WakeNet3-Europe – 2nd Major Workshop

Presented by

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SESAR projects 9.11 & 9.30
Aircraft systems for wake encounter alleviation
Outline

• Introduction – Background – Motivation

• Description of solutions

• Scope of projects

• Work share – schedule

• Interdependencies

• Summary - Outlook
Introduction

• Two wake vortex related projects are contained in SESAR WP9 „Aircraft systems“:
  • P9.11 – Aircraft systems for wake encounter alleviation
  • P9.30 – Weather Hazards/Wake vortex sensor

• Both projects have been launched by the SESAR Joint Undertaking (SJU) in June 2010 after a successful project initiation phase in early 2010
Safe and efficient air transport requires adequate aircraft separation
  - For collision avoidance (incl. runway occupancy constraints)
  - For avoidance of severe wake turbulence encounters

Very few wake-related accidents to commercial transport aircraft but
  - Number of events expected to increase with the increasing traffic density
  - Current horizontal separation minima in cruise may lead to strong encounters

Current wake turbulence separations are limiting air transport capacity

Complementary mitigation strategies allow to safely reduce wake turbulence separation requirements:
  - Benign vortex aerodynamic design
  - New ATM concepts (e.g. weather-dependent and/or pair-wise separations)
  - Ground-based wake prediction & monitoring systems
  - On-board wake encounter prediction, alerting & avoidance systems
  - On-board wake encounter alleviation systems
Background - Motivation

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On-board systems for the prevention of severe wake encounters:

**Wake Encounter Prevention System (WEPS)**

Two interacting & complementary system solutions:

1. **On-board wake encounter prediction, alerting & avoidance system**
   - **WEPS-P (Prediction to Avoid) P9.11**
     - Identification of potential wake encounters based on air-to-air data link and model-based wake prediction
     - Determination of small-scale, short-term avoidance maneuvers

2. **On-board wake encounter alleviation system enabled by detection**
   - **WEPS-C (Control to Alleviate) P9.30**
     - Alleviation of wake encounter upsets through dedicated flight control function
     - More robust, less vulnerable aircraft
     - Based on current and new air data sensors, including forward-looking LiDAR
Wake Encounter Prevention System (WEPS)

WEPS-P  (Prediction to Avoid)  P9.11
• Model-based prediction, alerting & avoidance – all flight phases
WEPS-P – Sketch of operational principle

- Model-based prediction, alerting & avoidance – all flight phases

*Engineering display*

*Out-of-cockpit view*
WEPS-P – Specific sub-functions

- **Prediction of evolution of wakes of surrounding aircraft enabled by**
  - Probabilistic wake prediction models
  - Broadcast of traffic and meteo data to WEPS-equipped A/C via ADS-B data link or comparable

- **Conflict Detection**
  - Detection of conflict between intended flight path and predicted zone of wake location
  - Decision for Alerting/Avoidance using encounter severity metrics developed and validated in P6.8.1

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WEPS-P – Specific sub-functions

• Conflict Resolution
  ‣ Vertical avoidance manoeuvre
  ‣ Lateral avoidance manoeuvre
  ‣ Vert. + Lat. avoidance manoeuvre
  ‣ Speed adjustment
  ‣ Go-Around

• Human Machine Interface & Human Factors
  ‣ Presentation of information to the pilots
  ‣ Alerting logic

• System interfaces
  ‣ Interaction with existing surveillance systems
  ‣ Inputs from other airborne systems
Wake Encounter Prevention System (WEPS)

WEPS-C (Control to Alleviate) P9.30
• Encounter alleviation system enabled by detection – all flight phases

WEPS-C is an extension of WEPS-P functionality
WEPS-C – Specific sub-functions

- **Alleviation flight control**
  - Today's Fly-by-Wire flight control already reduces the effect of a wake encounter
  - Further improvement of alleviation of wake encounter effects deemed possible
  - Different, new and dedicated control strategies are enabled if
    - Type of disturbance is known (through WEPS-P)
    - Measurement of disturbance can be improved (e.g. through new sensors)

- **New, forward-looking sensor**
  - Short-range, forward-looking LiDAR sensor capable of measuring line-of-sight velocity at several points in front of the aircraft

- **Human-Machine Interface & Human Factors**
  - Definition of pilot - flight control interaction
  - Mode annunciation
WEPS – Expected Benefits

- Solution delivers benefits in two main areas:

  ▶ SAFETY
  - By providing the means to predict an imminent wake encounter and determining an avoidance maneuver, the solution directly contributes to safety by reducing the number of wake encounter incidents.

  ▶ CAPACITY
  - When integrated into an appropriate new separation scheme, the solution allows reduced wake-related separations for equipped aircraft, thus directly contributing to runway capacity increases.
WEPS – Expected Benefits

- **WEPS-P (prediction to avoid):**
- Probabilistic prediction with uncertainty
WEPS – Expected Benefits

- WEPS-P (prediction to avoid):
  - Capacity gain vs. number of alerts

Current reference probability of encounter with given severity including variability of weather

Probability of event per operation

Separation Distance [NM]

P(S) [1/op]

1 2 3 4 5

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WEPS – Expected Benefits

- WEPS-P (prediction to avoid):
  - Capacity gain vs. number of alerts

![Graph showing probability of event per operation (P(S) [1/op]) vs. separation distance (SD [NM])]

- Probability of alert (i.e. G/A)
- Current reference probability of encounter with given severity including variability of weather
- Reduction in encounter probability
- Remaining encounter probability with WEPS-P for given σ-level

False Alarm Rate

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WEPS – Expected Benefits

- WEPS-P (prediction to avoid):
  - Capacity gain vs. number of alerts

![Diagram showing probability of alert vs. separation distance](image)

- Probability of alert (i.e. G/A)
- Current reference probability of encounter with given severity including variability of weather
- Remaining encounter probability with WEPS-P for given $\sigma$-level

- $P(S) [1/\text{op}]$
  - Probability of event per operation

- $\text{SD [NM]}$
  - Separation Distance

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WEPS – Expected Benefits

- **WEPS-P (prediction to avoid):**
  - Capacity gain vs. number of alerts

\[
P(S) \text{ [1/op]}
\]
Probability of event per operation

\[
SD [NM]
\]
Separation Distance

- Probability of alert (i.e. G/A)
- Current reference probability of encounter with given severity including variability of weather
- Remaining encounter probability with WEPS-P for given \(\sigma\)-level

\[\sigma = 3\]
WEPS – Expected Benefits

- WEPS-P (prediction to avoid):
  - Capacity gain vs. number of alerts

![Graph showing the relationship between P(S) [1/op] and separation distance (SD [NM]) with and without WEPS-P.](image)

- Acceptable number of alerts (i.e. go-arounds)
- Probability of alert (i.e. G/A)
- Current reference probability of encounter with given severity including variability of weather
- Remaining encounter probability with WEPS-P for given σ-level

Reference separation

Required separation with WEPS-P

Separation Distance

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WEPS – Expected Benefits

• WEPS-C: Additional capacity gain through alleviating flight control
  › All flight phases
WEPS – Specific issues

• Meteo data fusion onboard the WEPS-equipped aircraft
  ‣ Accuracy of the weather data received by surrounding a/c impacts the wake prediction algorithm – sensitivity?

• Traffic data fusion onboard the WEPS-equipped aircraft
  ‣ Accuracy of the traffic data received impacts the conflict detection

• Integration with existing Collision Warning/Avoidance systems
  ‣ WEPS must not lead to TCAS/EGPWS and other alerts

• Integration with Flight Guidance and/or Autopilot systems
  ‣ How will the avoidance manoeuvre be initiated/performed?
    Manual/automatic guidance?
WEPS – Specific issues

- **Sensor capabilities**
  - Which sensor capabilities (accuracy, number of measurements, frequency of measurements...) are necessary for an efficient alleviation flight control?
  - When are those sensor capabilities available?

- **Operational procedures**
  - How would the selected alleviation strategy impact cockpit procedures?

- **Safety and benefit assessment**
  - Scope of modeling required for certification
Develop and explore the concepts with regard to operational feasibility, benefits and acceptance:

- Concept of Operations
- HMI and operating procedures
- Human Factors
- System integration & certification aspects

Target Levels of Maturity:

- Advance WEPS-P & WEPS-C to TRL6 (End of R&T)
- Integration into verification & validation platforms and means
- Evaluation of system level behaviour and performance on validation platforms (incl. research flight simulator)
- Validation of functions with flight test results
Both projects are closely related to

- P6.8.1 "Flexible and Dynamic Use of Wake Turbulence Separations"
  - develops ConOps taking into account ground-based and onboard solutions
- P12.2.2 “Runway WV detection, prediction and decision support tools”
  - develops ground-based wake prediction & detection solutions
• Additional interdependencies with other SESAR projects, e.g:
  ‣ P9.21/9.22 ADS-B capabilities evolution
  ‣ P9.47 New TCAS evolution
  ‣ WP 4/5 Consideration of solution in high-level en-route and TMA concepts

• Links outside SESAR include:
  ‣ Standardization bodies (RTCA, EUROCAE)
  ‣ ICAO Wake Vortex Study Group
  ‣ LiDAR sensor manufacturers
  ‣ WakeNet
  ‣ GreenWake project
• Airbus is sole project member in both projects

• Several Airbus departments contributing to projects
  ‣ Cockpit Functions
  ‣ Human Factors
  ‣ Communication/Navigation/Surveillance
  ‣ Flight & Integrations tests ...

• Some specific tasks will be subcontracted to external partners
• Projects follow
  ‣ a TRL schedule
  ‣ the E-OCVM validation lifecycles

• Major interaction with P6.8.1 foreseen in definition of Pairwise Dynamic Separation concept (PWS)

TBS: Time-Based Separations  
WDS: Weather-Dependent Separations  
PWS: Pair-Wise Separations  
TRL: Technology Readiness Level
Summary & Outlook

• SESAR projects 9.11 & 9.30 will develop an airborne system that helps
  ‣ Improving wake turbulence safety in all phases of flight
  ‣ Enabling more efficient wake turbulence separation schemes

• Projects specifically address
  ‣ Operational concepts
  ‣ Technical feasibility and maturity
  ‣ Validation of safety and capacity gains

• Outlook
  ‣ Evaluate extended operational concepts and adaptation of functions in support of other separation systems like ASAS
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