

Presented by

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Research, Methods & Tools



SESAR projects 9.11 & 9.30

Aircraft systems for wake encounter alleviation

WakeNet3-Europe Specific Workshop on Concepts

8-FEB-2011, NATS

- **Introduction – Background**
- **Description of solutions & projects**
- **Operational concept and benefits**
- **Research Needs with regard to Operational Concepts**
- **Summary - Outlook**

- **Two wake vortex related projects are included 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**

- **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 ("concepts") 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

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 - On-board wake encounter prediction, alerting & avoidance systems → 9.11
 - On-board wake encounter alleviation systems → 9.30

- 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

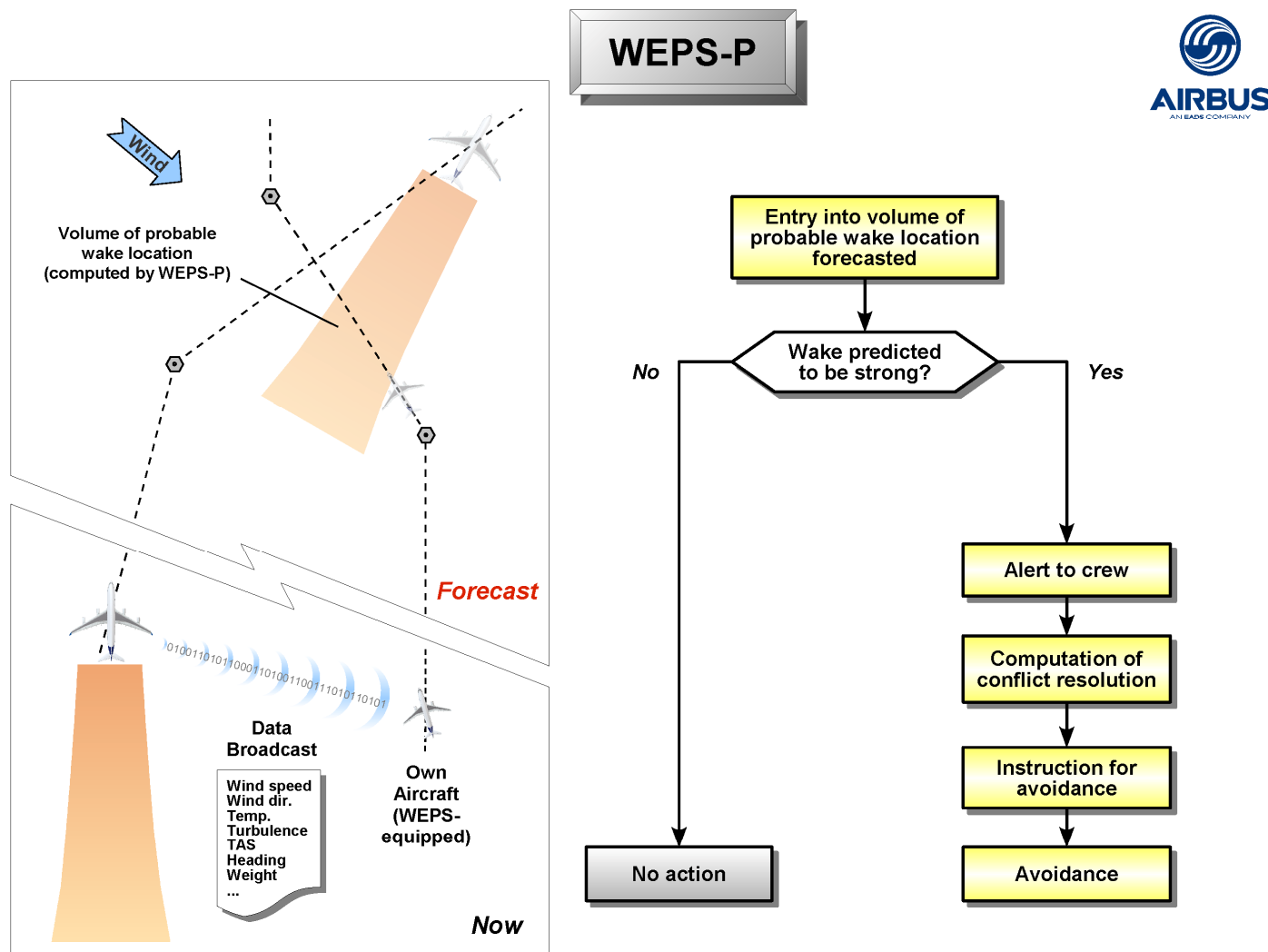
Wake Encounter Prevention System (WEPS)

WEPS-P (Prediction to Avoid) P9.11

WEPS-P – Scetch of operational principle



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

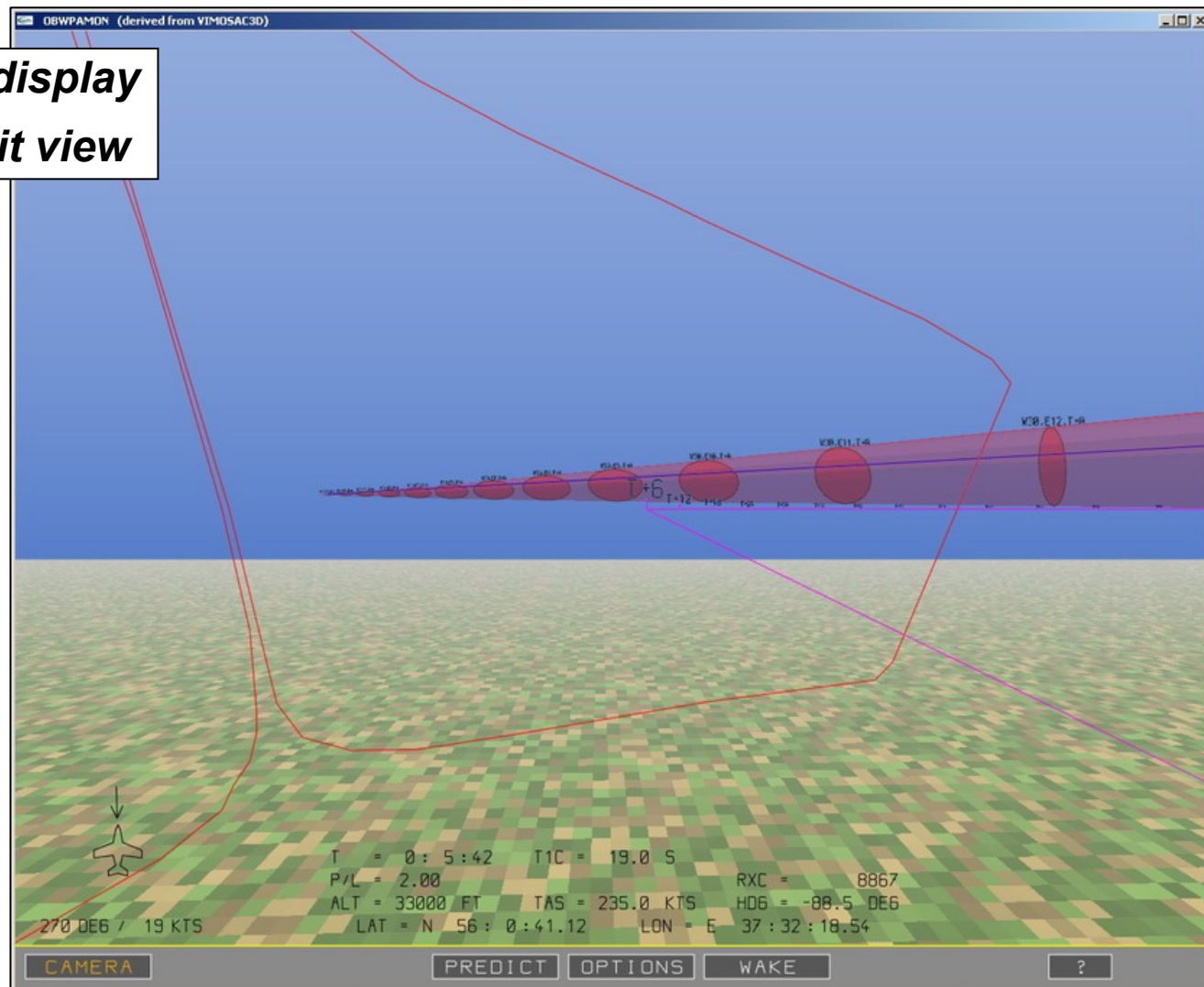


WEPS-P – Scetch of operational principle



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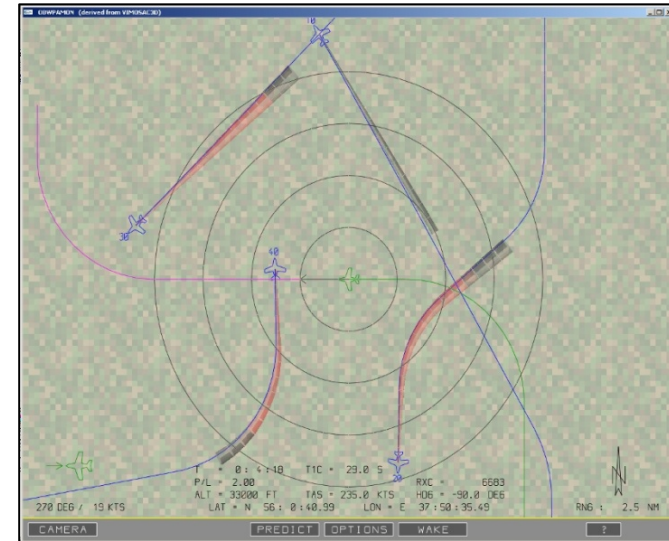
Engineering display
Out-of-cockpit view



WEPS-P – Specific sub-functions

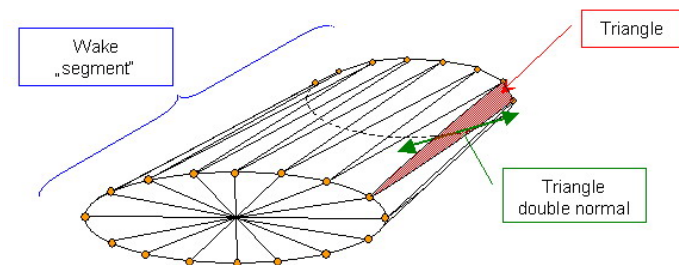
- **Prediction of evolution of wakes of surrounding aircraft enabled by**

- ▶ Probabilistic wake prediction models
- ▶ Broadcast of traffic and meteo data to WEPS-equipped A/C via ADS-B data link or comparable



- **Conflict Detection**

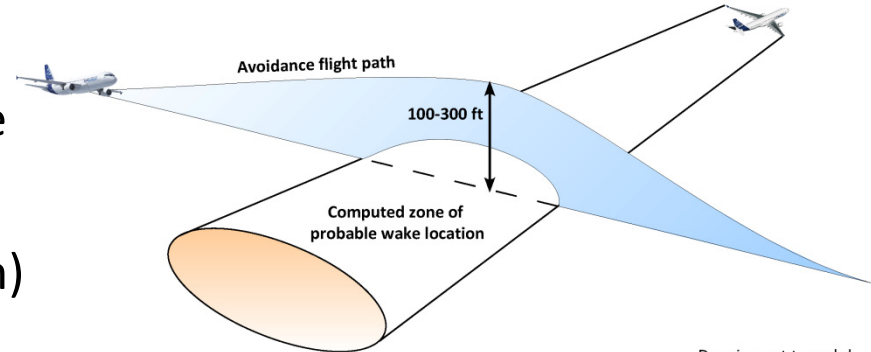
- ▶ Detection of conflict between intended flight path and predicted zone of wake location
- ▶ Decision for Alerting/Avoidance using encounter severity metrics developed and validated in P6.8.1



- **Conflict Resolution**

- ▶ Vertical avoidance manoeuvre
- ▶ Lateral avoidance manoeuvre
- ▶ Vert. + Lat. avoidance manoeuvre
- ▶ Speed adjustment
- ▶ Go-Around (during final approach)

Vertical Avoidance Manoeuvre



Drawing not to scale!

- **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



Display design specification, only !

Depicted size of vortex location zone is exaggerated.

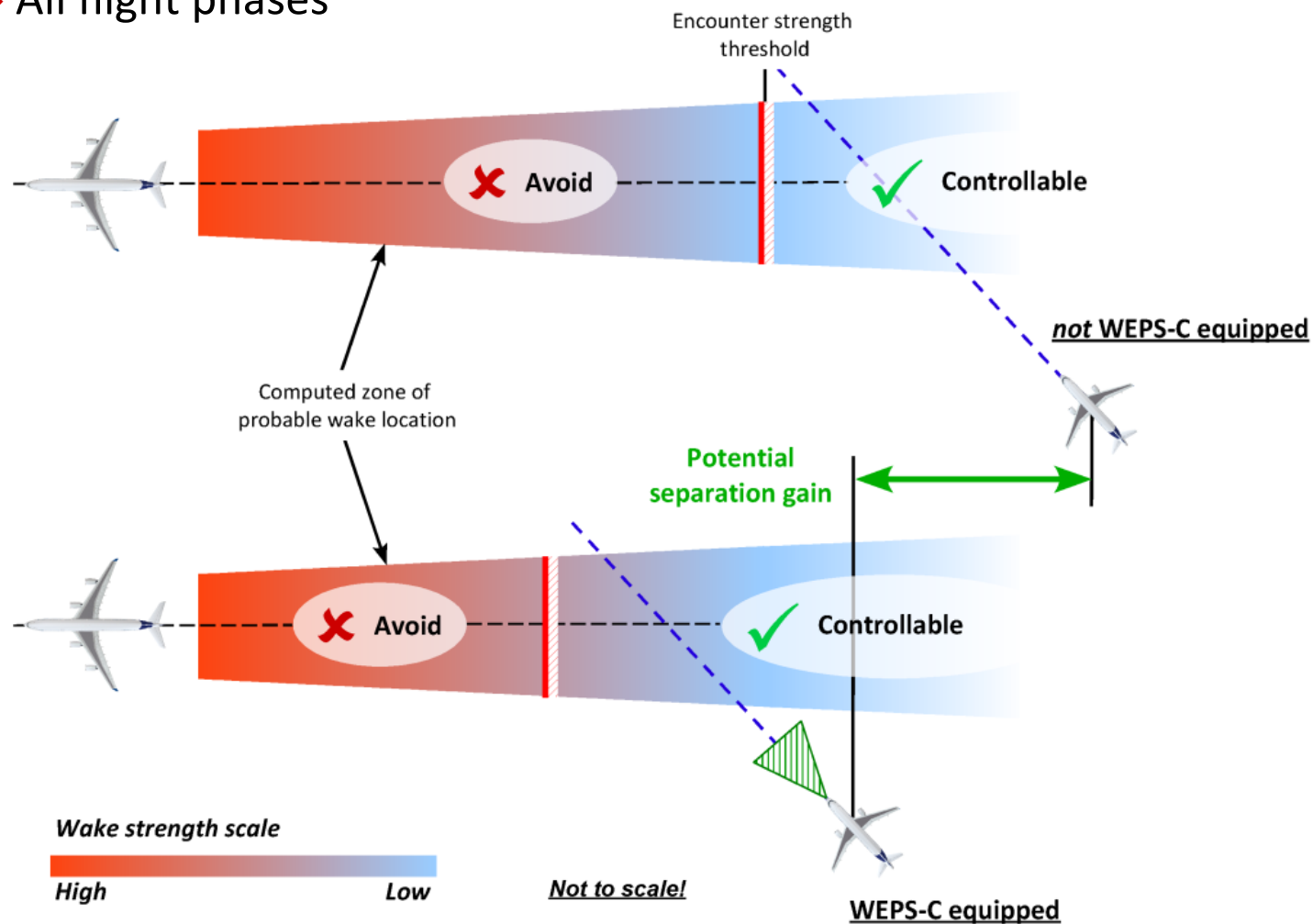
Wake Encounter Prevention System (WEPS)

WEPS-C (Control to Alleviate) P9.30

WEPS-C – Additional alleviation

- **WEPS-C : Additional capacity gain through alleviating flight control**

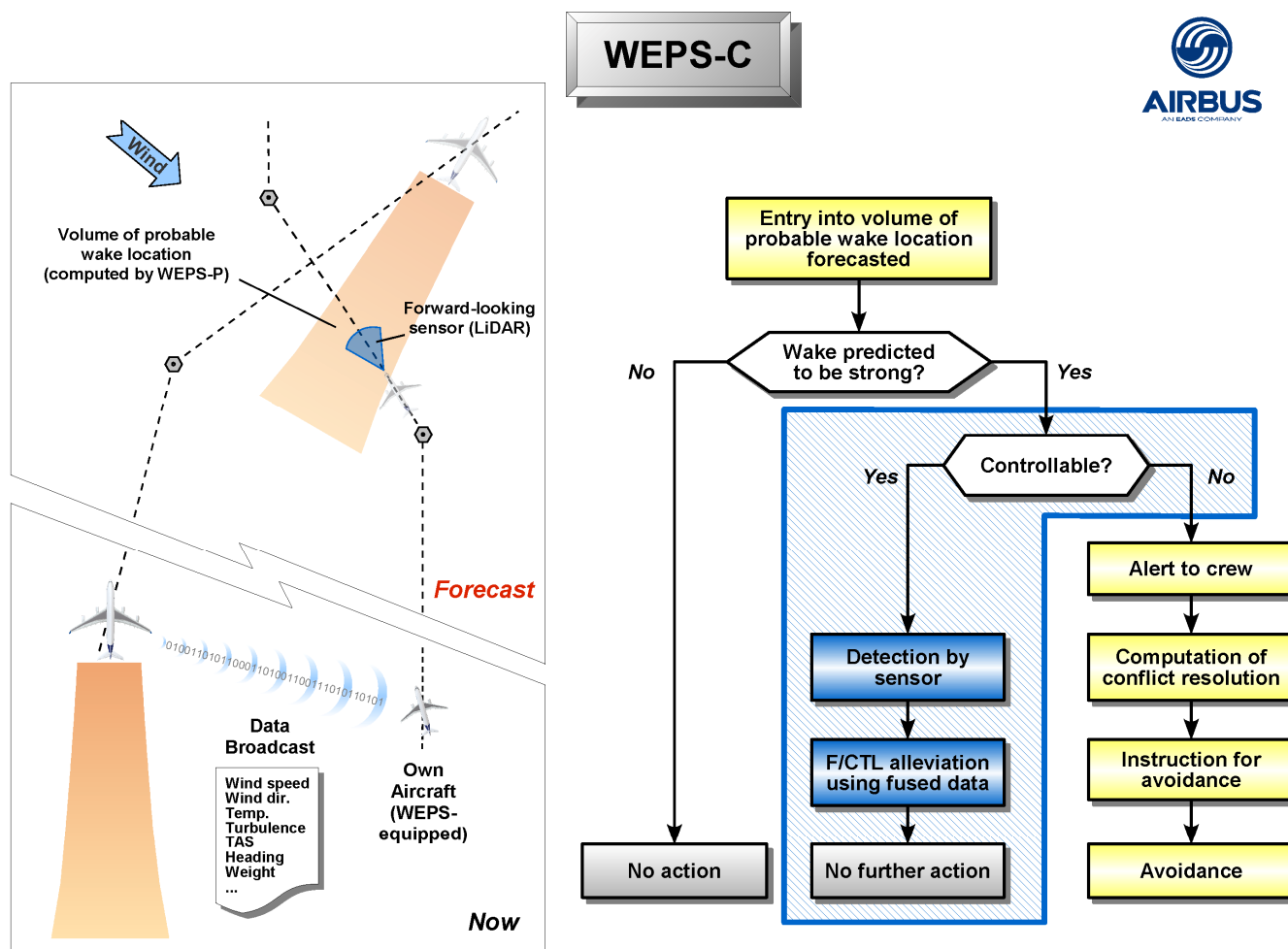
- ▶ All flight phases



WEPS-C – Scetch of operational principle



- Encounter alleviation system enabled by detection – all flight phases



► WEPS-C is an extension of WEPS-P functionality

- **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**

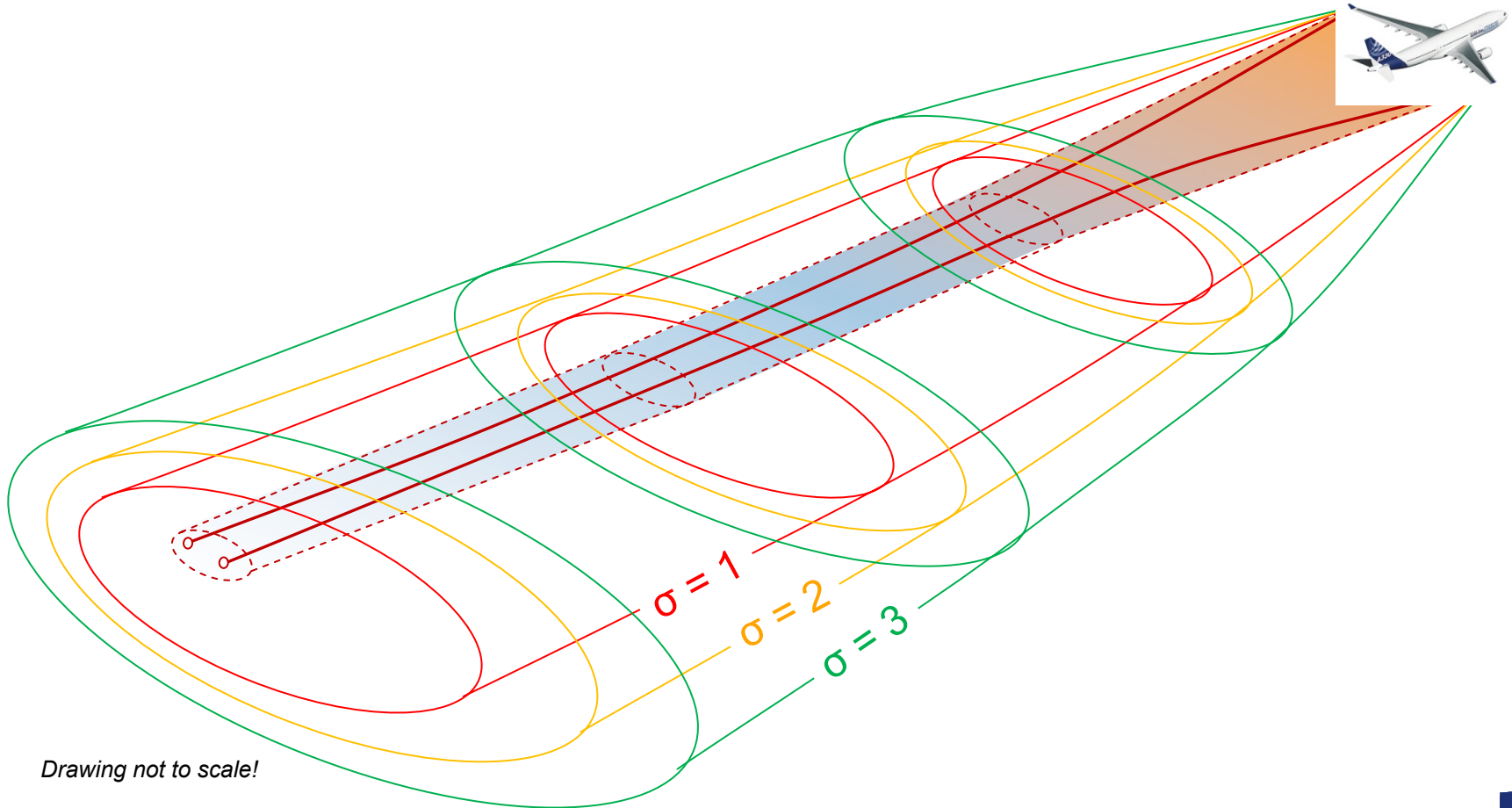
- ▶ Definition of pilot - flight control interaction
- ▶ Mode annunciation

- **Wake turbulence separation responsibilities**
 - ▶ No change versus today's methods of managing aircraft separations
- **Decreased aircraft vulnerability to wake encounter due to WEPS-C:**
 - ▶ Fully transparent
- **In case of predicted severe wake encounter, WEPS-equipped aircraft perform a short-term, small scale avoidance manoeuvre**
 - ▶ No approval through ATC (ACAS/TCAS like)
 - ▶ Potentially, automatic information to ATC (ACAS/TCAS)

- **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
 - Independent from new ATC separation schemes
 - ▶ **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.
 - Requires new separation scheme like pair-wise separations

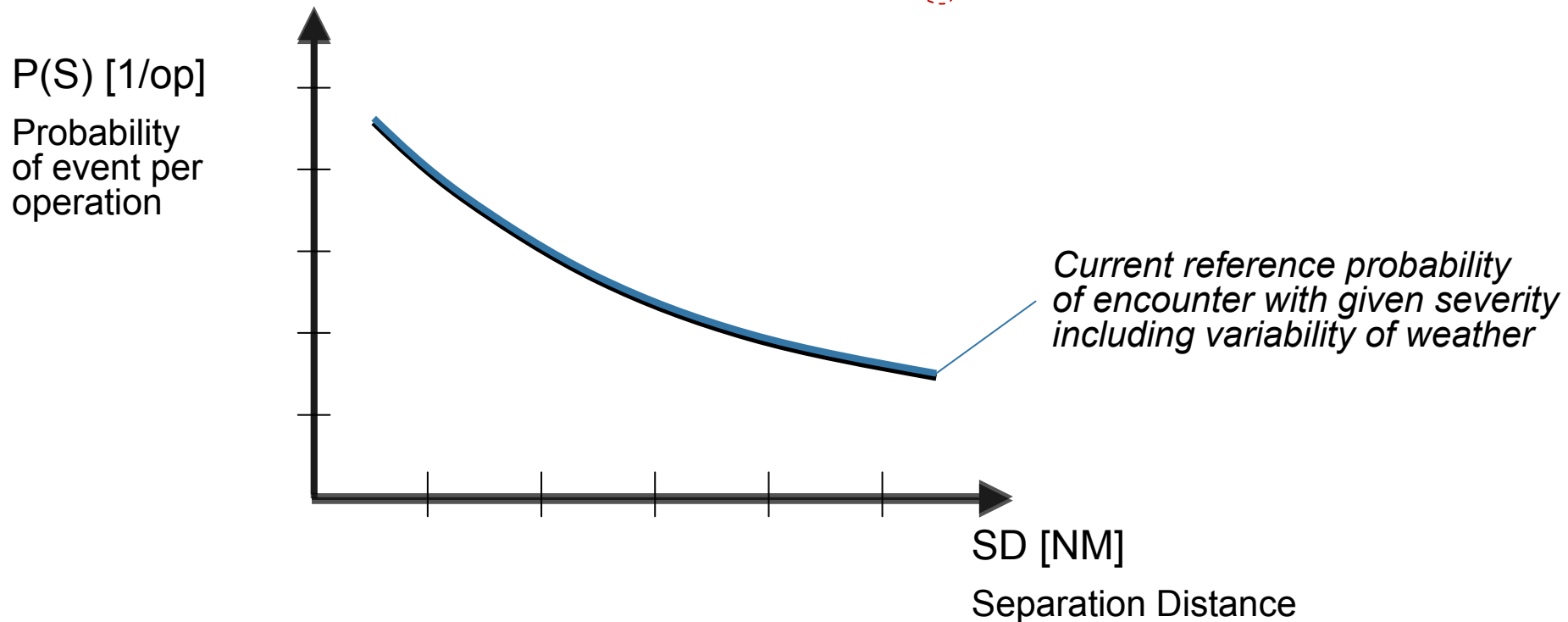
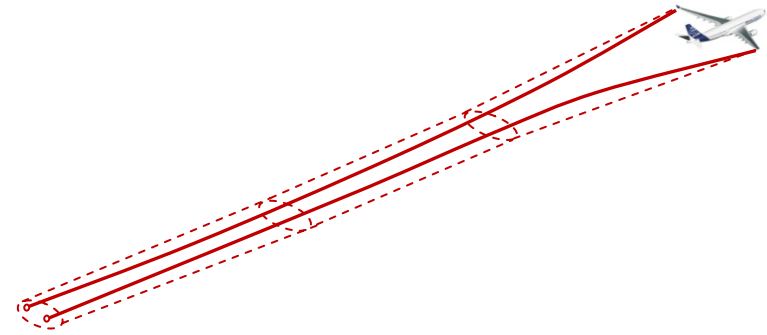
WEPS – Expected Benefits

- **WEPS-P (prediction to avoid):**
 - ▶ Probabilistic prediction with uncertainty



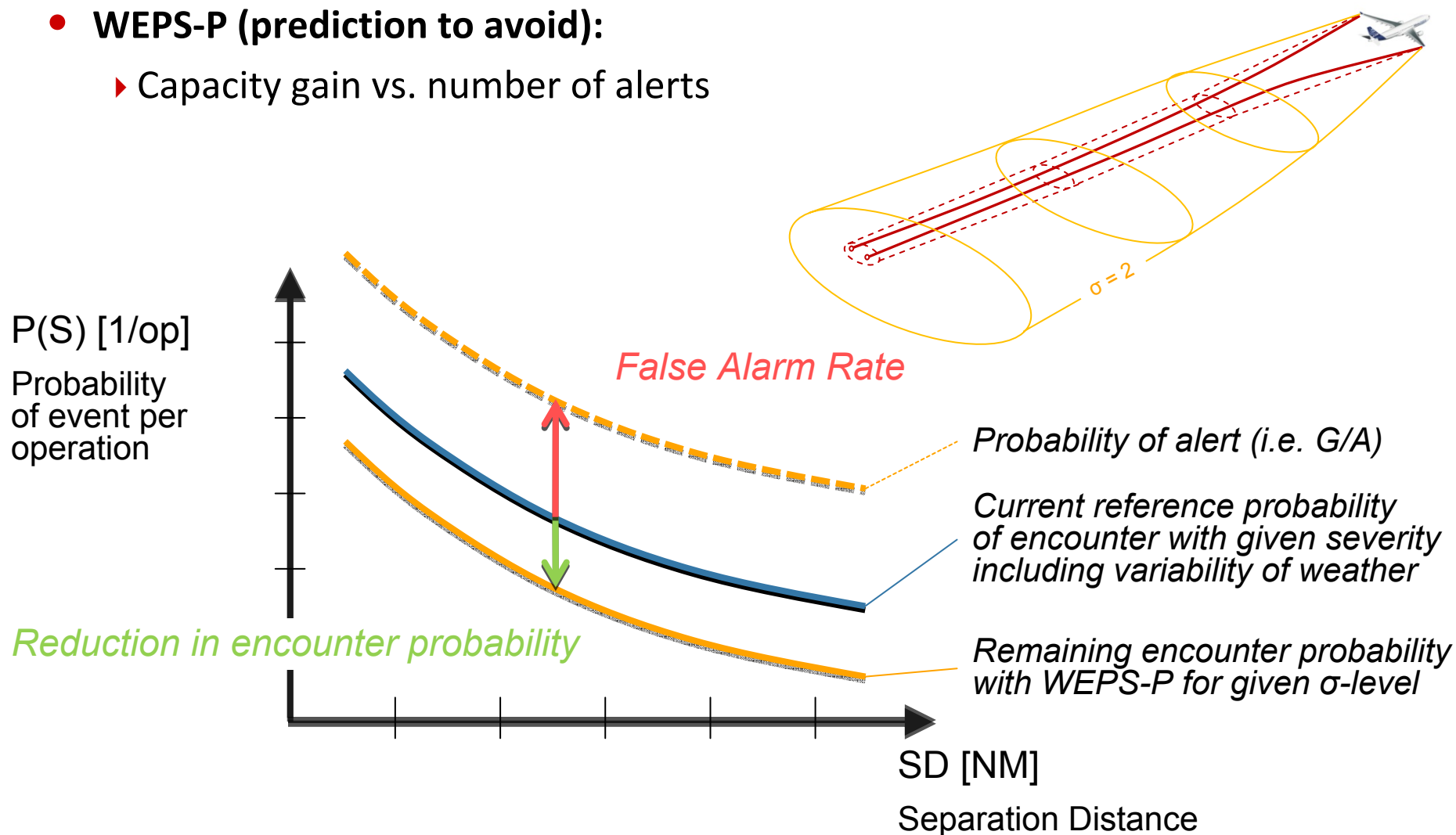
WEPS – Expected Benefits

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



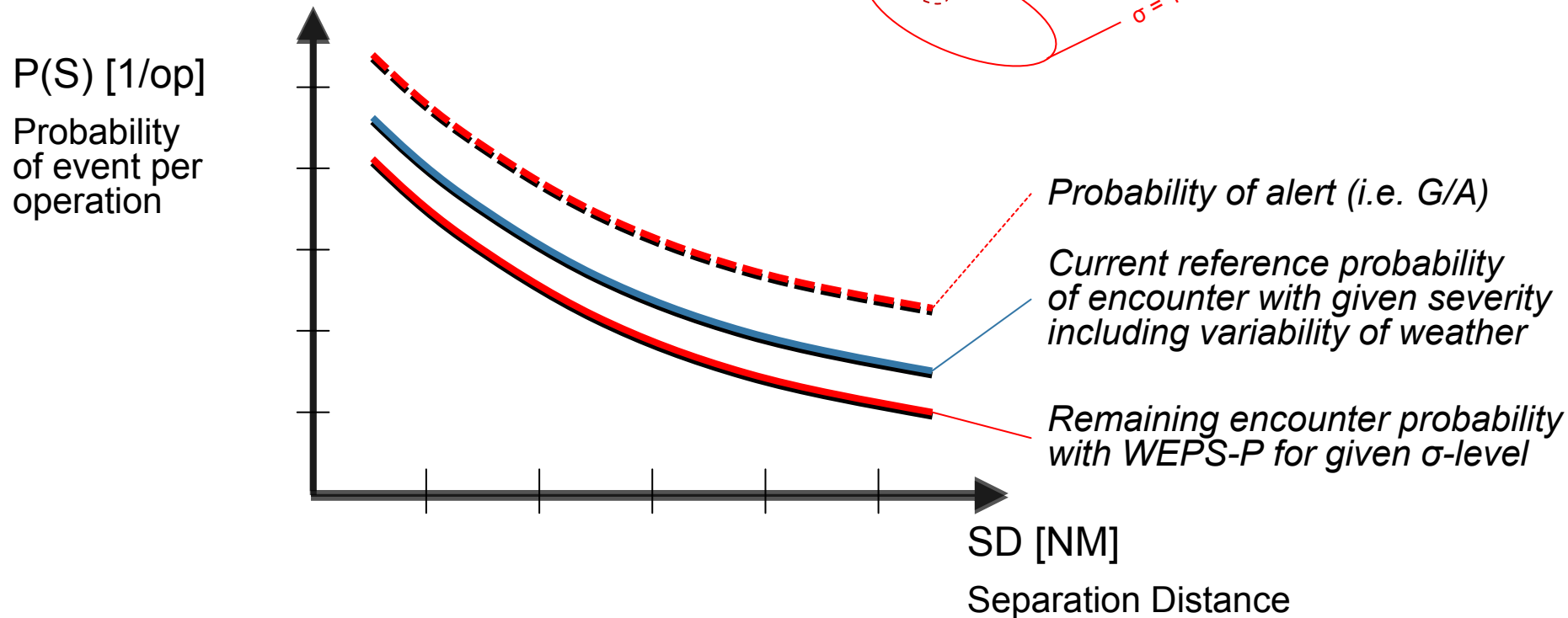
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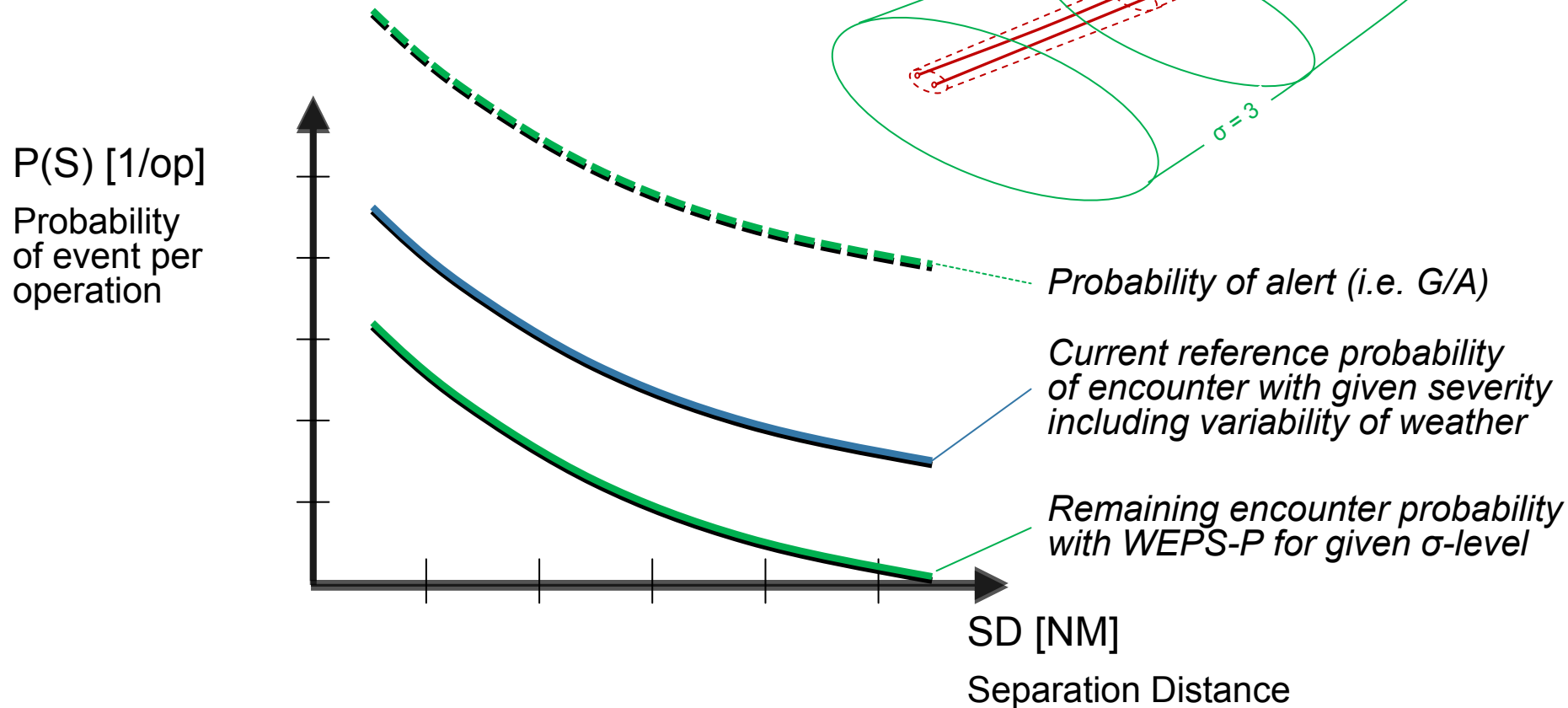
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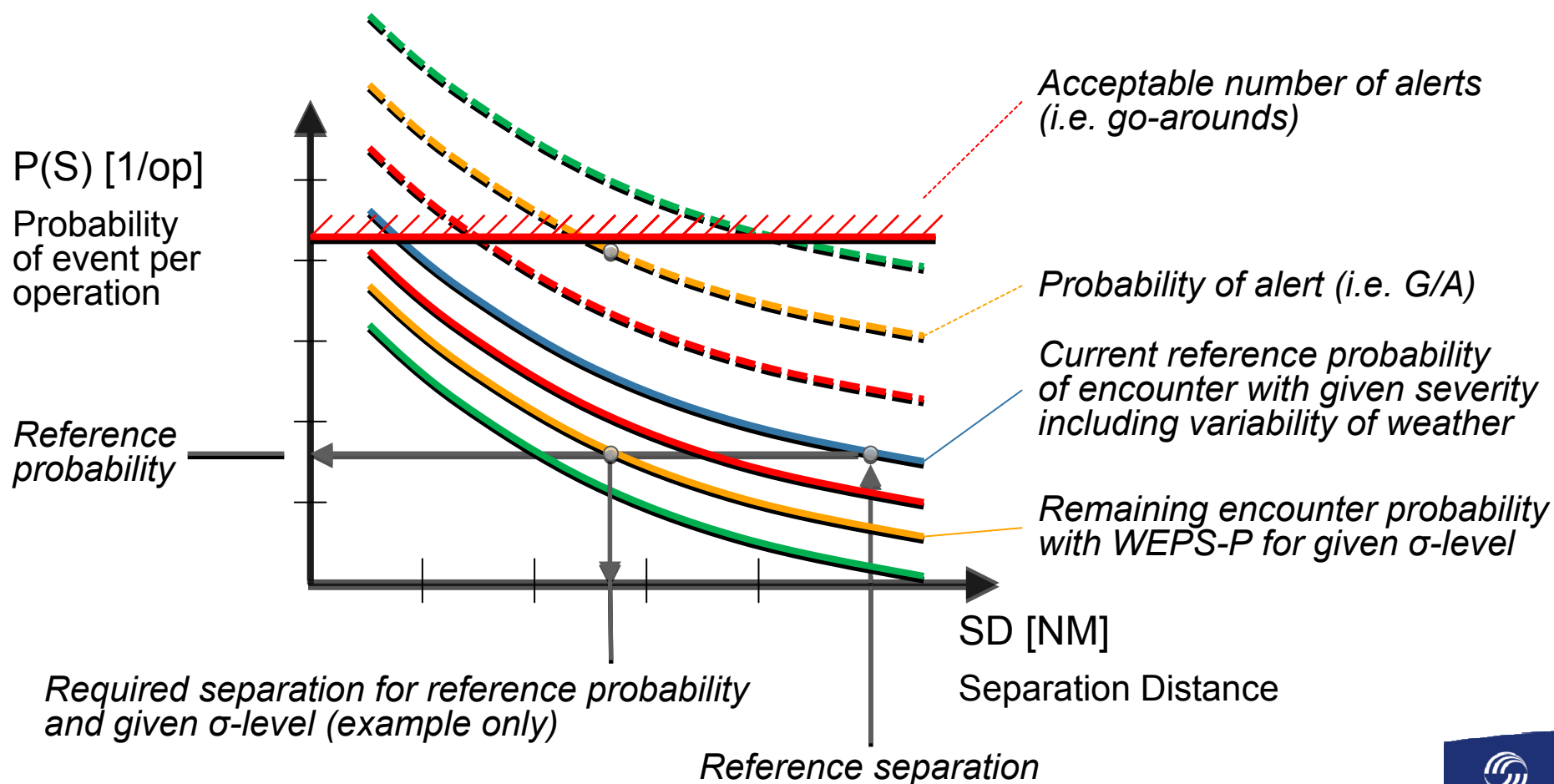
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WEPS – Expected Benefits



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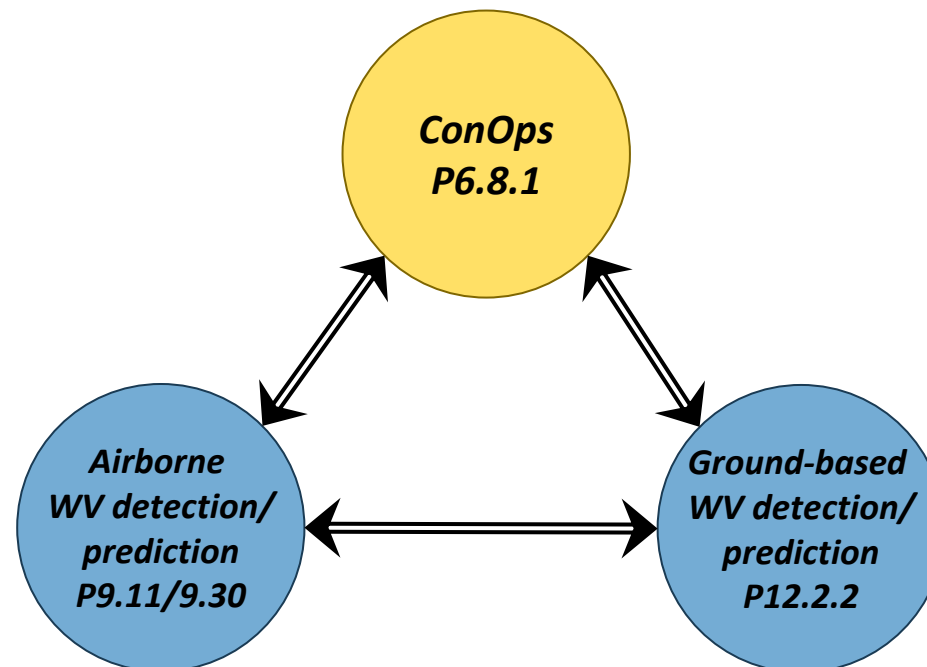
- **Develop and explore the concepts with regard to operational feasibility, benefits and acceptance:**
 - ▶ Concept of Operations
 - ▶ HMI and operating procedures
 - ▶ Human Factors
 - ▶ System integration & certification aspects

- **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

SESAR 9.11 & 9.30 – Interdependencies



- **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



SESAR 9.11 & 9.30 – Interdependencies



- **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 Turbulence Study Group
 - ▶ LiDAR sensor manufacturers
 - ▶ WakeNets
 - ▶ GreenWake project

- **Some selected issues related to Operational Concept**
 - ▶ Interaction with ATC in case of avoidance
 - No info at all ?
 - Automated downlink of system activation ?
 - Requirement for ATC clearance ?
 - ▶ Avoidance maneuver definition in case of manual flight / vectoring
 - ▶ HMI / Pilot interface
 - Is it helpful to display probable wake locations to the pilot ?

- **Research Needs related to Airborne Systems Operational Concept**
 - ▶ Harmonized and integrated wake vortex operational concepts
 - Assure harmonization between airborne and ground-based wake vortex advisory systems and their contributions and roles in the context of new wake vortex separation rules.
 - Use of airborne wake vortex system and benefits in the context of future air traffic operational concepts (e.g. ASAS Self Separation).
 - ▶ Safety assessment
 - Additional activities are needed to identify how the capabilities of airborne wake vortex systems can / have to be taken into account in wake vortex safety assessments

- **SESAR projects 9.11 & 9.30 evaluate an airborne system that shall**
 - ▶ Improve wake turbulence safety in all phases of flight
 - ▶ Enable more efficient wake turbulence separation schemes
- **Projects specifically address**
 - ▶ Operational concepts
 - ▶ Technical feasibility and maturity
 - ▶ Validation of safety and capacity gains
- **Outlook & Research Needs**
 - ▶ Evaluate extended operational concepts and adaptation of airborne wake vortex functions in support of other separation systems like ASAS

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