ESA Multi-GNSS Products

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08/03/2019
ESOC Navigation Support Office

- Located at the European Space Operations Centre in Darmstadt
- Providing high precision GNSS orbit and clock products since 1992:
  - IGS (GPS+GLONASS)
  - GRAS GSN
  - GGSP/OVF (+Galileo)
  - Copernicus
  - etc.
**Multi-GNSS**

- All projects push to exploit advantages of Multi-GNSS

<table>
<thead>
<tr>
<th></th>
<th>In Operation</th>
<th>In Orbit</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS</td>
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</tr>
<tr>
<td>GLO</td>
<td>24</td>
<td>26</td>
</tr>
<tr>
<td>GAL</td>
<td>22</td>
<td>26</td>
</tr>
<tr>
<td>BEI</td>
<td>33</td>
<td>38</td>
</tr>
<tr>
<td>QZS</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td><strong>114</strong></td>
<td><strong>126</strong></td>
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</table>
Multi-GNSS Efforts at ESOC

- Daily processing routine of multi-GNSS, based on IGS routine
  - Minimal-constraint 24 hours network-solution of all operational GNSS satellites
  - Started in 2005 as experiment to study characteristics of the new constellations

- Centre-piece of ongoing development work at ESOC:
  - Orbit & Clock modelling
  - Cycle Ambiguity resolution
  - Differential Code/Carrier Biases
  - L-Band signal combinations (all available signals)
  - ESA Earth Orientation Parameters (based on GNSS, VLBI, SLR and DORIS)
  - POD of Formation Flying and Constellations
  - GNSS Space Service Volume
ESA's GNSS Observation Network (EGON)

Legend:
- Operational station (23)
- Agreed future station (2)
- Planned future station (6)

- Provides Multi-GNSS data (23)
- TDS Reference station (6)
- TDS Real Time station (8)
- EURREF station (5)
- External Reference Code (14)
- ESA Deep Space station (3)

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Day-boundary orbit differences (worst case)
GALILEO Radiation Pressure Modelling
SLR Residuals with only ECOM (empirical model)

Credit: T. Springer

2016
GALILEO Radiation Pressure Modelling
SLR Residuals with Box-Wing model (physical model)

Credit: T. Springer
GALILEO Radiation Pressure Modelling
SLR Residuals with Box-Wing model (physical model, improved)

SLR Residuals
boxwing 2018

SLR Residuals
boxwing 2018
Next Generation Radiation Pressure Model
ARPA (Aerodynamics and Radiation Pressure Analysis)

- **In Testing:**
  Replacement of Box-Wing model by **Raytracing** Procedure

- Detailed information about satellite geometry and surface properties allows improved modelling of **Radiation Pressure** and **Air Drag** (LEO)

Galileo FOC.
Credit: ESA-P. Carril

Ray-Source simulating the Sun or the Earth
Credit: F. Gini
QZSS Inter-System Bias

- In 2017 the number of QZSS satellites increased from one to four.

- One receiver model is tracking QZSS with a significant ISB:
  - GPS-QZSS Inter Ambiguity Resolution not possible (anymore)
  - Alternative: QZSS-QZSS DD ~5% Improvement in orbit
BeiDou-3 Satellites Clock Bias

- **Ideal Case:**
  One Inter-System Clock Bias per Station w.r.t. GPS
  - True for Galileo
  - True for QZSS
  - (Mostly) True for BeiDou-1/-2

- BeiDou-3 Clock Biases are not aligned
  - Requires one bias per station per satellite
  - Ambiguity fixing impossible
ESOC MGNSS Final Products

- Final products with 13 – 6 days delay

<table>
<thead>
<tr>
<th>Products</th>
<th>Format</th>
<th>Ext.</th>
<th>Interval</th>
<th>Period</th>
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- Available at:
  - http://navigation-office.esa.int
  - (soon) GNSS Science Support Centre https://gssc.esa.int
Application of MGNSS solution at ESOC

- Test environment and template for ongoing and future projects, e.g.
  - Copernicus POD
  - GRSP (Galileo Reference Frame)

- Performance Monitoring for:
  - ESA’s GNSS Observation Network (EGON)
  - UTC(ESA)
  - Reference solution for external projects

- Galileo Predictions for the ILRS
- IGS-IGMA Pilot Project (International GNSS Monitoring and Assessment)