

VLBI processing at ESOC

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- ESOC's Navigation Support Office
Introducing our office
- 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

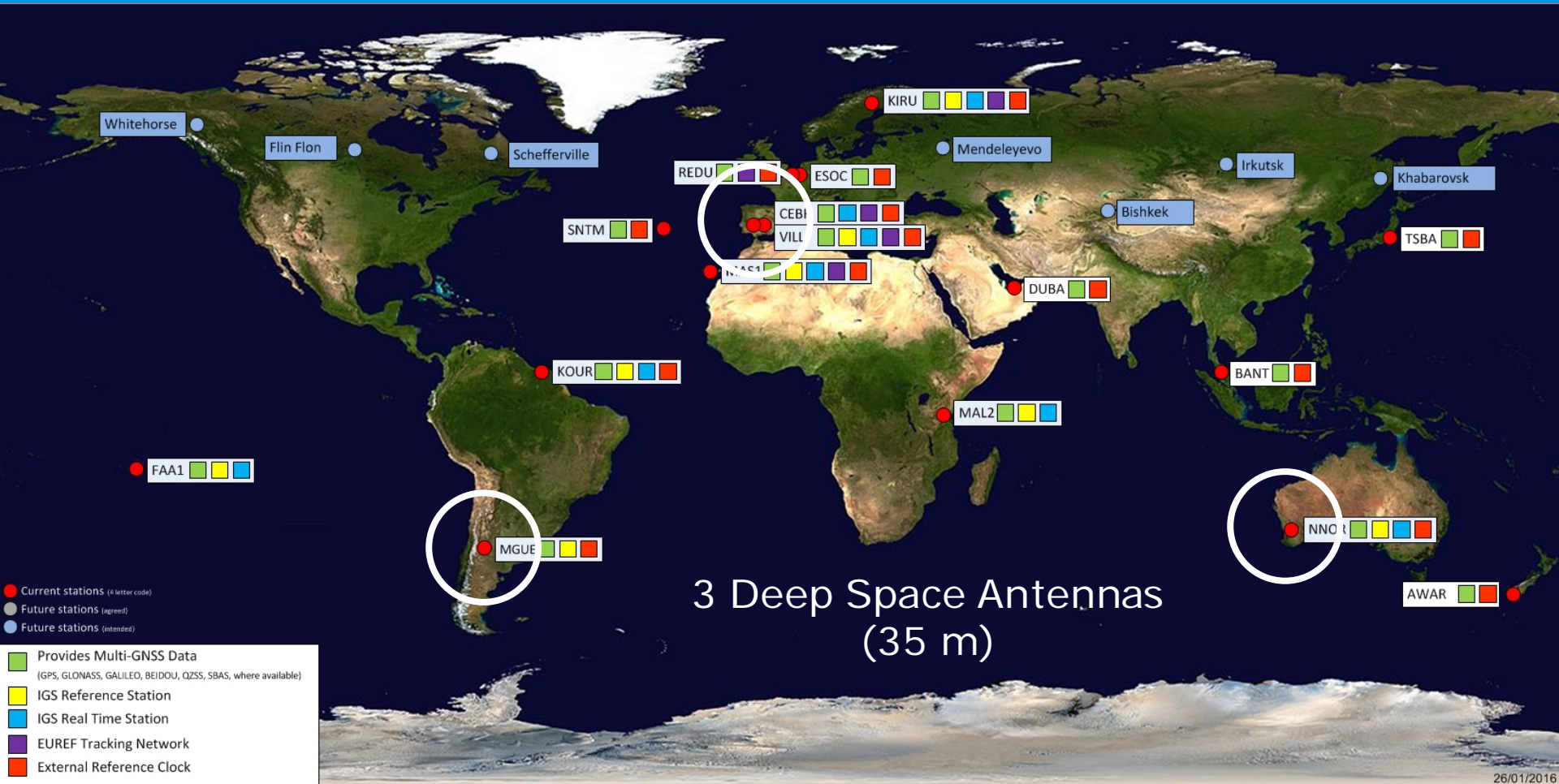


- Provision of [geodetic reference](#) for ESA missions
- Leader of the [Galileo Geodetic Service Provider \(GGSP\)](#) consortium
- Operation of own global [GNSS sensor station network](#)
- [Precise Orbit and Clock Determination](#) for LEOs and GNSS satellites
 - Development of [state of the art models 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



3 Deep Space Antennas
(35 m)

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

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)



The screenshot shows the NAPEOS VLBI console interface. The main window displays the following data:

Mode: VLBI Host: [redacted] **BAHN**

Transponders Statistics, Number of transponders 16

SAT-ID	TRAN	#Obs/#Reject	Mean	RMS
0133+476VLBI		3 0	0,602	0,707
2229+695VLBI		3 0	0,031	0,046
0059+581VLBI		6 0	0,386	0,502
1803+784VLBI		3 0	0,289	0,341
2209+236VLBI		6 0	0,211	0,579
0202+319VLBI		4 0	0,097	0,754
0119+115VLBI		12 0	0,136	0,470
0955+476VLBI		3 0	0,306	0,456
0657+172VLBI		1 0	0,671	0,671
0716+714VLBI		9 0	-0,219	0,409
0718+793VLBI		6 0	-0,251	0,391
1128+385VLBI		7 0	-0,219	0,393
1849+670VLBI		5 0	-0,445	0,542
1144+402VLBI		5 0	-0,424	0,456
0017+200VLBI		3 0	-0,371	0,537
0642+449VLBI		1 0	-0,955	0,955

Station Statistics, Number of stations 3

ID	#Obs/#Reject	Mean	RMS
7331	53 0	-0,015	0,582
7224	49 0	-0,009	0,428
7345	52 0	-0,033	0,468

Buttons: Run STOP

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	$w(eI)$
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

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

A large radio telescope dish is being lowered into place by a yellow crane. The dish is a complex metal lattice structure. The background is a clear blue sky. The crane is positioned to the right of the dish, and several cables are visible supporting the structure.

**VLBI in NAPEOS
under construction!**

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