



Technische
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GBAS Interoperability Trials and Multi-Constellation/Multi-Frequency Ground Mockup Evaluation

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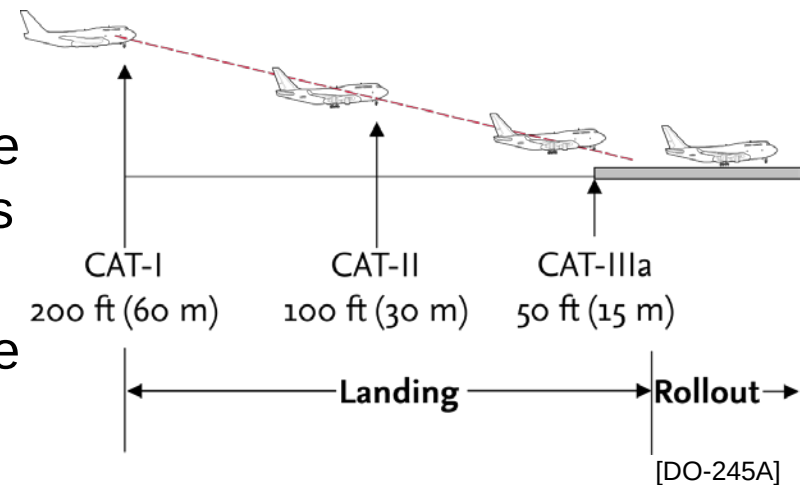
Introduction

- Trials conducted within SESAR 15.3.7: Multi-Constellation / Multi-Frequency GBAS
 - GBAS mockup at Toulouse airport
 - DGAC / DSNA
 - Interoperability GBAS flights
- Cooperation with
 - Electronic Navigation Research Institute (ENRI, Japan)
 - EUROCONTROL
 - DGAC / DSNA

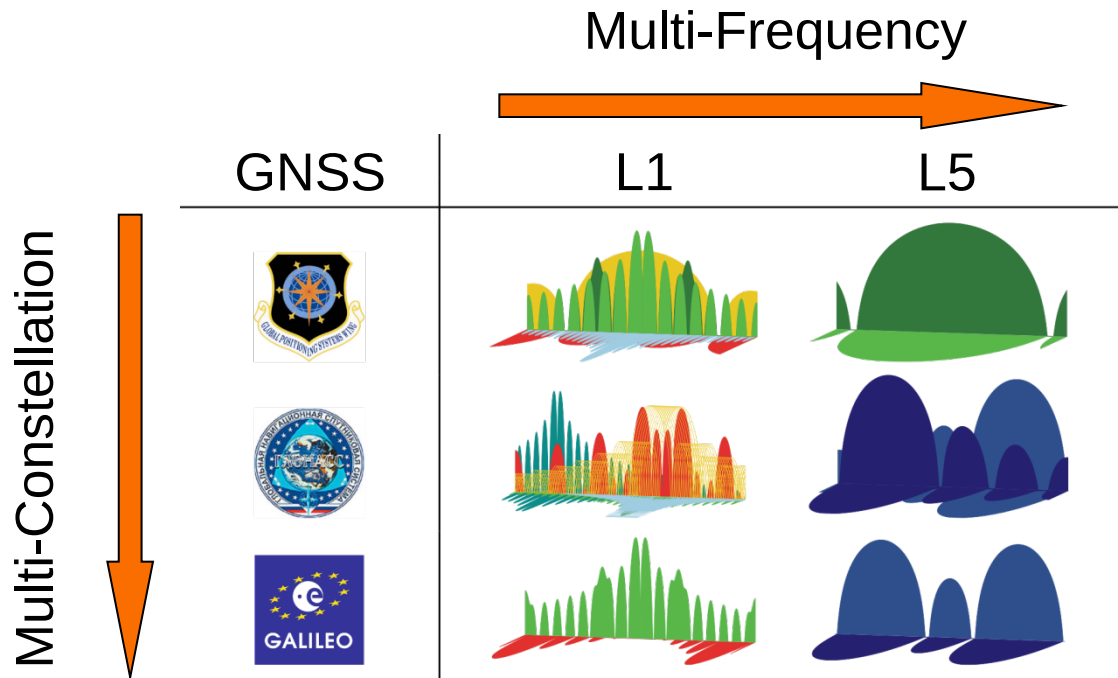


The Ground Based Augmentation System (GBAS)

- Ground Based Augmentation System (GBAS)
 - Precision approaches using differential satellite navigation
 - Ground facility broadcasts information to approaching aircraft
- Different GBAS precision approach services
 - GAST-C: approach service to enable CAT-I precision approach operations (certified and in operation)
 - GAST-D: approach service to enable CAT-II/III precision approach operations (standards finalized, not approved yet)



Future GBAS



- Multi-Constellation GBAS

- More usable satellites

- Multi-Frequency GBAS

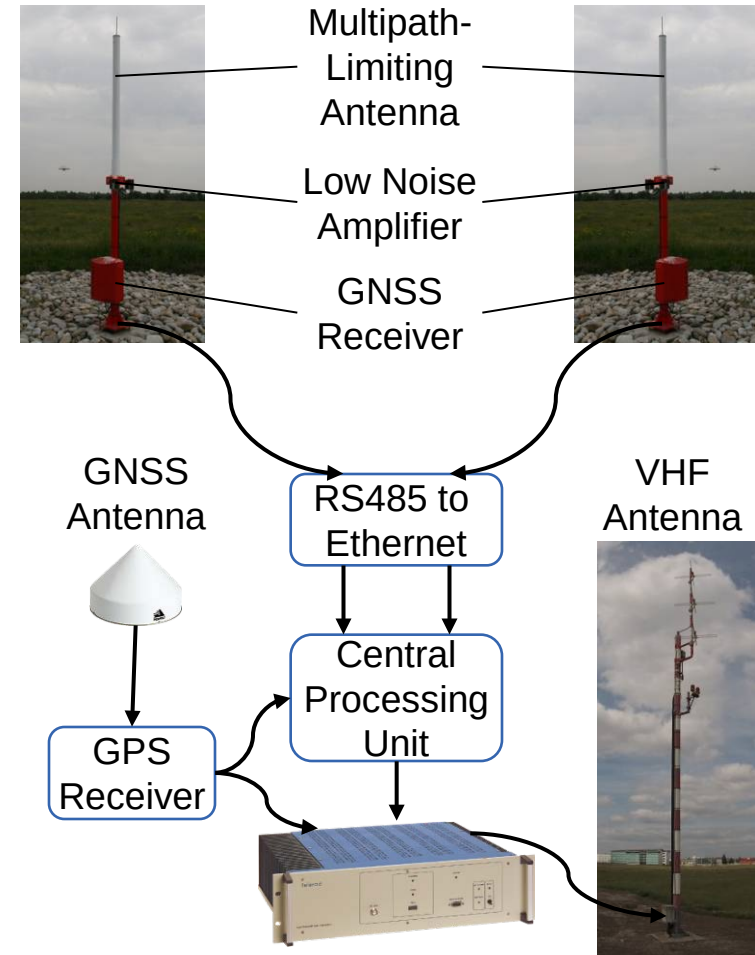
- Mitigation of most ionospheric errors

- Challenge: Backwards compatibility

- VDB data link with limited capacity
- Additional messages for new services
- Seamless integration of legacy GAST-C equipment

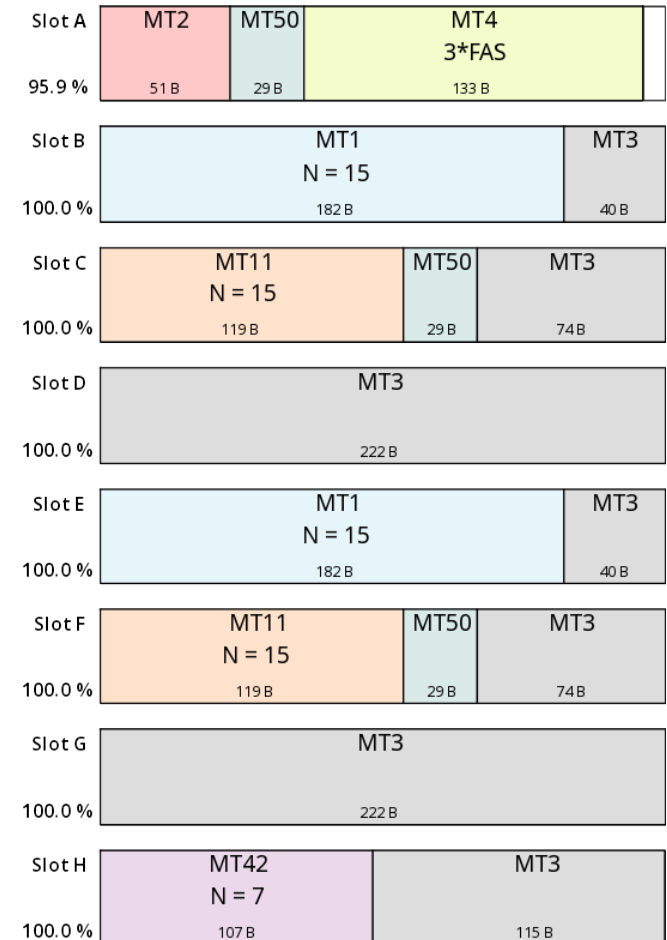
Experimental Setup in Toulouse

- Experimental GBAS ground installation at Toulouse airport
 - Collaboration of Eurocontrol, DSNA, Thales
 - TU Braunschweig as subcontractor to Eurocontrol
- Combination of existing and additional equipment



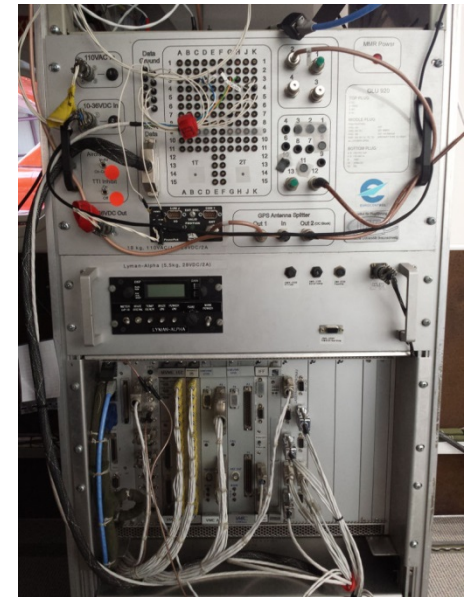
VDB Transmission

- Different transmission schemes configurable
 - All messages for GAST-C and GAST-D operation (MT1, MT2, MT4, MT11, MT3)
 - Additional messages for Multi-Frequency GBAS (MT42, MT50)
 - GPS and Galileo
- Shown example
 - Dual VDB transmit antennas
 - 8 slots per frame assigned
 - 15 L1 corrections (MT1, MT11)
 - 7 L5 corrections (MT42)



Airborne GBAS Setup

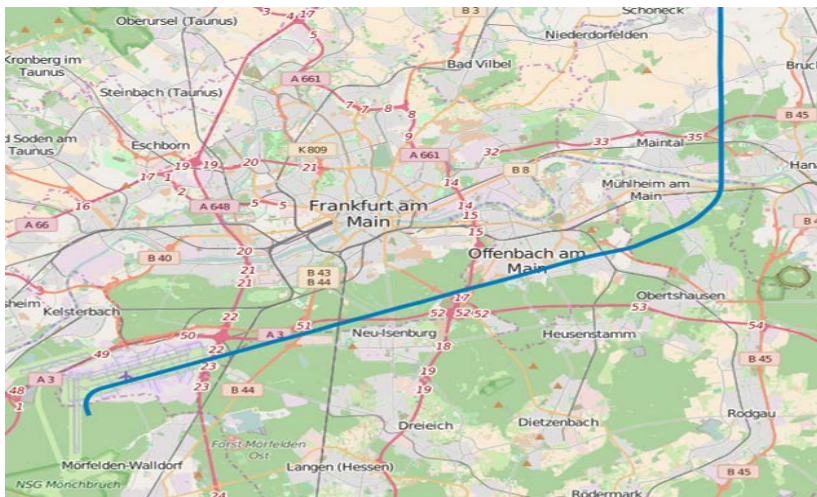
- Research aircraft D-IBUF
 - Dornier 128-6 with research equipment for GBAS flight trials
 - Rockwell-Collins GLU-925 (MMR)
 - Thales TLS-2060 (prototype MMR)
 - Javad Delta (GNSS receiver)
 - Telerad RE-9009A (VDB receiver)
- Experimental software
 - ENRI (GAST-D)
 - TU Braunschweig (GAST-F)
 - EUROCONTROL (Pegasus, GAST-F)



Flight Trials in Germany

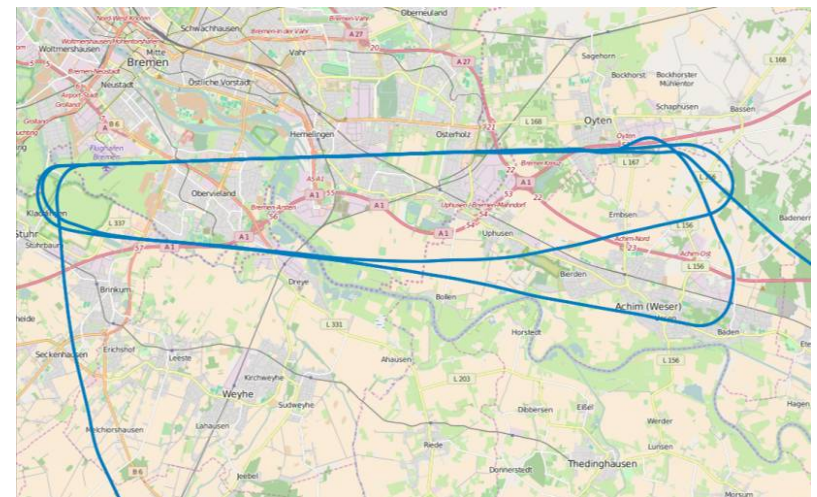
Frankfurt (EDDF / FRA)

- 1 approach, runway 25 L
- Experimental SESAR GAST-D prototype by IndraNavia
- Two VDB transmitters



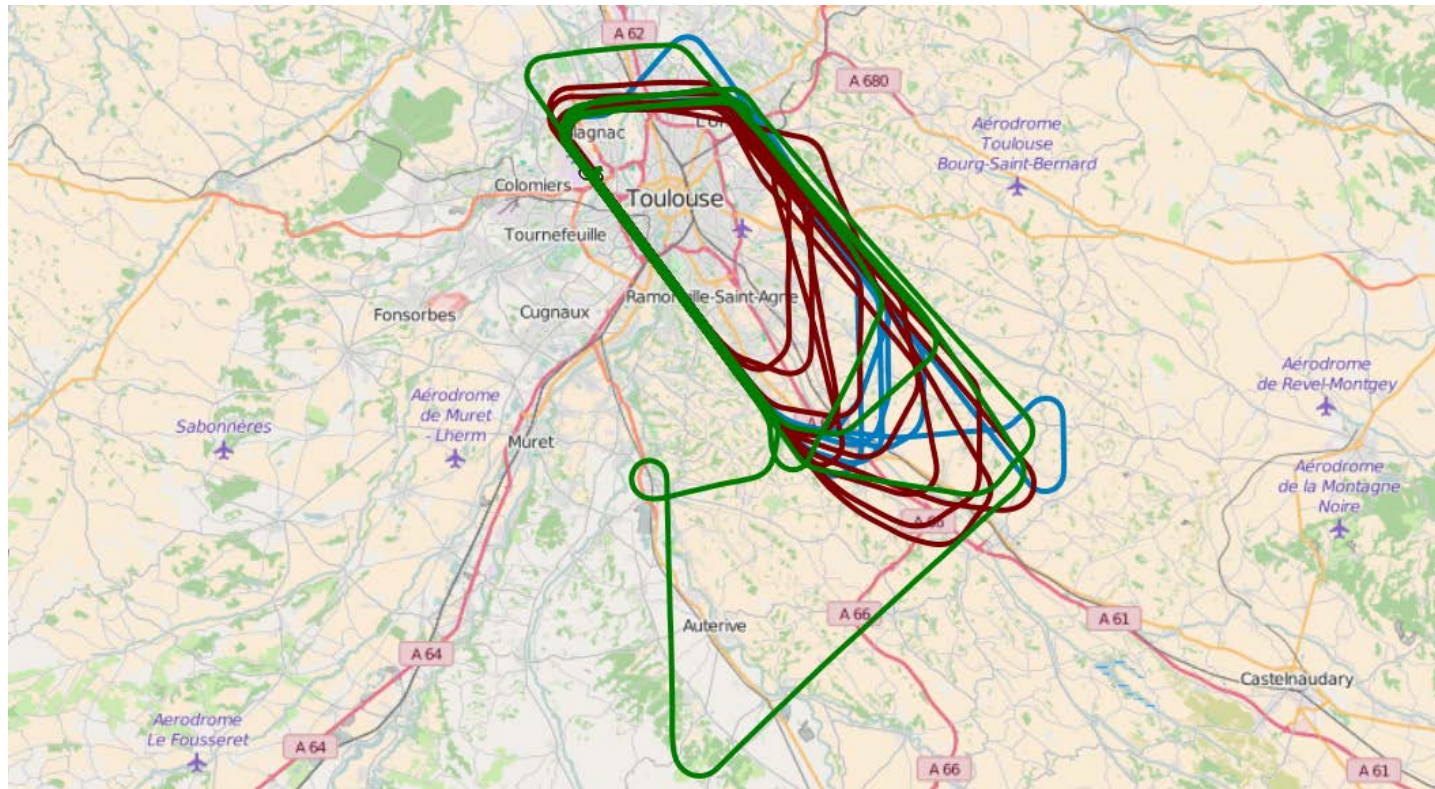
Bremen (EDDW, BRE)

- 3 approaches, runway 27
- Operationally approved GAST-C installation by Honeywell



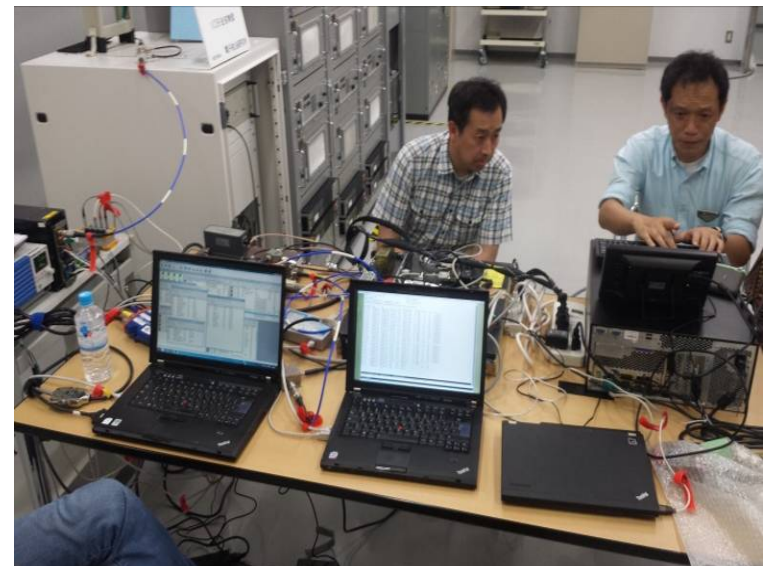
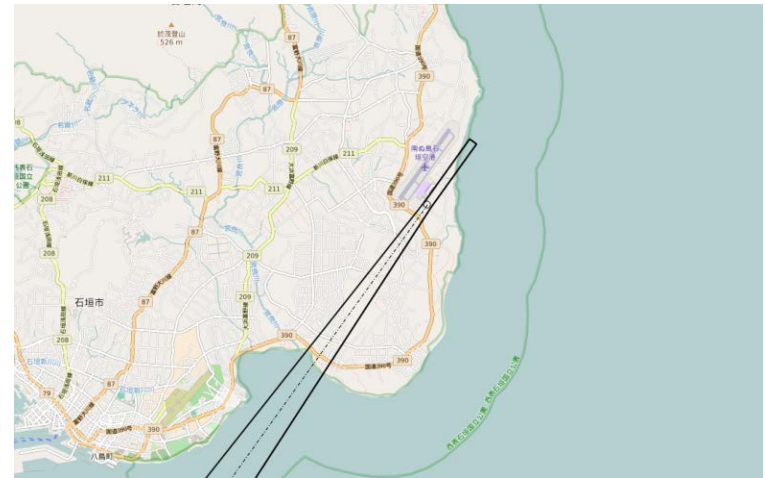
Flight Trials in Toulouse

- 32 approaches in three flights
 - Runways 32L and 32R
 - Experimental MC/MF GBAS mockup



Static Trials in Japan

- New Ishigaki Airport (ROIG / ISG)
 - Low magnetic latitude location, possibility of plasma bubbles
 - GAST-D prototype ground facility by ENRI and NEC
 - Additional virtual approach for testing
- Equipment tested within JCAB radar station
 - Thales GAST-D MMR prototype
 - Telerad VDB receiver
 - Javad GNSS receiver



Tested GBAS Ground Facilities and Receivers

	TLS-2060 MMR	GLU-925 MMR	ENRI software	TU-BS software
Honeywell (GAST-C)	Bremen	Bremen	Bremen	Bremen
Thales (GAST-C)	Braunschweig	Braunschweig	Braunschweig	Braunschweig
IndraNavia (GAST-D)	Frankfurt	Frankfurt	Frankfurt	Frankfurt
Thales (GAST-D)	Braunschweig	Braunschweig	Braunschweig	Braunschweig
TU-BS (GAST-F)	Toulouse, Braunschweig	Toulouse, Braunschweig	Toulouse, Braunschweig	Toulouse, Braunschweig
ENRI / NEC (GAST-D)	Ishigaki	– *)	Ishigaki	Ishigaki

*) : already tested during previous flight trials

Results of GBAS Ground Facility Mockup

- Simulation of different ground facility configurations
 - Single and dual VDB transmit antenna
 - Use of L5 navigation data (GPS CNAV, Galileo F/NAV) or L1 navigation data (GPS LNAV, Galileo I/NAV) for L5 corrections
- Broadcast VDB signal-in-space according to proposal
 - VDB signal usable by all implementations
 - Sufficient VDB capacity even for dual VDB scenario
- Challenges
 - Differences between L1 and L5 navigation data
 - High update rate of Galileo navigation data (10 minutes)

Example: Approach in Toulouse

- Single visual approach at runway 32R

- Flown manually
- Established on Localizer: 11 nm
- Established on glide path: 8 nm

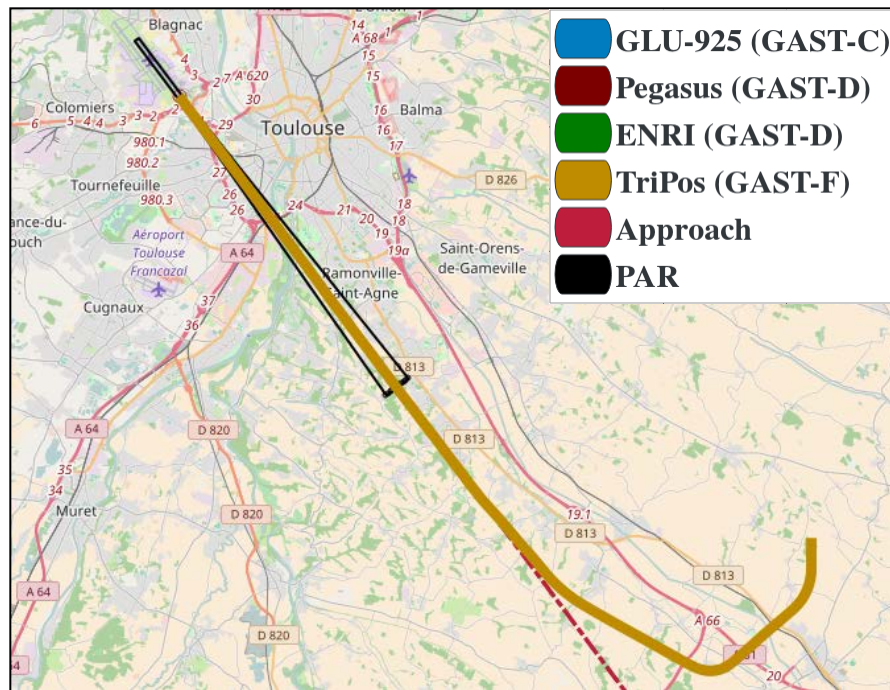


- Comparison of different GBAS solutions

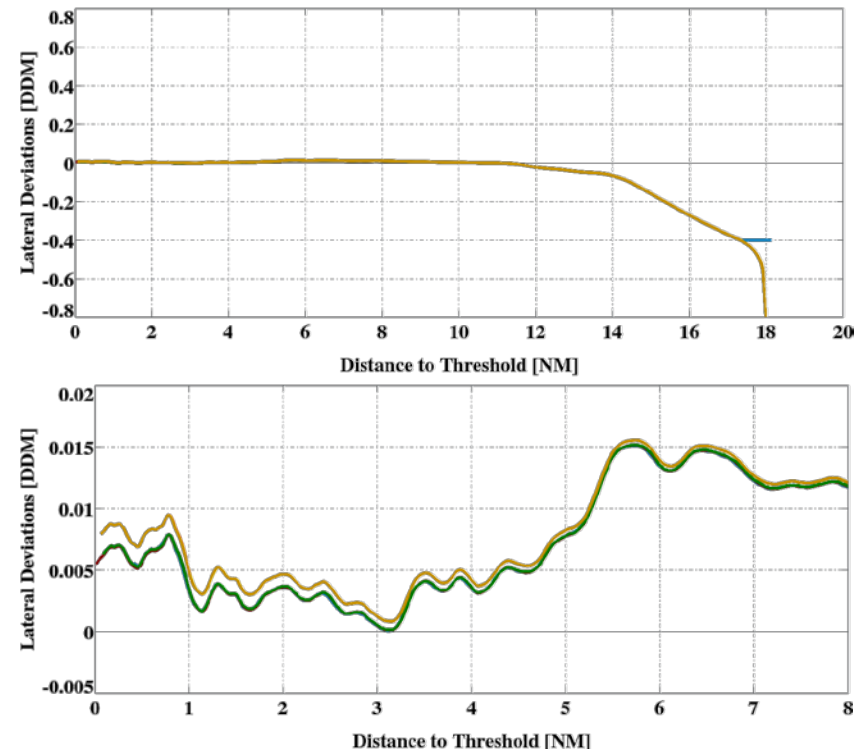
- Rockwell-Collins GLU-925 (GAST-C MMR)
- EUROCONTROL Pegasus (GAST-D software)
- ENRI (GAST-D software)
- TU Braunschweig TriPos (GAST-F software)

Flight Test Results from Toulouse – Lateral Guidance

- Lateral trajectory
 - Black: Precision Approach Region (PAR)
 - Red: FAS path

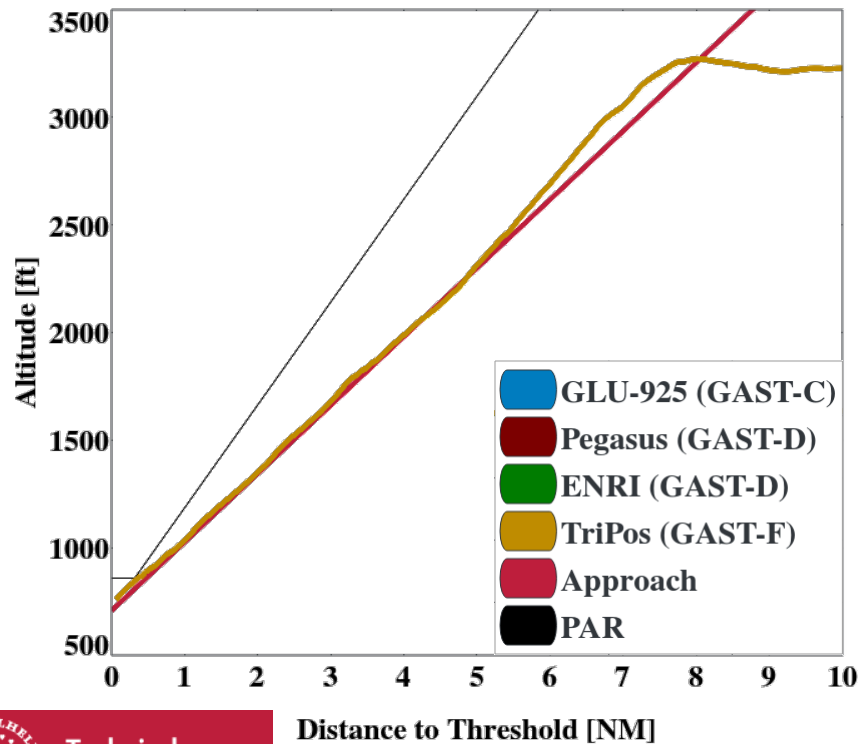


- Angular deviations
 - Plotted over distance to threshold
 - Overview & detailed view

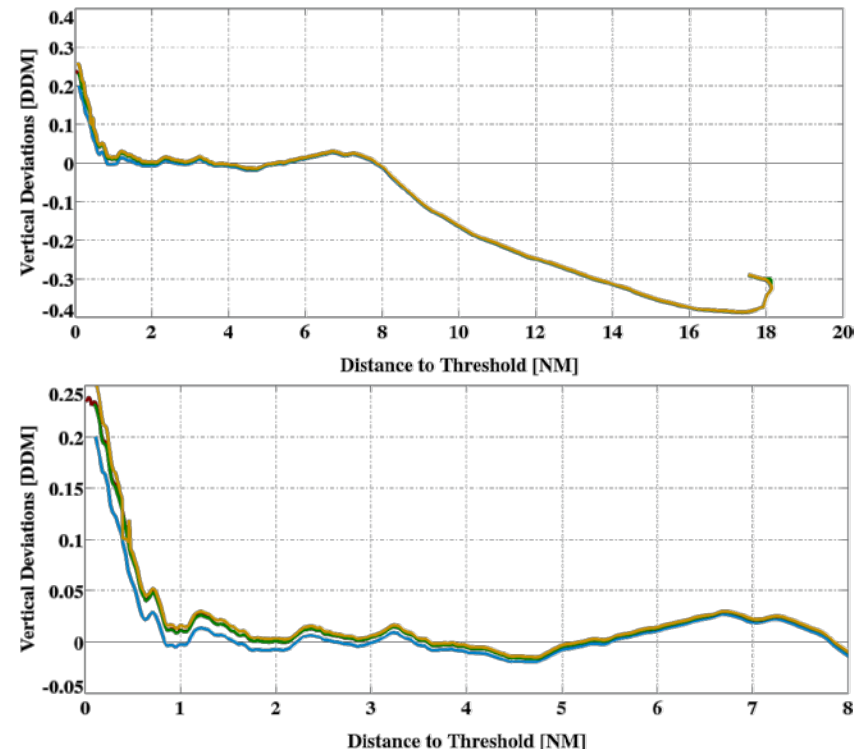


Flight Test Results from Toulouse – Vertical Guidance

- Vertical trajectory
 - Black: Precision Approach Region (PAR)
 - Red: FAS path



- Angular deviations
 - Plotted over distance to threshold
 - Overview & detailed view



Flight Test Results from Toulouse – Summary

- Continuous GBAS solutions for all receivers
 - Consistent lateral and vertical deviations
 - Backwards compatibility
- Minor differences only
 - Different receivers / antennas
 - Lever arm corrections
 - Different number of satellites used
 - GAST-F processing algorithms not finalized
- Successful validation of backwards compatibility and feasibility of GAST-F processing!

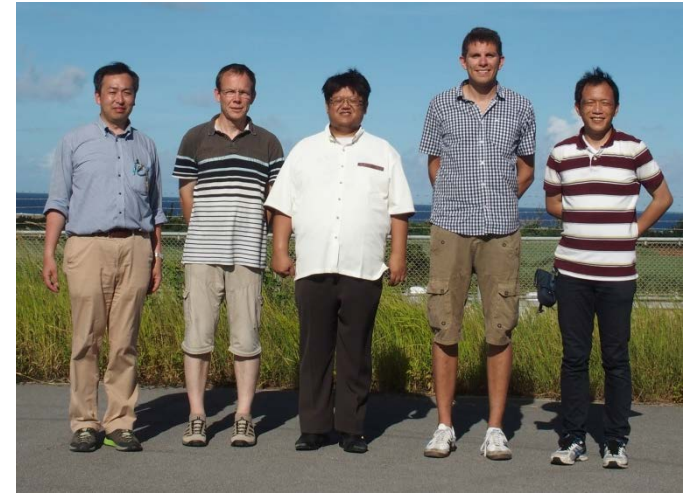
- ENRI GAST-D software used during flight trials
 - Real-time processing with live display
 - Seamless GAST-C/D operation with all GBAS ground stations
 - Results in close agreement with other implementations
- European GBAS receivers tested with Japanese GBAS ground station prototype
 - Flawless operation of Thales GAST-D MMR prototype
 - Correct switching between different approaches
 - Smooth GBAS calculations with software solutions
- Compatibility with independent Japanese developments!

Summary

- GBAS Mockup Datalink Facility (GMDF)
 - Generation of GAST-F broadcast in Toulouse
 - Usable signal for flight tests, first MC/MF GBAS flights!
- GBAS Interoperability Validation Flights (GIVF)
 - Successful test of the interoperability of independent GBAS implementations
 - GAST-C, GAST-D and GAST-F solutions in good agreement
- Very successful international cooperation
 - Short notice planning and close collaboration on technical level
 - Combination of the strengths of all partners

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Thank you very much!



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