In-Flight Wake Encounter Prediction with the Wake Encounter Avoidance and Advisory System (WEAA)

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Outline

- Motivation
- Wake Encounter Avoidance and Advisory (WEAA) System Concept and Architecture
- Experimental System Implementation
- Flight Test Execution
- Initial Flight Test Results for Conflict Detection
- Conclusions / Further Work
Background Work at DLR: Warning and Avoidance in Presence of Atmospheric Disturbances

Motivation: safety increase, all-weather capability enhancement

- Prediction / detection of hazardous disturbance
  - Large-scale disturbance: e.g. thunderstorm
    - Known position / dimension
  - Small-scale disturbance: e.g. wake vortex
    - Unknown position / dimension or insufficient time-to-conflict

- Strategic avoidance
  - (flight plan change)
- Tactical avoidance
  - (small-scale manoeuvre)
- Alerting / compensation by flight control
Tactical Hazard Avoidance
Objectives: Wake Encounter Avoidance & Advisory (WEAA)

- airborne system for **tactical small-scale evasion** from wake vortices to avoid possibly hazardous wake encounters
- initially **pure safety net** function (no means of defining separation)
- pilots’ **situational awareness** in case of a predicted, imminent or even current encounter is key issue
- NB: wake encounter alleviation by F/CTL is not part of WEAA but can be integrated

- DLR objectives:
  - system proof-of-concept under operational conditions
  - in-depth investigation of selected components
  - trade-off studies and benefit analysis (→ future standards)
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
- **alert flight crew and guide** required **evasive manoeuvres** (e.g. on PFD)
- **generate overview display to increase pilots’ situational awareness** (e.g. on ND and VSD)
WEAA – Flight Test Overview

Objectives:
- feasibility demonstration: initial system functionality (wake prediction and conflict detection) under operational conditions
- allow analysis of requirements on wake generator and meteo data

Prerequisites
- establishment of necessary hardware and software infrastructure on board test a/c ATRA
- data reception and processing under real-life conditions
- controlled conditions for experiment
  → usage of DLR’s Falcon 20 as wake generator aircraft
  → telemetry emulating ADS-B transmission from Falcon
  → safe encounters due to relative sizes of aircraft

2014 campaign
- validation of meteo data fusion (industry subcontract), wake prediction and trajectory prediction in cruise flight
  → deliberate wake encounters flown to confirm wake position
  → contrail visibility required
- test of conflict detection (developed in industry subcontract)
- gathering of data for design of conflict resolution (evasion strategy)
F/T-Campaign 2014

Hardware

Falcon (generator)

experimental cockpit display

telemetry

ATRA (follower)

experimenter rack

ADS-B IN Rx and telemetry
Aircraft Systems
ADS-B Data Link Simulation Concept

DLR’s Falcon is not equipped with ADS-B OUT
→ wake generator data transmitted via telemetry (with ADS-B resolution, accuracy, update rate)
→ more accurate and comprehensive (inertial, meteorological) reference data recorded

• Position (Latitude, Longitude, Altitude)
• Ground Speed
• True Airspeed
• True Heading
• Wind Speed
• Wind Direction
• Aircraft Status

part of the current ADS-B standard but not observed in practice (nor used in flight test)
F/T Campaign 2014
Overview

- 3 test flights in April 2014 from Braunschweig
- Falcon D-CMET as wake generator, A320 ATRA carrying WEAA system
- **contrail prediction** allowing identification of favourable flight times and altitudes

- determination of altimeter offsets in formation flight at beginning of flight test (for reference only)
F/T Campaign 2014
F/T Execution

- test execution in Temporarily Restricted Airspace (TRA) in North-Eastern Germany
- in-trail flight with small encounter angles (blue pattern)
- race-track pattern with wind-dependent orientation for generator aircraft Falcon and crossing of wake by ATRA at larger encounter angles (green patterns)
F/T Campaign 2014
System Display – Example: Crosswind

- Own track prediction
- Conflict position
- Current vortex wake
- (Past) generator track
- Time and distance to conflict
- Generator track prediction
- Generator position

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F/T Campaign 2014
Display Integration into ATRA

Prediction: Conflict with future wake vortex
Sample Encounter Video
F/T Campaign 2014
Sample Results

encounter
distance ~ 4 nm

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WEAA – Conclusions and Further Work

Status
- successful flight tests with ATRA and Falcon for operational wake vortex prediction, visualisation and conflict detection
- 70+ encounters flown
- high quality reference data available

System Development Plans
- extensive data evaluation
- further development of meteo data fusion
- investigation of requirements on trajectory prediction for use in conflict detection
- study of avoidance functionality
  - prediction lead times (cf. RTCA WV TT)
  - generation of avoidance trajectories
  - display and flyability of avoidance trajectories (AVES simulator study)
- trade-off studies for input parameter requirements
- implications of emerging standards
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