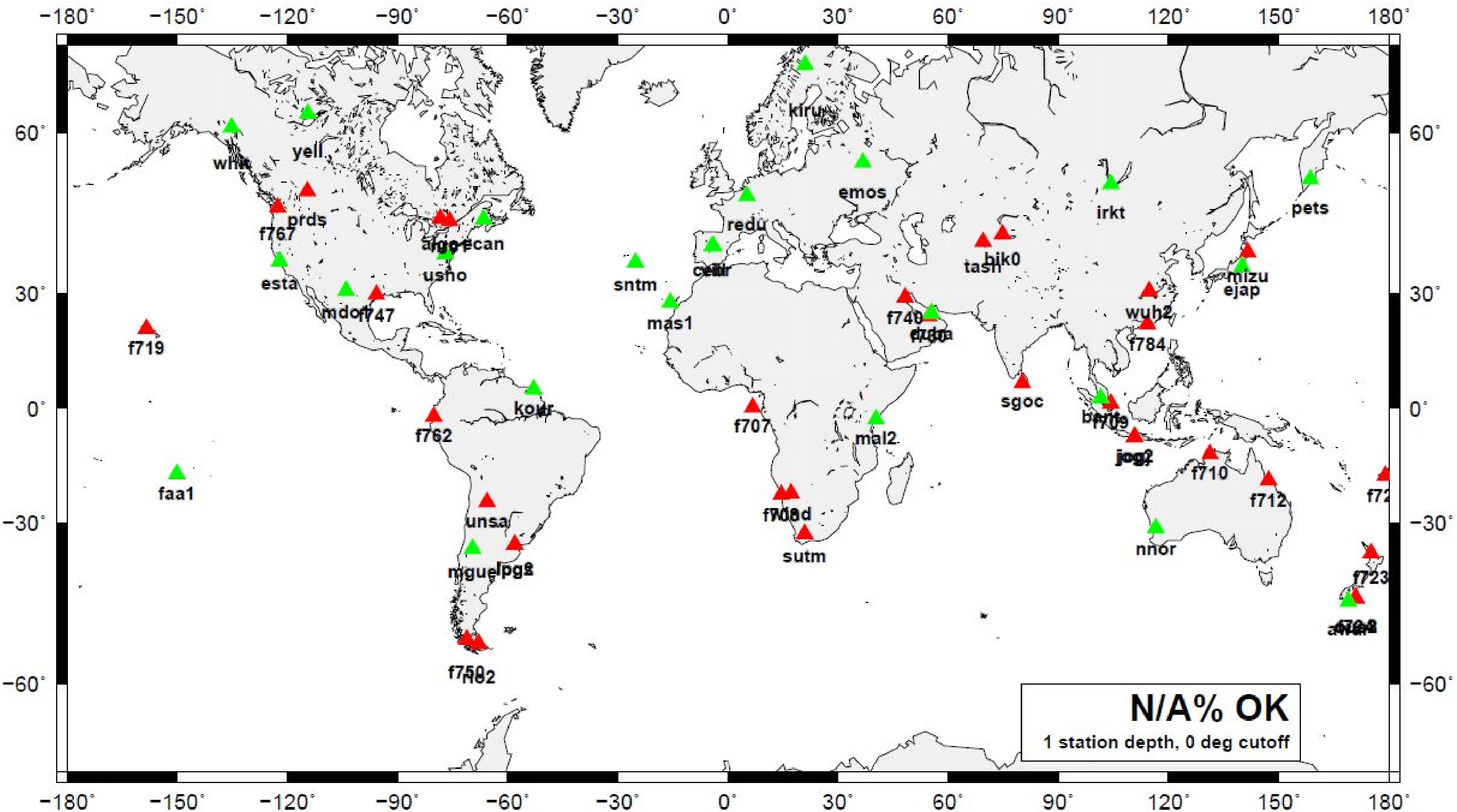
3. ESOC ground network extension



3. GSN present network



3. Extension



-180° -150° -120° -90° -60° -30° 0° 30° 60° 90° 120° 150° 180°
60° 30° 0° -30° -60°
yell
prds
f767
esta
mdo
f747
f719
faa1
usno
sntm
mas1
redu
emos
kiru
irkt
pets
mizu
ejap
wuh2
f784
f740
sgoc
f707
mal2
kour
f762
unsa
mgue
sutm
f710
f712
nnor
f723
N/A% OK
1 station depth, 0 deg cutoff

3. Faster ESOC hardware

- New hardware can process at 2-3 times the present speed
- Will allow a modified processing strategy, allowing several options (also combined):
  - Clearly improved timeliness (34 → 28 min)
    - though data retrieval remains the bottleneck [*RT]
  - Increased station network, significantly improving accuracy
    - Primarily of interest for other types of Earth Observation missions
    - Improved consistency is still a bonus

3. Synergies: general

- Several running projects of ESOC's Navigation Support Office include relevant aspects for GRAS GSN evolutions.
- Best effort projects (IGS and other international collaborations), usually concentrating on highest accuracy, support to all constellations, but not timeliness [*RT]
- Operational projects, with requirements on availability and/or timeliness, sometimes also with payment depending on Key Performance Indicators

3. Synergy: Galileo Orbit Validation Facility

- Collaboration between ESOC and other European expert centres (for orbits/clocks: GFZ and Bern University)
- Reference solutions for GPS and Galileo aiming for:
  - High availability (99%)
  - Highest accuracy
  - Weekly (‘final’) solutions
- Use of well over 100 stations for processing
- GPS solutions comparable to IGS
- Galileo solutions the best presently available anywhere (also for all new satellites)

3. Synergy: commercial service

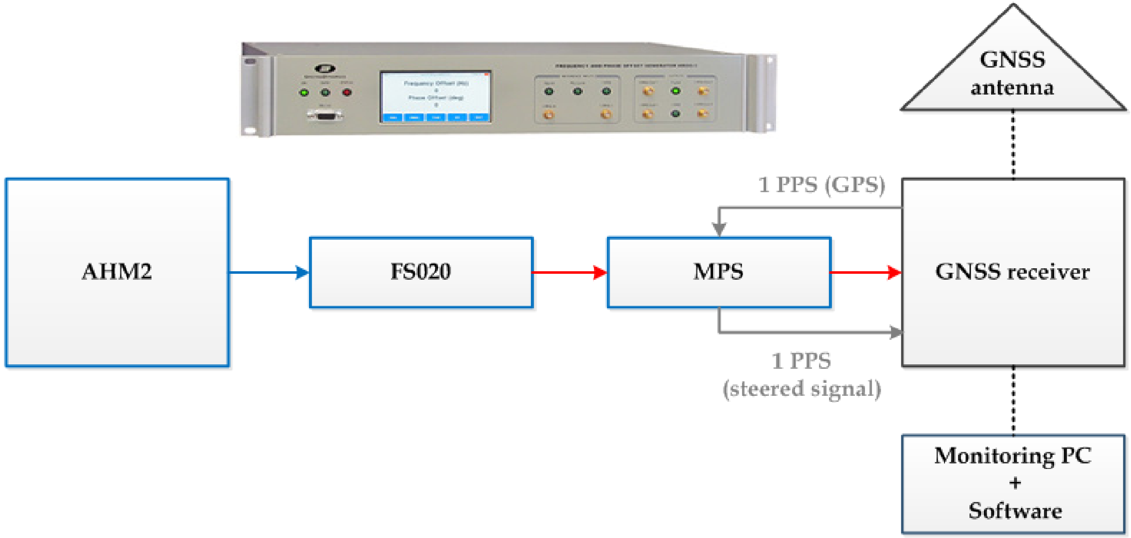
- Service of ESOC to a commercial operator
- Reliable solutions for <u>all four constellations </u>aiming for:
  - Highest accuracy
  - Real-time service [*RT]
  - High availability
- GPS and Glonass operational since many years
- Target of improving over JPL products (GPS) achieved
- Galileo available but waiting for operational nav.message
- Beidou operational since a few months

3. Real-time

- ESOC is one of the leading IGS centres in Real-Time processing (for clock solutions)
  - Partner GSN network operators equally expert.
- Timeliness gain potentially significant (15-20 min), but only if customer also has real-time capability
- Real-time clock accuracy approaching batch solutions
- ESOC Real-Time capability includes all four global constellations and also QZSS
- Software considered sufficiently robust for operational implementation, though pending data standardisation issues

3. Time reference

- ESOC is setting up an implementation of UTC(*k*)
- Hardware and processing already in place
- In future, the ESOC GNSS network and all precise orbit and clock products will be fully aligned to UTC



Acknowledgment to the teams

- ESOC team:
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Thank you for your attention