# VLBI processing at ESOC

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9th IVS General Meeting
Johannesburg | South Africa
13-19 March 2016

# Outline

- ESOC's Navigation Support Office
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- Motivation
  - Why are we interested in VLBI?
- VLBI implementation in NAPEOS
  - Current status and next steps

# ESOC's Navigation Support Office

## Who we are

**ESA**
(European Space Agency)

**ESOC**
(European Space Operations Centre)

**Ground Systems Engineering Department**

**Navigation Support Office**

**(OPS-GN)**

~25 highly-motivated engineers

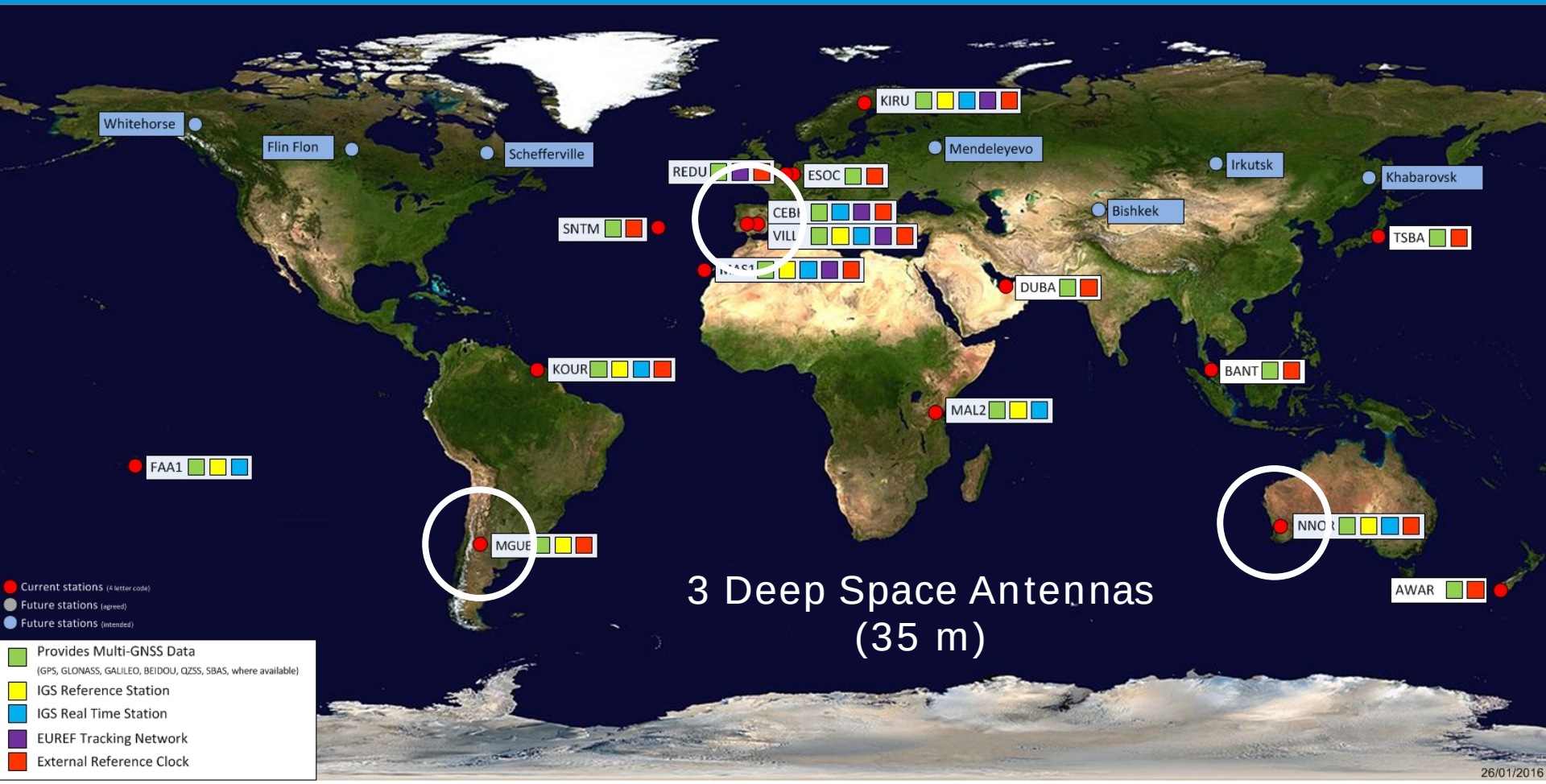
# ESOC's Navigation Support Office
## What we do

- Provision of geodetic reference for ESA missions
- Leader of the Galileo Geodetic Service Provider (GGSP) consortium
- Operation of own global GNSS sensor station network
- Precise Orbit and Clock Determination for LEOs and GNSS satellites
    - Development of state of the art models and algorithms for high-precision GNSS/SLR/DORIS/Altimetry data processing
    - Own software package: NAPEOS
      Capable of combined processing of the data from all different satellite-geodetic techniques within one single software package
- Realization of UTC (ESOC) - under development
- Contribution to Geodetic Reference Frame Realization via IGS, ILRS, IDS analysis center activities and product generation including reprocessing

Looking forward to participating in the IVS!

# ESA's GNSS Sensor Station Network

## operated by the Navigation Support Office



# Motivation
## Why are we interested in VLBI?

Enhancing the processing capabilities of NAPEOS for VLBI tracking data will allow us to …

- complete ESOC's capabilities in generating independent EOPs
    - get independent of external services to ensure the operational capability of ESOC
- enhance our contribution to the IERS service with UT1-UTC and nutation products
- contribute to the IVS service as analysis centre
- enable NAPEOS to combine all space-geodetic techniques at the observation level

# Motivation
## The missing elements …

| | Parameter | GNSS | SLR | DORIS | VLBI |
|---|---|---|---|---|---|
| CRF | Quasar positions | | | | x |
| | Satellite orbits | x | x | x | |
| EOP | Nutation | | | | x |
| | UT1-UTC | | | | x |
| | LOD | x | x | x | x |
| | Polar motion | x | x | x | x |
| TRF | Station positions | x | x | x | x |

# VLBI implementation in NAPEOS

| NAPEOS implementation steps | Status |
|---|---|
| • Read observations from NGS card format | ☺ |
| • Set up database for source and site coordinates | ☺ |
| • Set up new observation type “VLBI group delay” | ☺ |
| • Set up observation equation | ☺ |
| • Apply observation corrections | 😐 |
| • Compute partial derivatives to enable parameter estimation | 😐 |
| • Enable combination at observation level (e.g. for troposphere, station coordinates, clocks) | 😐 |
| • Apply observation weighting when combining different observation types | 😐 |

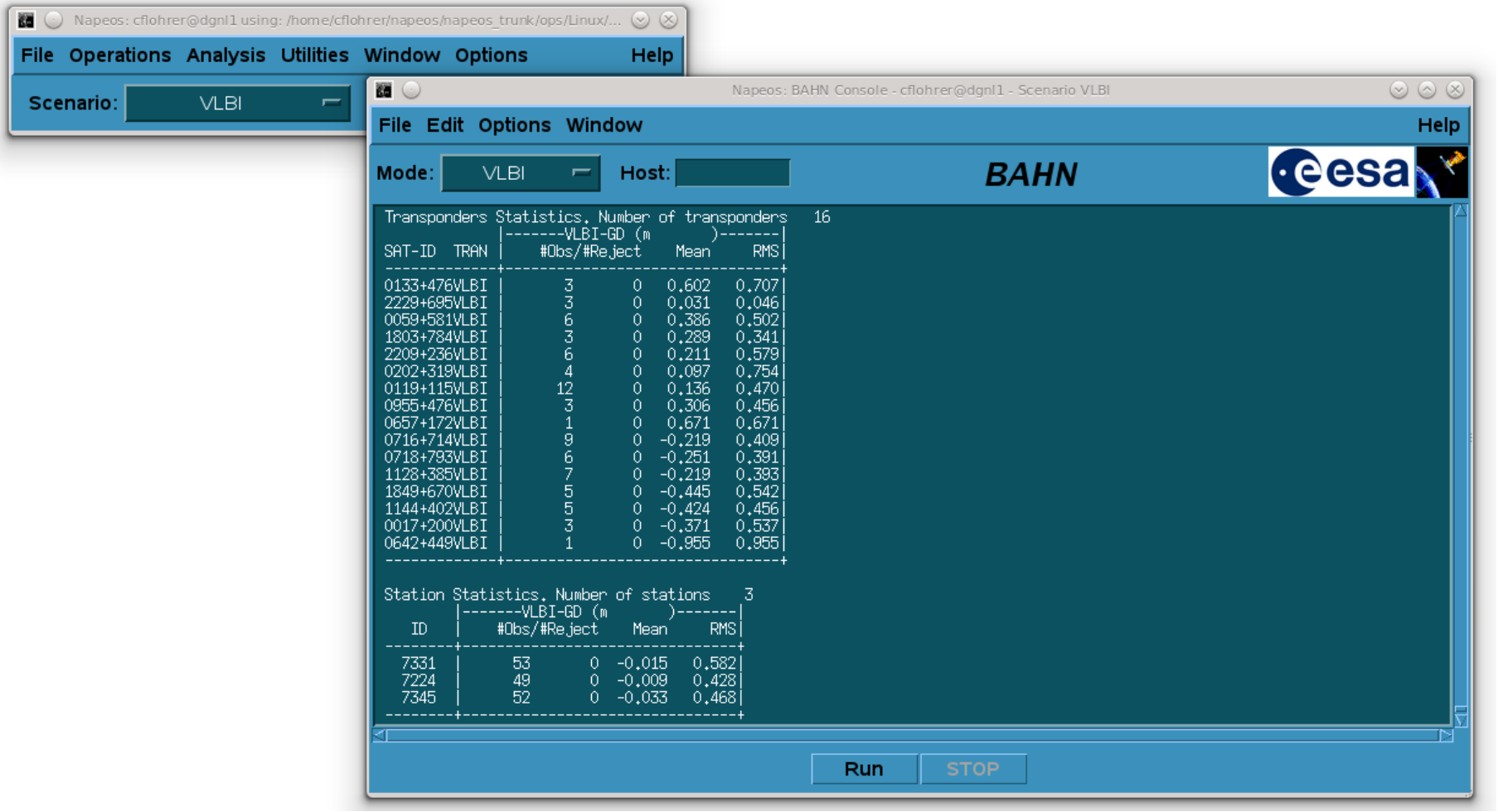
# VLBI implementation in NAPEOS
## Observation corrections

$$\tau_0 = \tau_g + \tau_{rel} + \tau_{clk} + \tau_{trp} + \tau_{ion} + \tau_{inst}$$

| Observation corrections | Maximum order of magnitude | Status |
|---|---|---|
| • Geometric delay | Earth radius | ☺ |
| • Relativistic corrections | 1000 m | 😐 |
| • Clock synchronisation (offset w.r.t. reference clock) | Several km | ☺ |
| • Tropospheric delay | 10 m | ☺ |
| • Ionospheric delay (X-band) | 2 m | ☺ |
| • Instrumental delay (axis offset) | 1 m | ☹ |

# VLBI implementation in NAPEOS

## Initial results: O-C residuals (m)



# VLBI implementation in NAPEOS

## Parameter estimation + combination + observation weighting

$$w_{code} \neq w_{phase} \neq w_{slr} \neq w_{doris} \neq w_{vlbi}$$

| | Parameter | GNSS | SLR | DORIS | VLBI |
|---|---|---|---|---|---|
| CRF | Quasar positions | | | | (x) |
| | Satellite orbits | x | x | x | |
| EOP | Nutation | | | | x |
| | UT1-UTC | | | | x |
| | LOD | x | x | x | x |
| | Polar motion | x | x | x | x |
| TRF | Station positions | x | x | x | x |

$w(\mathrm{el})$

# VLBI implementation in NAPEOS

## Status and next steps

**2015**

- Kick-off to enhance NAPEOS for VLBI
- Contact TU Vienna → first hands on experience using VieVS
- First implementation steps in NAPEOS → VieVS used for validation of observation model and for debugging!


**NOW**

- O-C residuals at the 0.5 m level
  - without taking into account axis offsets
  - with clock offsets only
  - with troposphere model only, no troposphere parameters

**2016**

- Complete implementation of observation corrections
- Implementation of VLBI parameter estimation
- Comparison of results with other groups

**2017**

- Combination of VLBI with GNSS and SLR
- Active participation in the IVS

# VLBI in NAPEOS under construction!

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