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

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and the ESOC and EUMETSAT teams
(see last slide)

2015 IROWG workshop
Melbourne, 20/04/2015
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.
1. GRAS GSN brief introduction

2. Status:
   a. Evolution history
   b. Present performance

3. Evolution perspectives
• 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.
• 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

3. SERVICE LEVEL INDICATORS

The SLI presented in this report have been adapted from [RD-1] to agree with the GSN requirements and results in the metrics usually employed. Once the definition of the new SLI is completed, [RD-1] will be adapted accordingly.

3.1 SLI for February 2016

<table>
<thead>
<tr>
<th>SLI Id</th>
<th>SLI Title</th>
<th>SLI value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLI 1</td>
<td>Completion of the GSN NRT product transmission</td>
<td>100.00 %</td>
</tr>
<tr>
<td>SLI 2</td>
<td>Timeliness of the Delivered Data for current month</td>
<td></td>
</tr>
<tr>
<td>SLI 3</td>
<td>NRT GPS Clock products delivery performance</td>
<td>100.00 %</td>
</tr>
<tr>
<td>SLI 4</td>
<td>NRT Station T2D products delivery performance</td>
<td>No T2D prod</td>
</tr>
<tr>
<td>SLI 5</td>
<td>Enhanced products generation</td>
<td>100.00 %</td>
</tr>
<tr>
<td>SLI 6</td>
<td>SSD products delivery performance</td>
<td>No SSD prod</td>
</tr>
<tr>
<td>SLI 7</td>
<td>GPS Navigation file generation</td>
<td>100.00 %</td>
</tr>
<tr>
<td>SLI 8</td>
<td>GPS Almanac file generation</td>
<td>100.00 %</td>
</tr>
<tr>
<td>SLI 9</td>
<td>Status and Configuration file delivery performance</td>
<td>100.00 %</td>
</tr>
<tr>
<td>SLI 10</td>
<td>Accuracy of the Delivered Data for current month</td>
<td></td>
</tr>
<tr>
<td>SLI 11</td>
<td>NRT GPS Position accuracy performance</td>
<td>4.08 cm</td>
</tr>
<tr>
<td>SLI 12</td>
<td>NRT GPS Velocity accuracy performance</td>
<td>0.003 mm/s</td>
</tr>
<tr>
<td>SLI 13</td>
<td>NRT GPS Clock accuracy performance</td>
<td>SIGMA 0.26</td>
</tr>
<tr>
<td>SLI 14</td>
<td>NRT Station T2D accuracy performance</td>
<td>No T2D prod</td>
</tr>
</tbody>
</table>

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’)  

<table>
<thead>
<tr>
<th>Date</th>
<th>Accuracy (cm)</th>
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<tbody>
<tr>
<td>October '14</td>
<td>3.91</td>
</tr>
<tr>
<td>November '14</td>
<td>3.43</td>
</tr>
<tr>
<td>December '14</td>
<td>5.05</td>
</tr>
<tr>
<td>January '15</td>
<td>3.59</td>
</tr>
<tr>
<td>February '15</td>
<td>4.08</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td><strong>4.05 cm</strong></td>
</tr>
</tbody>
</table>
2b. Orbit accuracy (February 2015)
## 2b. Clock accuracy (ns), RMS & Sigma

<table>
<thead>
<tr>
<th></th>
<th>Overall RMS constellation</th>
<th>Overall Sigma constellation</th>
</tr>
</thead>
<tbody>
<tr>
<td>October ’14</td>
<td>0.46</td>
<td>0.26</td>
</tr>
<tr>
<td>November ’14</td>
<td>0.43</td>
<td>0.12</td>
</tr>
<tr>
<td>December ’14</td>
<td>0.38</td>
<td>0.34</td>
</tr>
<tr>
<td>January ’15</td>
<td>0.42</td>
<td>0.13</td>
</tr>
<tr>
<td>February ’15</td>
<td>0.52</td>
<td>0.26</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td><strong>0.44 ns</strong></td>
<td><strong>0.24 ns</strong></td>
</tr>
</tbody>
</table>
2b. Clock accuracy (Feb. 2015) - Sigma

GSN near real time Satellite clock bias vs IGS rapid product

SIG clock offset [ns]

requirement
prn-01
prn-02
prn-03
prn-04
prn-05
prn-06
prn-07
prn-09
prn-10
prn-11
prn-12
prn-13
prn-14
prn-15
prn-16
prn-17
prn-18
prn-19
prn-20
prn-21
prn-22
prn-23
prn-24
prn-25
prn-27
prn-28
prn-29
prn-30
prn-31
prn-32
2b. Timeliness of clock products (min)
• 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)
1. GRAS GSN brief introduction

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3. Evolution perspectives
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
  - Synergy with other activities
  - 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
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 all four constellations 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:
  - C. Flohrer, C. García Serrano, M. van Kints, G. Läufer, I. Romero, R. Zandbergen
  - S. Chandrasekar
  - W. Enderle, E. Schönemann

- EUMETSAT team:
  - Y. Andrés, M. Burla, C. Marquardt, F. Wollenweber
Thank you for your attention