Experimental HMI Integration for Flight Tests

German Aerospace Center (DLR)

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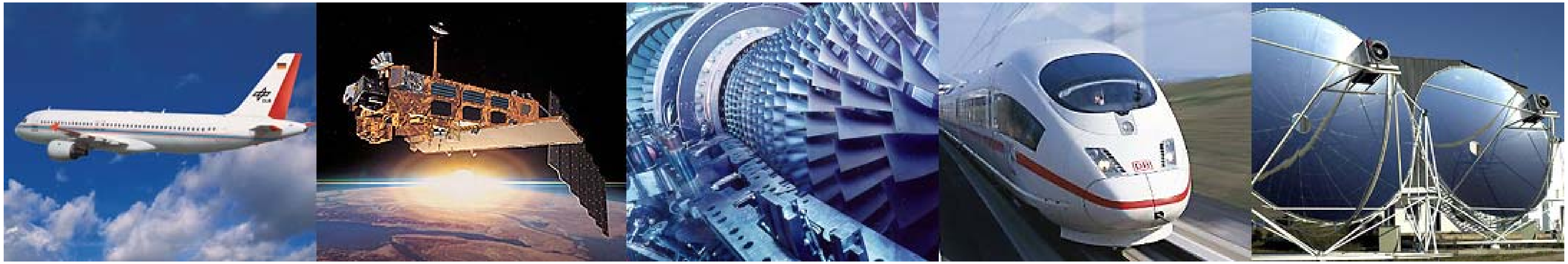
DLR – German Aerospace Center
Introduction



- Research Institution
    - Aeronautics, Space, Transport, Energy, Security
- Space Agency
- Project Management Agency

DLR

Locations and Employees

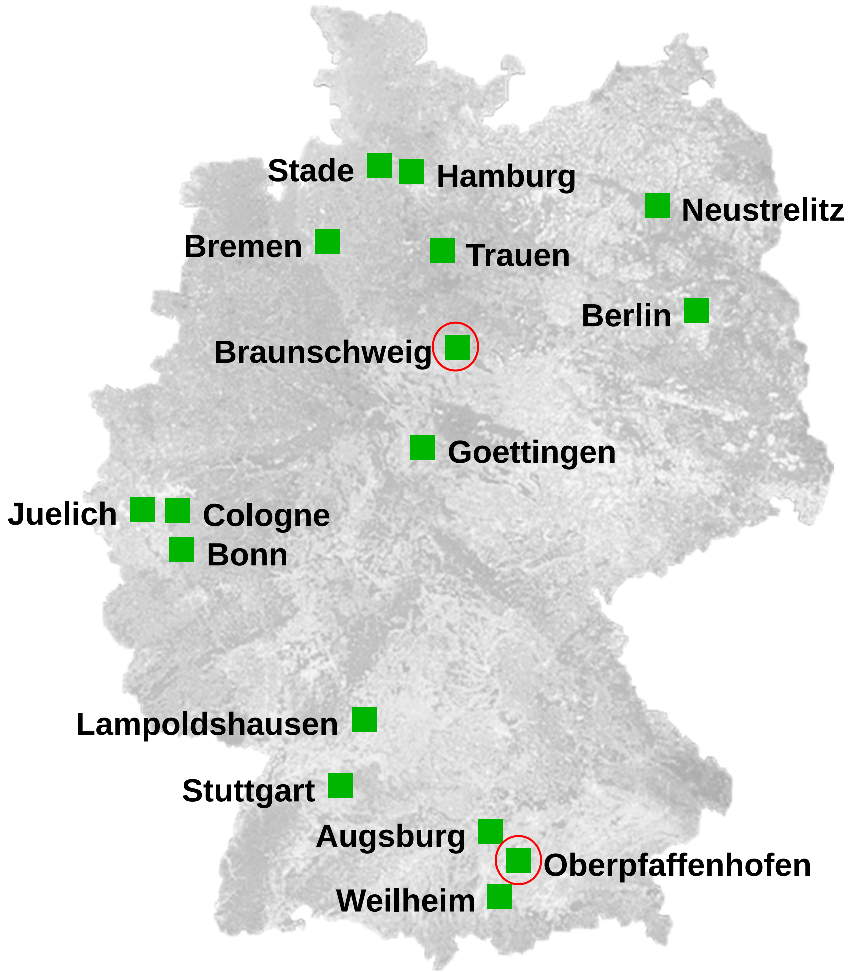
- Almost 8000 employees across 34 institutes and facilities at
  ■18 sites

- Offices in Brussels, Paris and Washington

- Flight operation department at 2 locations

- Oberpfaffenhofen: atmospheric research and instrumented earth observation

- Braunschweig: flight research



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Flight Test Infrastructure

- Flight tests for improvement of efficiency, safety and mitigation of environmental impact
- Development and demonstration of new technology concepts
- Evaluation of results from simulations and ground tests
- Development and certification of modifications of research aircraft
- Resources and competences in flight test and airborne research operation
- Part-21 Design Organization and Flight Operation Department including Aircraft Maintenance Organization
- Instrumented aircraft / telemetry ground station

Research Aircraft at a Glance

Briefing Content

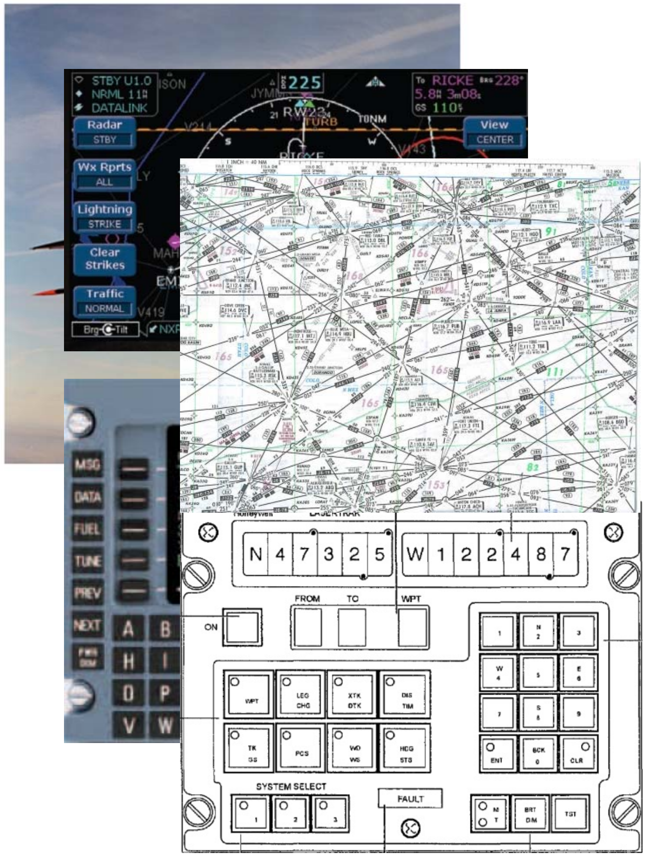
- Motivation for HMI testing

- HMI integration and testing
  - Aircraft integration
  - Procedures and safety concept

- Research examples
  - FHS flight trials
  - ATRA flight trials

- Lessons Learned

Motivation for HMI Testing



- HMI important in general (safety related) – Example “TCAS event”

How to put a FPL into such a system?

- HMI used for flight trails to compensate deficiencies in baseline infrastructure

- HMI as research objective itself

HMI Integration and Testing

- HMI research is a main objective at the Institute of Flight Guidance
- Different stages of HMI integration
- Development and primary evaluations conducted in cockpit simulator of the Institute of Flight Guidance
- Familiarization sessions with pilots and flight test engineers in the simulator
- HMI transfer to aircraft in a similar setup as in simulator
- Different aircraft require different HMI setups

Aircraft Integration - ATRA

Long term goals:
- Use basic avionics displays for experimental video signals
- Develop interface to standard autopilot

Workaround for short and medium term use:
- Use foldable, experimental cockpit display
- Use HMI so that pilot can follow desired flight guidance manually

Integration with internal and external design office
- Foldable display integrated by Lufthansa Technik
- Basic Flight Test Instrumentation integrated by Airbus
- Experimental Systems integrated by DLR

Aircraft Integration - ATRA

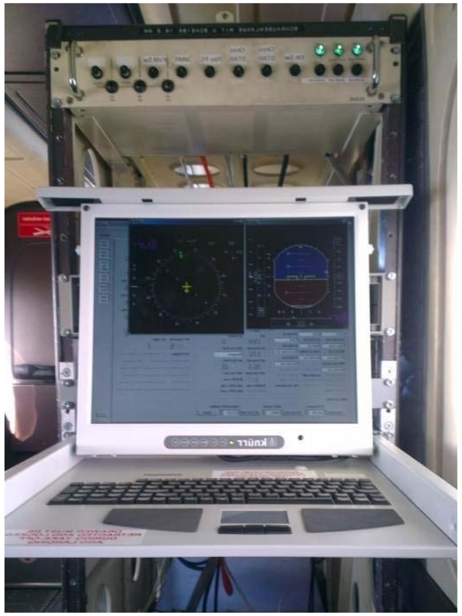
Aircraft Integration - CODE

Long term goals:
- Integrate digital autopilot with interface for experimental systems

Workaround for short and medium term use:
- Use fixed experimental cockpit displays
- Use HMI so that pilot can follow desired flight guidance manually

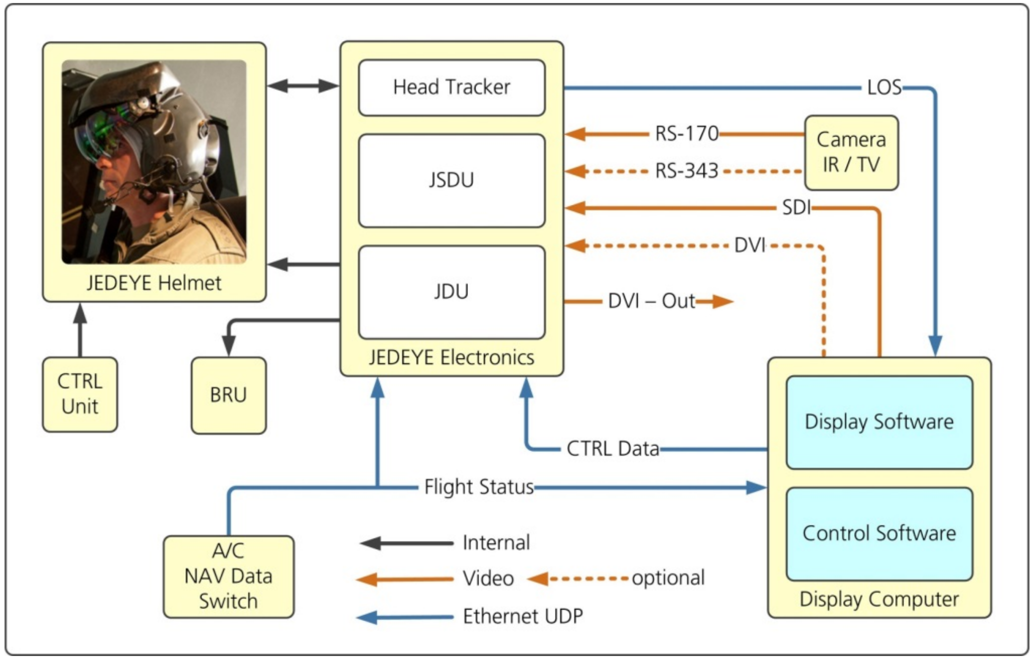
Integration with internal and external design office:
- Experimental Systems integrated by DLR
- Cockpit displays integrated by DLR in cooperation with RUAG Aerospace
- With displays installed, flights in VMC permitted only

Aircraft Integration - CODE



Aircraft Integration - FHS

- JedEye Helmet
- Binocular display system
- FOV: 80ºx40º with 60ºx40º overlap
- Compensating for head movement and aircraft maneuvers between video grabbing and display
- Distortion correction



Procedures & Safety Concept

Flight Test Procedure ATRA

Scientific Delegate

Engineering

Flight Test Team

Flight Test Request

D & Q of A/C Modification

Risk Assessment

A/C & Test Limitations

A/C Config. change

Test Plan (Flight Orders)

Flight Readiness Review

Procedures & Safety Concept – ATRA Example

- Flight Order: Limitations foldable display

- For departures with additional cockpit display in use:
    - Deploy additional cockpit display only if aircraft is in clean configuration and not before reaching 1000ft AGL
    - VMC is mandatory from ground up to 3000ft AGL
- When additional cockpit display in use, then manoeuvring exceeding an Angle of Bank (AoB) of 33° must be performed at or above FL 100
- In case of any uncertainties with aircraft systems, navigation or air traffic control, the additional cockpit display must be stowed immediately
- When descending below Minimum Sector Altitude (MSA) during the experimental approaches, the flight path must be cross-checked with visual cues or raw navigational data (ILS / GPS / NDB/DME and altitude)
- The additional cockpit display must be stowed:
    - Below MSA when not in VMC
    - Otherwise latest at 500ft AGL

Procedures & Safety Concept – FHS Example

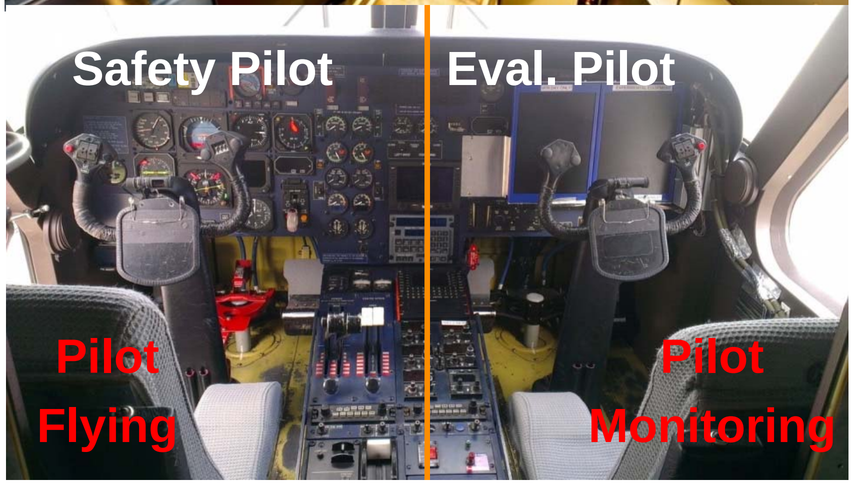
- Adjusting the position of the helmet until it feels comfortable

- Compensation of the divergence between the two displays (left and right) to achieve a unified sharp image while observing it with both eyes simultaneously (correlation process)

- Aligning the JedEye helmet with the longitudinal axis of the helicopter by overlapping the BRU symbol inside the helmet with the symbol inside the BRU (boresight reticle unit)

- Familiarization with JedEye's control unit (brightness and contrast) and symbology

Procedures & Safety Concept – General



- Ground Simulator (familiarization)
- Evaluation Pilot / Safety Pilot
- Concept used for every research aircraft

Research Examples

- Display evaluation of HMD in FHS

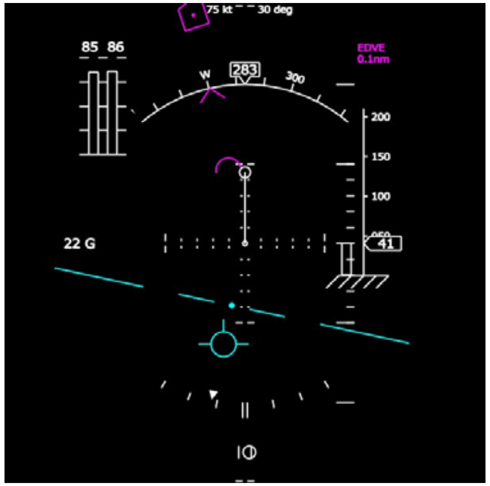
- Curved precision approaches using GBAS with ATRA

- Both already conducted in flight tests

Evaluation of Both State-of-the-Art and New Display Formats for Helicopter Flights under DVE Conditions

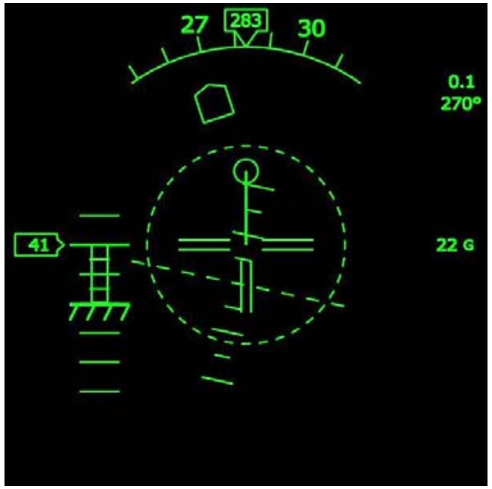
- Research objectives: Developing new 2D- and 3D-(virtual) conformal symbology for supporting the helicopter pilot during enroute flight and landing especially under degraded visual environments

- Examples of different 2D symbology:



BOSS

head-down



DeViLa

monocular, helmet-mounted

DLR version

binocular, helmet-mounted,

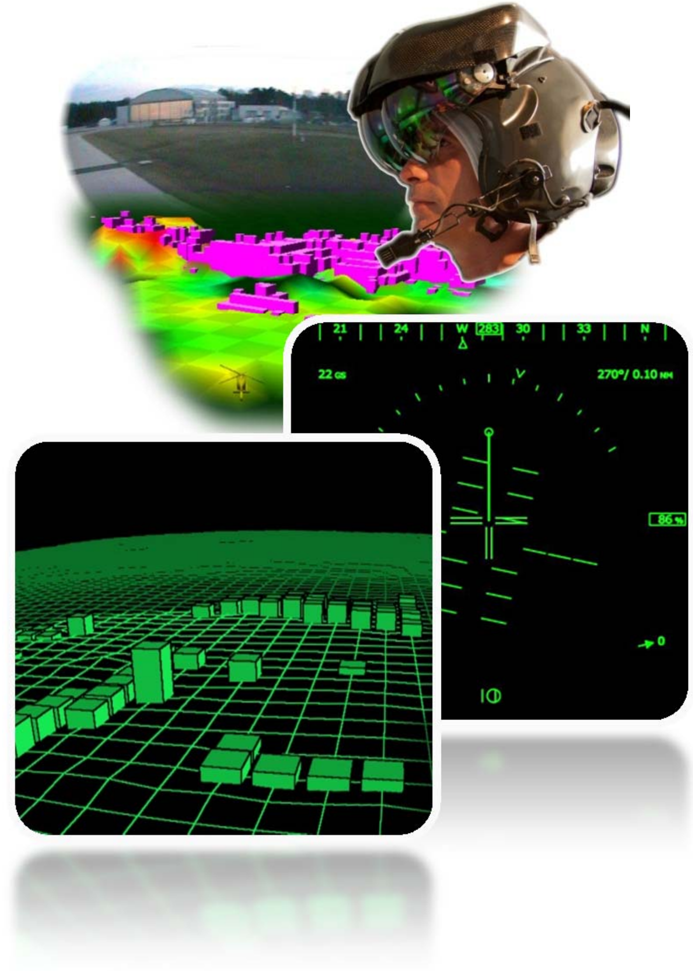
wide field-of-view

Preliminary Results of Flight Tests with JedEye HMD

- Up to now, approximately 10 flights have been conducted with the system
- The evaluation pilots had to fill in a questionnaire after the flight tests.

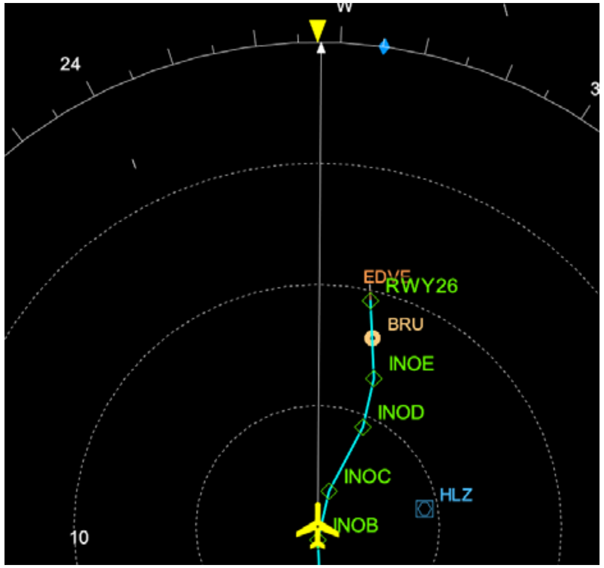
Preliminary results:

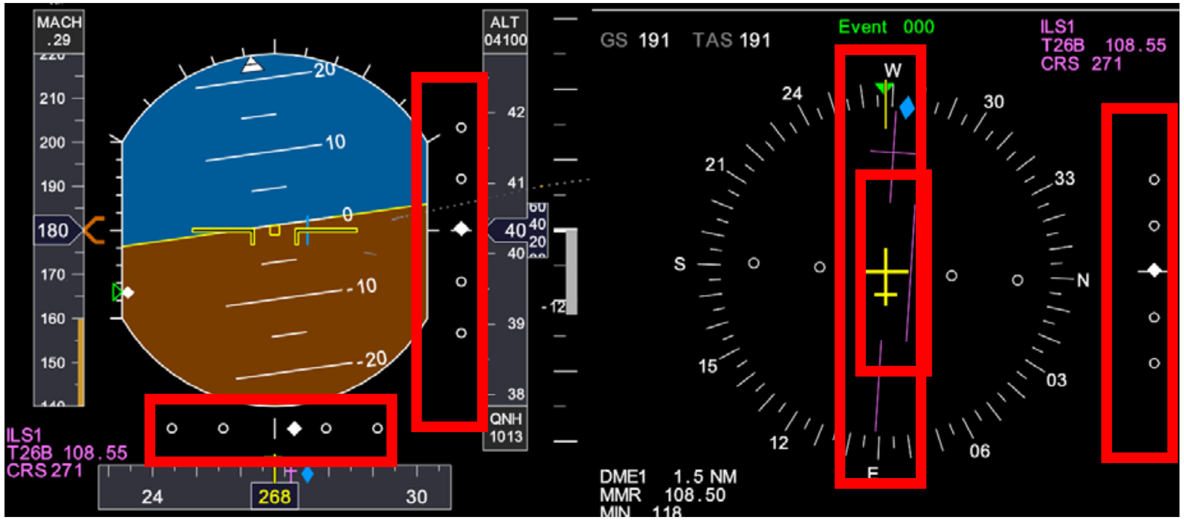
- In general the results show overall good pilot ratings for the HMD
- Subjective results indicate high wearing comfort and visual comfort
- Visual aspects are rated well, including contrast, brightness and acuity
- Pilots report no somatic implications such as neck pain, headache or watery eyes during helmet use



Display Layouts for Curved Precision Approaches

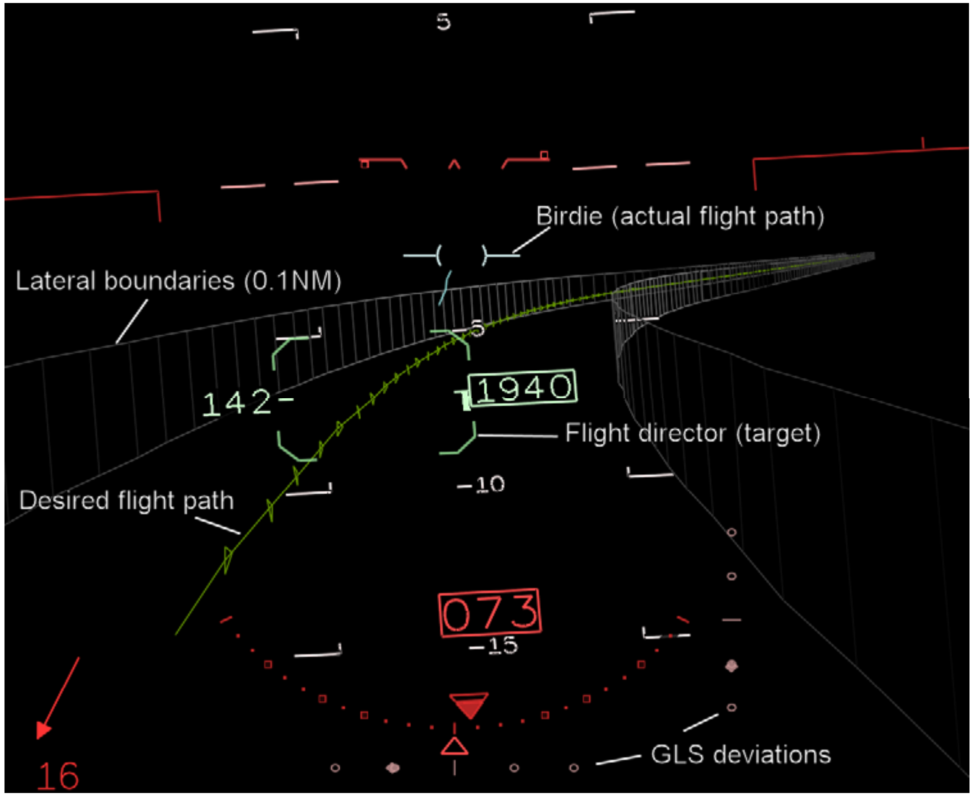
- Different display layouts were used for ATRA flights
  - “Raw data” with ILS-look-alike indications
  - Map display
  - Diamond shaped deviation symbols
  - Adaptive runway direction indication





Display Layouts

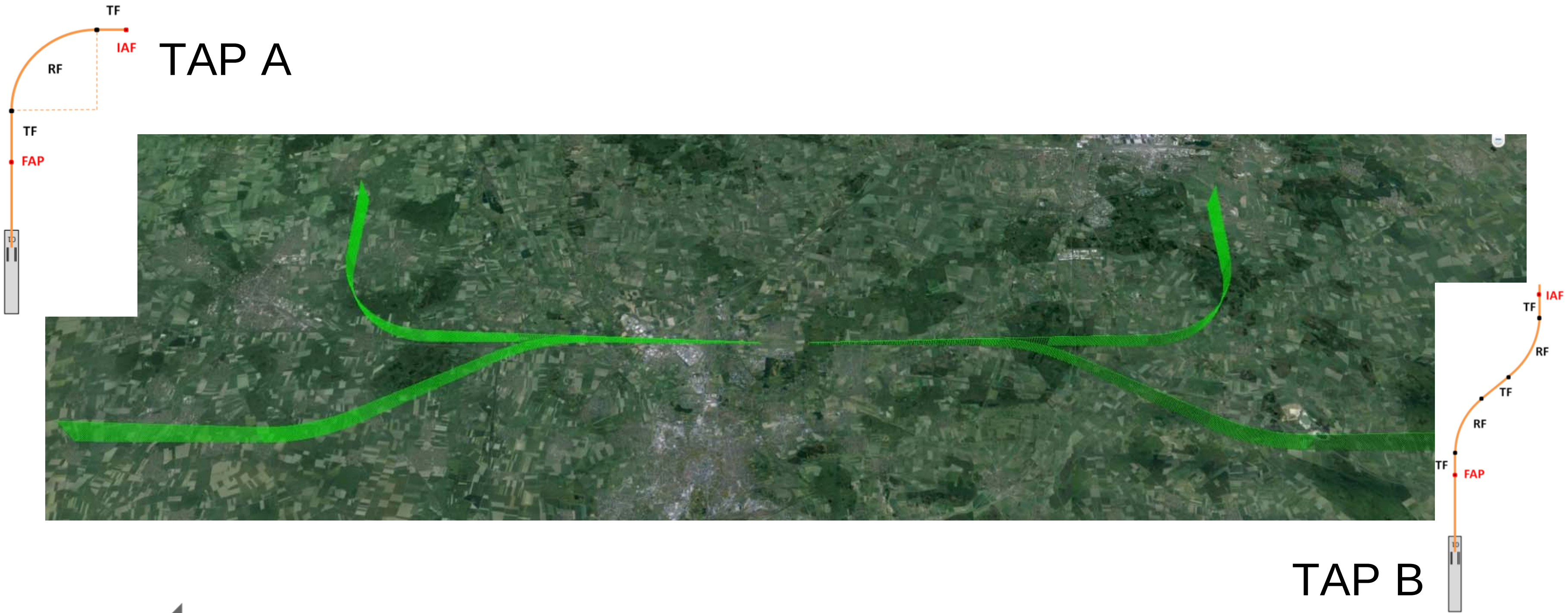
- Additionally flight director in PFD (green bars)
- Tunnel display as alternative display concept



GBAS Curved Approaches

- Implementation of Terminal Area Procedures (TAP) at Braunschweig airport
- Curved precision approaches with continuous 3 degree slope
- Flight Trials with D-ATRA conducted

TAP A



TAP B

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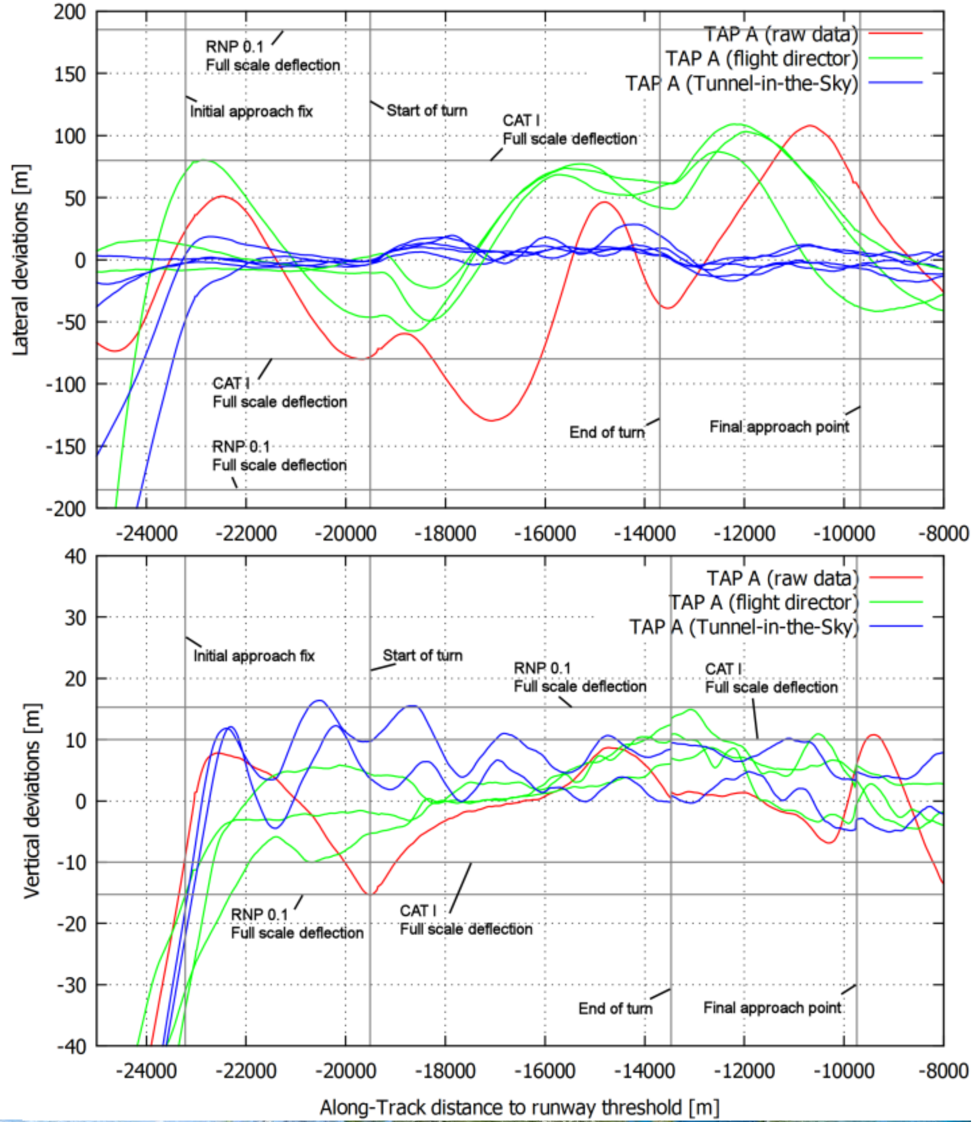
Flight Test Results – TAP A

- Manually conducted TAP A approaches with different display layouts

- Displacement sensitivities with RNP 0.1 values
    - Laterally 0.1NM (185m)
    - Vertically 50ft (15m)
- Laterally good results with tunnel display
- Laterally well below RNP 0.1 FSD with all display layouts

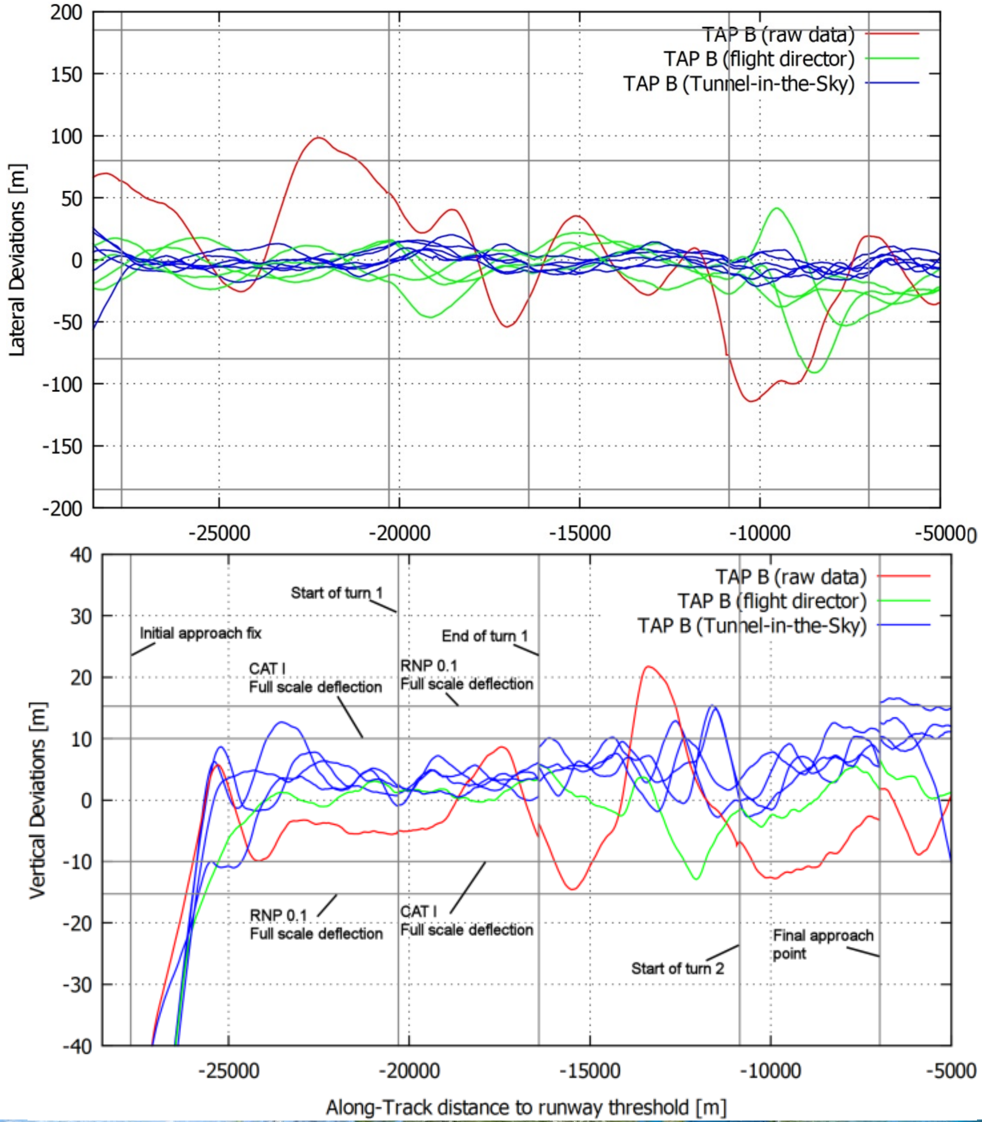
- Vertically good results with all display layouts (constant glide slope)
- Vertically within 50ft FSD



Flight Test Results – TAP B

- Manually conducted TAP B approaches with different display layouts
- Generally better flight path following performance than during TAP A
- Laterally with tunnel display well below FSD for CAT I FSD at threshold

- Vertically good results with all display layouts (constant glide slope)
- Vertically within 50ft FSD



Lessons Learned

- Procedure “Flight Test” appropriate but under constant review
- Testing and crew-familiarization regarding HMI in ground simulators reduces irritations in flight
- ATRA-HMI-concept appropriate as mid-term solution
- Limitations could be reduced, if HUD or baseline display could be used for experimental data
- Future experiments require interface to the auto flight system of the basic aircraft (CODE & ATRA)

Thank you for your attention

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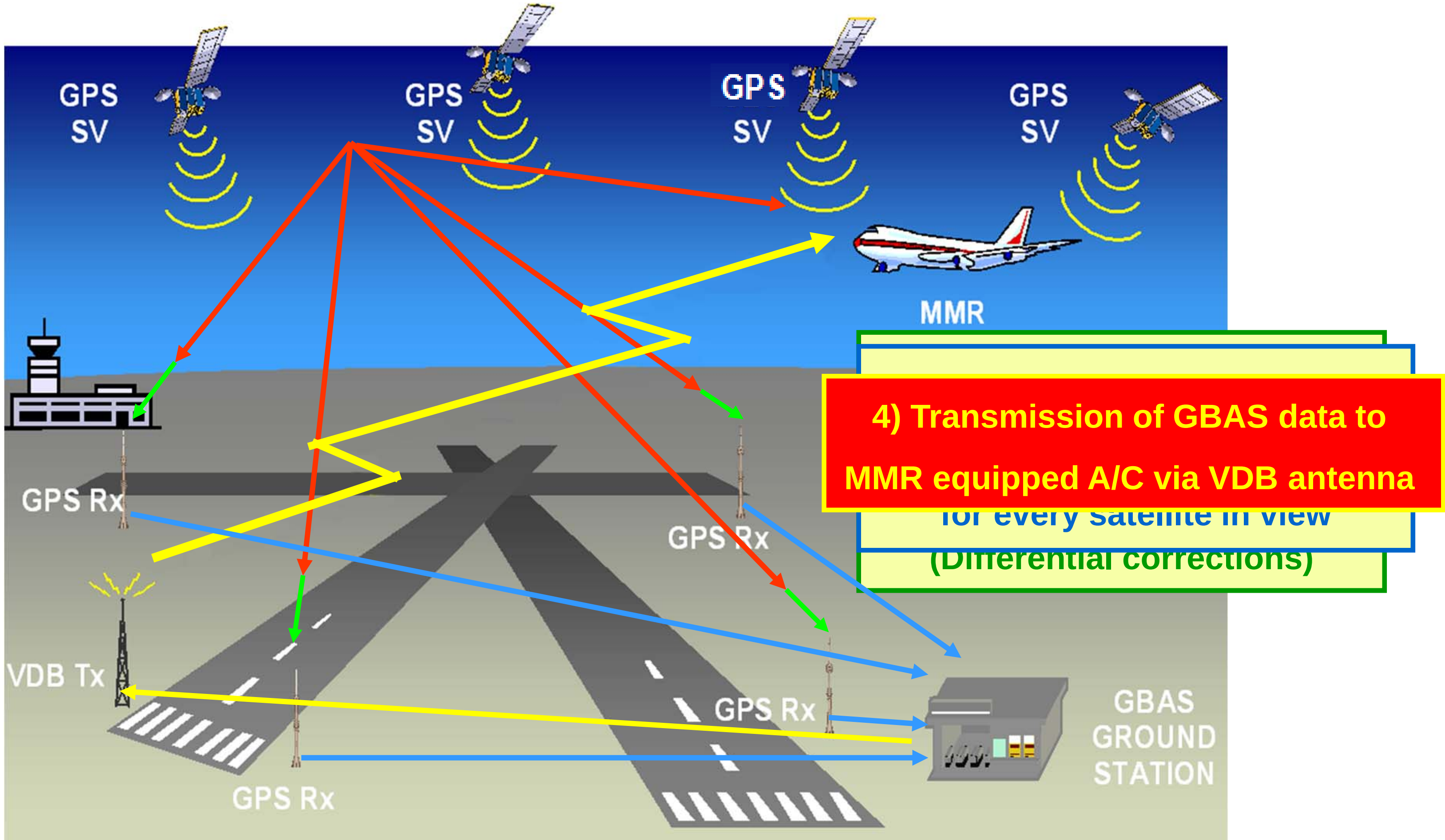
Backup

Ground Based Augmentation System (GBAS)



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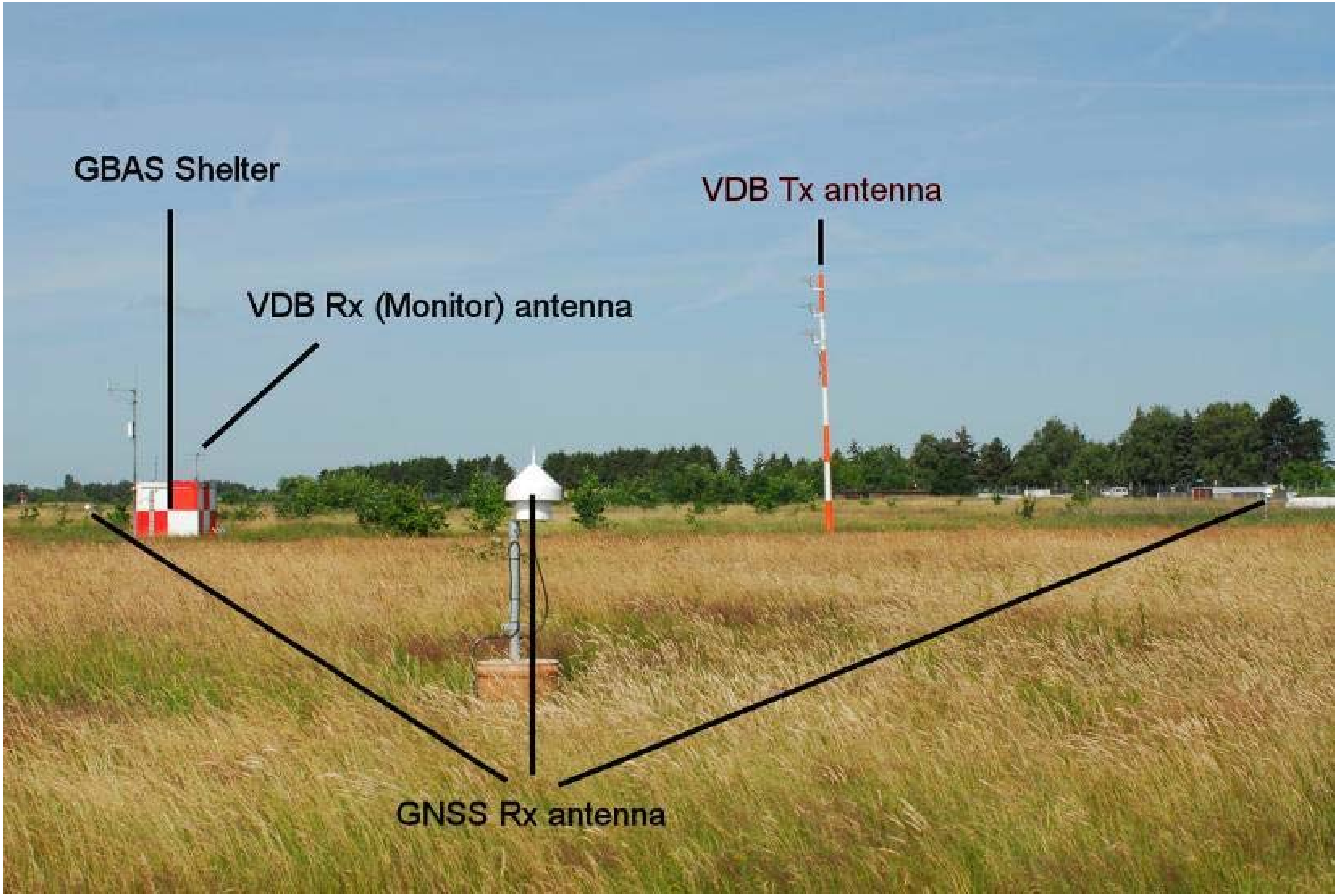

GBAS Shelter
VDB Tx antenna
VDB Rx (Monitor) antenna
GNSS Rx antenna

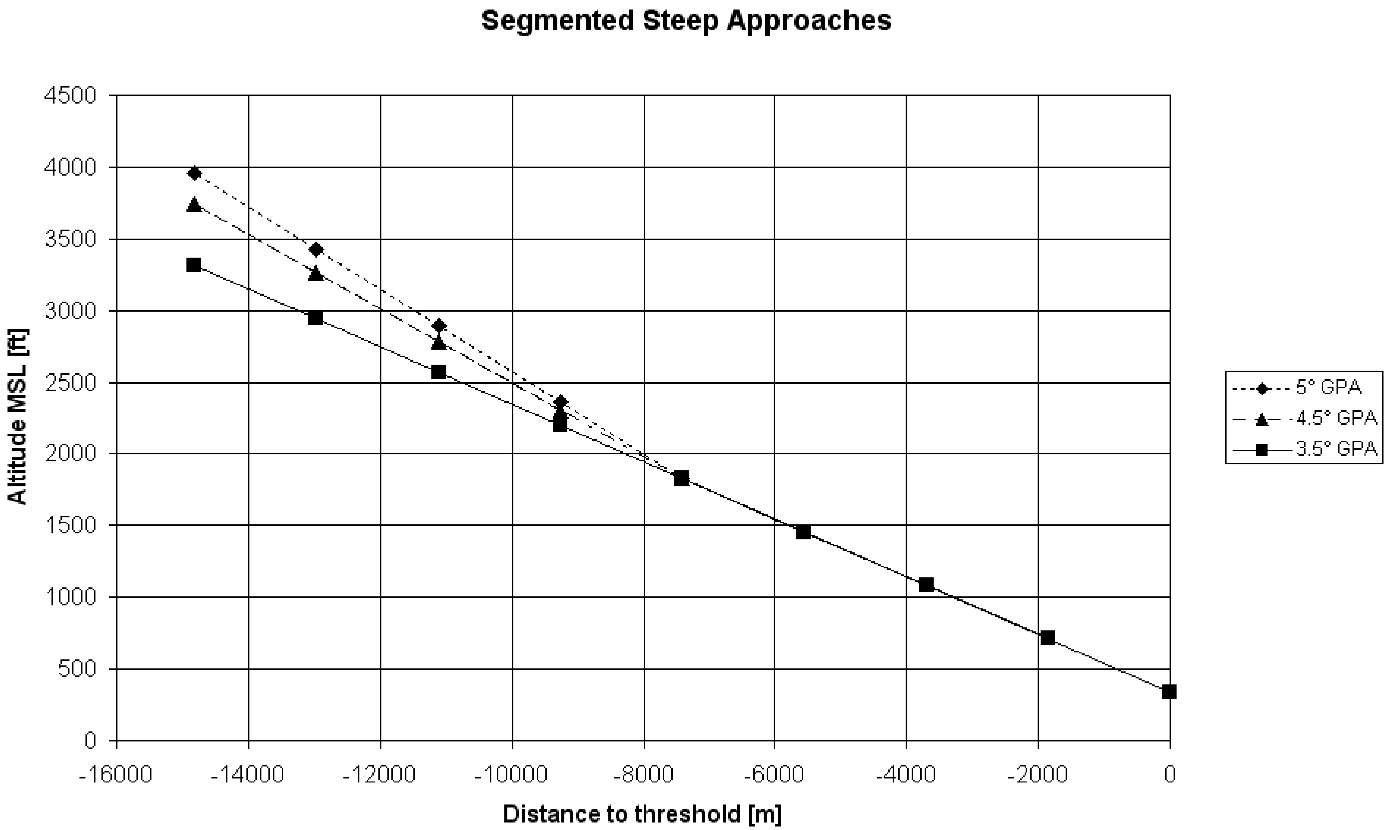
Institute of Flight Guidance – Operational GBAS research

- Segmented steep approaches
    - Compromise between noise reducing steep approaches and the resulting operational issues
    - Different flight trials conducted and evaluated

- Curved precision approaches
    - Terminal Area Path (TAP) functionality used for GBAS guided curved approaches

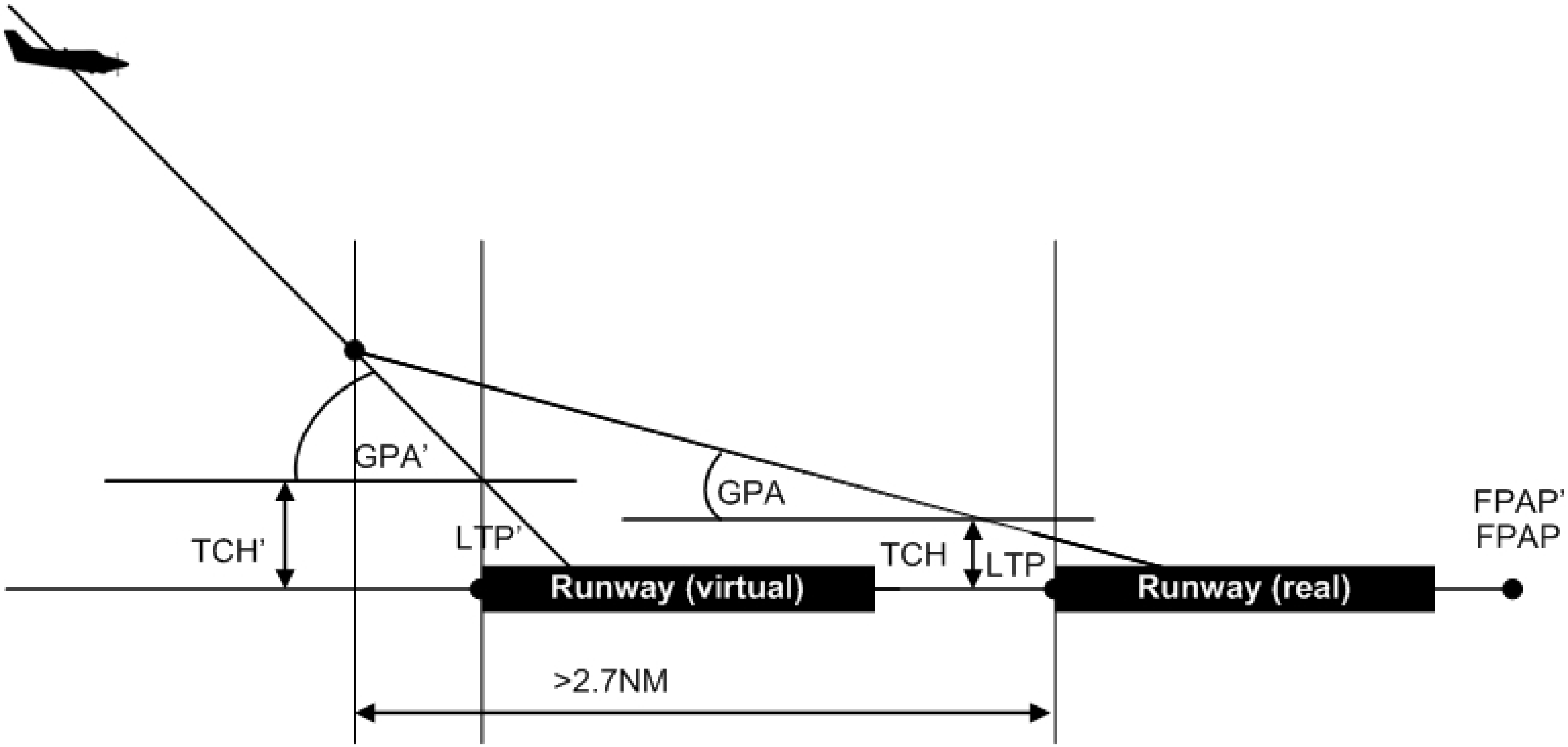
- GBAS based taxiing and auto taxi capabilities
    - Based on Terminal Area Path functionality

Segmented Steep Approaches - Layout



- Two final approach segments (FAS data blocks) combined
- Steeper segment for noise reduction, standard segment for Touch Down

Segmented Steep Approaches – FAS realization



- No sensitivity issues but active FAS data to ground without real runway
- FAS switching has to be assured

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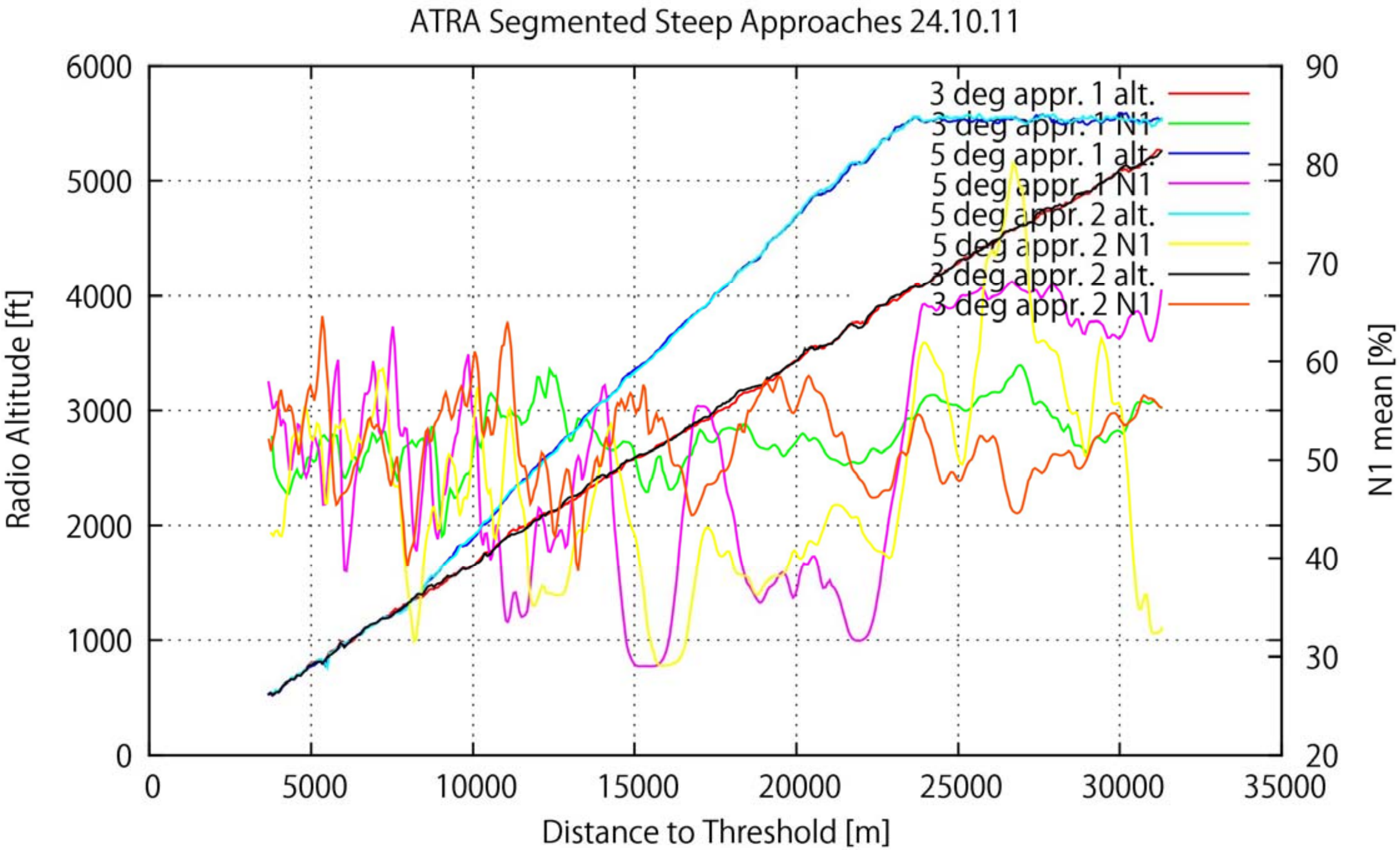
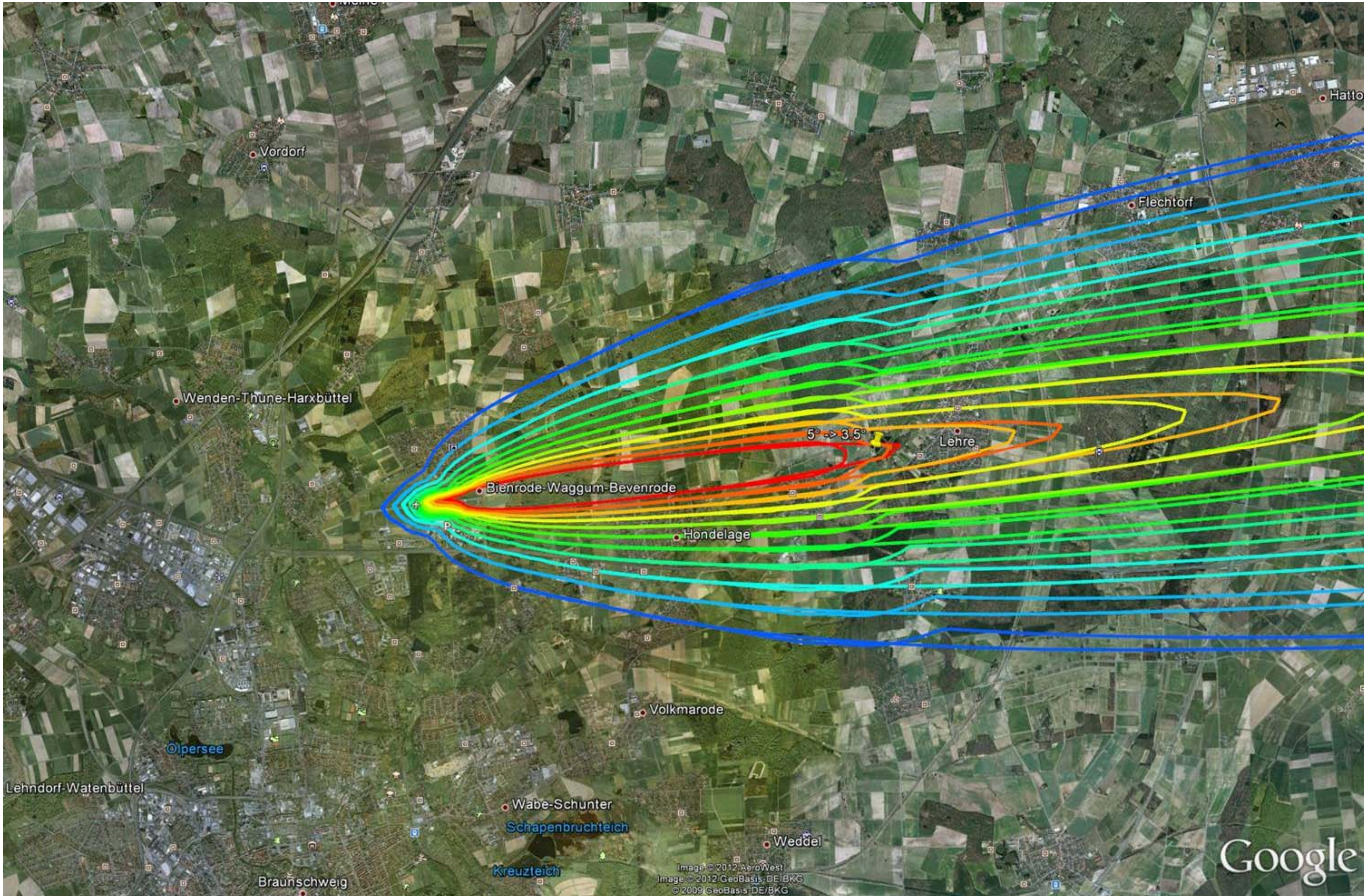
Segmented Steep Approaches – Flight Trials 2



- Mean N1 reduction by approx. 5% with auto thrust, manual flight
- Thrust near idle during steep segment with this aircraft (A320)


Vordorf
Flechtorf
Wenden-Thune-Harxbüttel
5° -> 3.5°
Lehre
Bienrode-Waggum-Bevenrode
Hondelage
Volkmarode
Olpersee
Lehndorf-Watenbüttel
Wabe-Schunter
Schapenbruchteich
Weddel
Kreuzteich
Braunschweig
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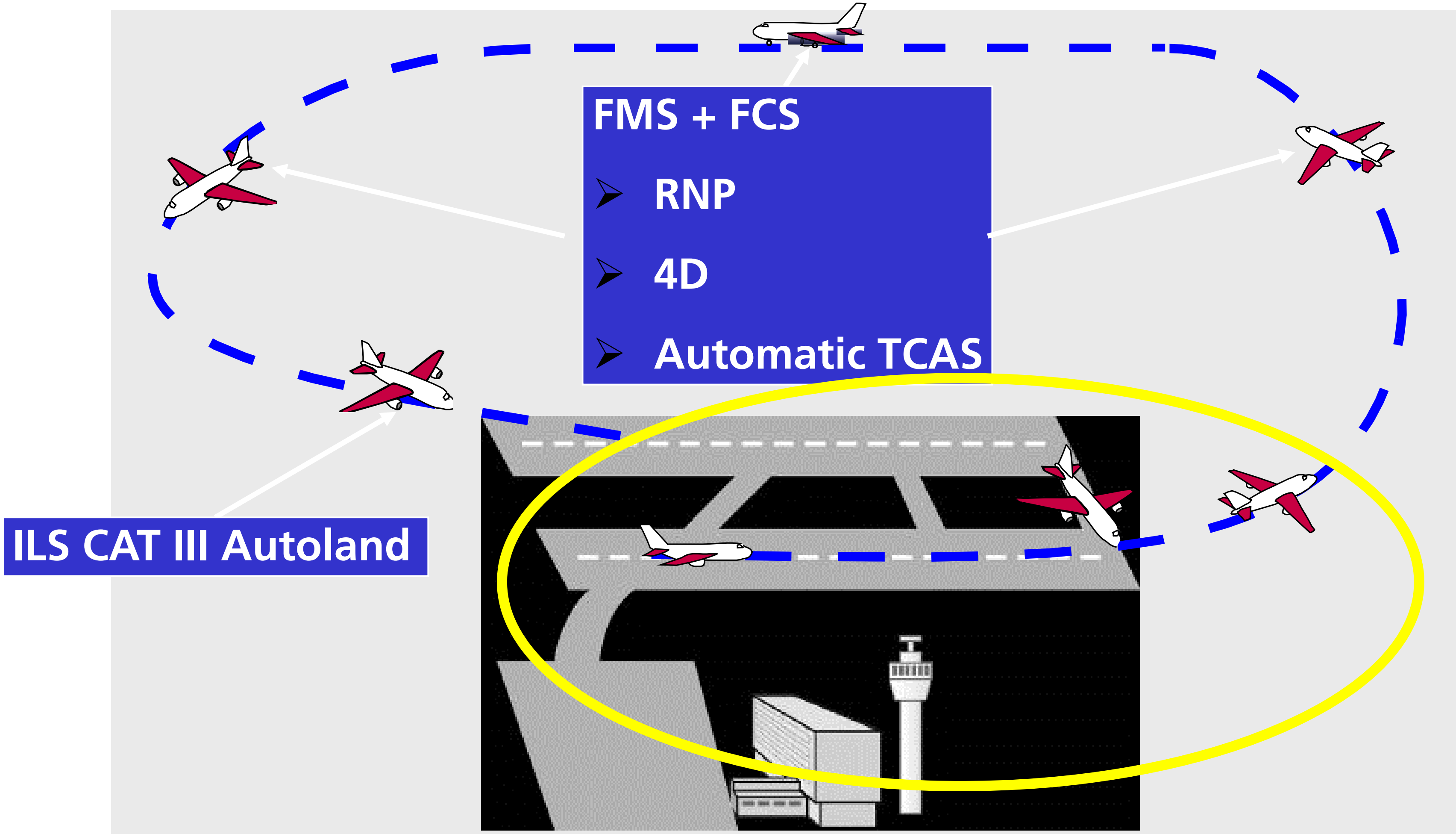
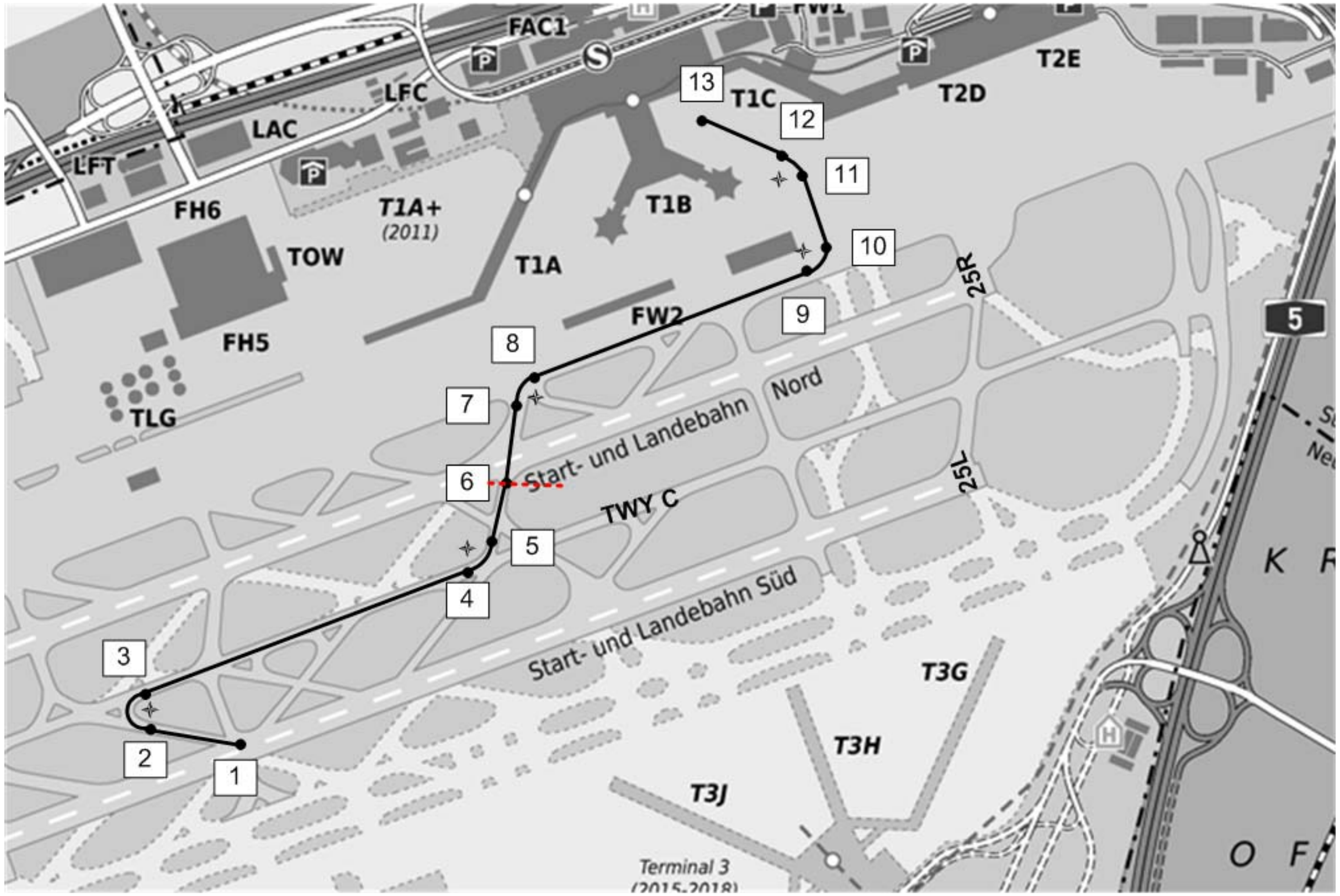
Outlook – Onboard Automation – Existing Gaps



Application of GBAS to Taxiing and On-Board Automation

- Typical taxi route in Frankfurt a.M. (EDDF) from RWY25L will be via TWY C
- Only some aircraft will go to southern or northern apron
- Large amount of standard routes can be defined with Ground-TAPs (standard segments) even at busy airport



Typical Taxi Route for EDDF as Ground-TAP

The DLR – Site in Braunschweig, Germany

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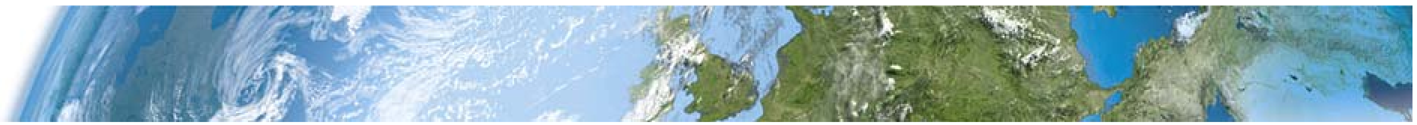

Integrated Simulation and Experimental Infrastructure