Flight Testing the Wake Encounter Avoidance and Advisory system: First results

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- Motivation and Objectives
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Background

- DLR Project WOLV
  - Developing weather and wake vortex expert systems along with operational concepts for the air traffic management and control at airports
  - Researching new sensors and delivering automated flight control and innovative flight crew information technologies for the aircraft
Motivation

- system for **tactical small-scale evasion** from wake vortices to avoid possibly hazardous wake encounters
- **pure safety net** function (no means of defining separation)
- however, supports reduction of separation distances by providing mitigation measures
- pilots’ **situational awareness** is key issue
- evasion **without ATC request** (similar to TCAS)
  \[ \rightarrow \text{stay within navigation limits} \]
- DLR objectives:
  system proof-of-concept, in-depth investigation of selected components
WEAA Objectives and Constraints

- **System Design Objectives**
  - Increase the pilots’ situational awareness in case of a predicted, imminent or even current encounter
  - Define, guide and monitor evasive manoeuvres (where possible)

- **Manoeuvre Design Constraints**
  - Evasion without ATC request, within navigation limits
  - Generally 4-D manoeuvre (adjustment of speed, track, flight path angle) possible but
    - ATC compatibility of speed changes
    - Manoeuvre should be kept as simple as possible
  - No conflict with TCAS and/or (E)GPWS/TAWS generated
  - Aircraft performance
  - Passenger comfort (accelerations)
WEAA System Architecture: Functions

- Predict wake vortices from flight state and planned trajectories of surrounding aircraft using meteorological data
- Detect wake conflicts, using prediction of own trajectory, in connection with hazard assessment where required
- Generate evasion trajectory, taking into account terrain data and surrounding traffic
- Generate overview display to increase pilot’ situational awareness (e.g. on ND and VSD)
- Alert flight crew and guide required evasive manoeuvres (e.g. on PFD and VSI)
WEAA System Architecture: Block diagram

- terrain data base
- traffic data
- met data
- sensor data
- flight plan
- a/c status
- evasion manoeuvre definition

WEAA Core System

- Terrain Avoidance
- Traffic Prediction
- Wake Vortex Detection / Prediction
- Wake Vortex Conflict Detection & Assessment
- Conflict Resolution
- HMI (Information)
  - Audio
  - Display
- AFS (or Pilot)
  - Manoeuvre Execution

- Flight Guidance (performance / restraints)

Monitoring
WEAA Functional System Breakdown

**Sensors / Data Sources**
- ADS-B (I/M)S-B
- ADIRU (WMS ?)
- EGPWS / TAWS
- FMS
- FMGC

**Data Preparation**
- Decoding
- Range Filter
- Signal Conditioning
- Wind vector
- Own flight state
- Flight plan
- P mode
- Configuration
- Mass
- RNP
- XTK error
- G/S, LOC where necessary
- Terrain Data (class a: terrain / ground proximity)

**Detection/Prediction**
- 4-D Trajectory Prediction (surrounding traffic)
- Wake Vortex detection and Characterisation
- Wake Vortex Evasion Prediction
- 4-D Wake Vortex Evasion Prediction
- Flight Performance Data (RAA ?)

**Conflict Detection and Evaluation**
- Safety Zone Traffic (for definition of evasion trajectory)
- Conflict Detection (Wake Vortex)
- Hazard Assessment (terrain, sink rate)
- Definition and Generation of Evasion Trajectory (type of manoeuvre, generation of trajectory)

**Conflict Resolution**
- Command generation
- Implementation of avoidance measures
- Convtarget target values

**Legend**
- Audio
- Display
- N/O
- VSI
- PFDR
- FMA

**WEAA System Boundary**

**Additional Notes**
- Wake vortex and traffic situation
- Increased situational awareness
- Wake vortex and traffic evolution prediction
- Wake vortex detection and characterisation
- Prediction of own trajectory
- Safety zone traffic (for definition of evasion trajectory)
- Flight phase dependent restraints (width of corridor, ground proximity)
- Flight performance (flight phase dependent, altitude)
- Flight phase dependent restraints (width of corridor, ground proximity)
- Ground proximity
- Further meteo data
- Flight plan
- A/P mode
- Configuration
- Mass
- RNP
- XTK error
- G/S, LOC where necessary
- Terrain Data (class a: terrain / ground proximity)

**Diagram Details**
- FMGS
- 4-D Trajectory Prediction (surrounding traffic)
- HMI (Information)
- Wake vortex and traffic situation
- Increased situational awareness
- Command generation
- Wake Vortex Hazard Assessment (e.g. hazard area, SHAPe)
System Integration for Flight Tests

**ADS-B Data:**
- Position (Latitude, Longitude, Altitude)
- Ground Speed
- True Airspeed
- True Heading
- Wind Speed
- Wind Direction
- Aircraft Status

**Modification:**
- **Falcon**
  - UHF Telemetry
- **ATRA**
  - UHF Telemetry, ADS-B Receiver,
    WEAA Workstation, Audio, Display,
    Guidance
ADS-B Receiver

![ADS-B Receiver Image]

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### ADS-B Client V1.0

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**Messages:**

Press Q <STOP>, R <REFRESH>
Display Concepts
First Results: Flight Track
Flight Tests: Film
Flight Tests: Film
First Results

- DLR Falcon 20 (D-CMET) fulfilled its role as wake generating aircraft satisfactorily.
- The telemetry link between Falcon and ATRA worked well.
- ATRA flown behind Falcon:
  - Wakes vortices were hit, angles for intercepting of the contrails were varied.
  - Flight in lining up with vortices was performed, light turbulences were observed during this manoeuvre.
  - Wakes vortices were also hit from above and below, Rate Of Descent and Rate Of Climb were varied.
- ATRA flown a predefined flight profile, which enabled different angles for intercepting of the contrails to hit the wakes vortices.
- Processing of received traffic data and (simplified) wake vortex prediction worked during the flights.
Summary

- Flight Test Equipment successfully installed
- WEAA concept successfully tested under real conditions
- ADS-B data link provided the necessary information
- Predefined profiles flown for Wake Vortex Detection/Prediction
- Wake vortex position determined by intentional encounters for validation of the wake vortex prediction model, accelerometers and ADC give more details about the wake
- Predefined profiles flown for Wake Vortex 4D conflict prediction
- Recorded data will be used for simulator and offline tests and to improve WEAA modules and displays (ND, PFD, VSD).
- Conflict resolution in flight is subject for the next campaign.