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**

Background - Motivation

- **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

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

WEPS

- **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

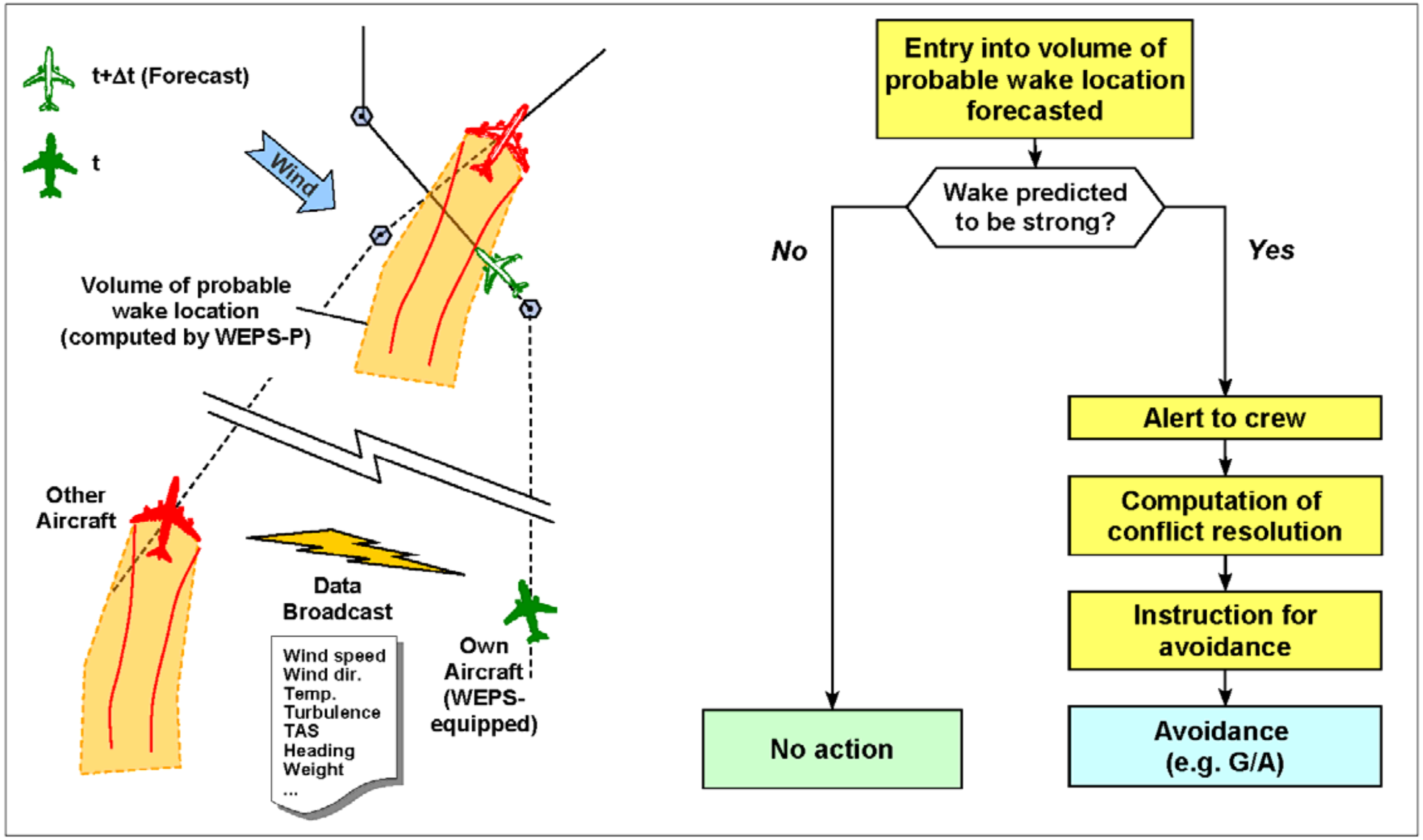
- Alleviation of wake encounter upsets through dedicated flight control function
- More robust, less vulnerable aircraft
- Based on current and new air data sensors, including forward-looking LiDAR

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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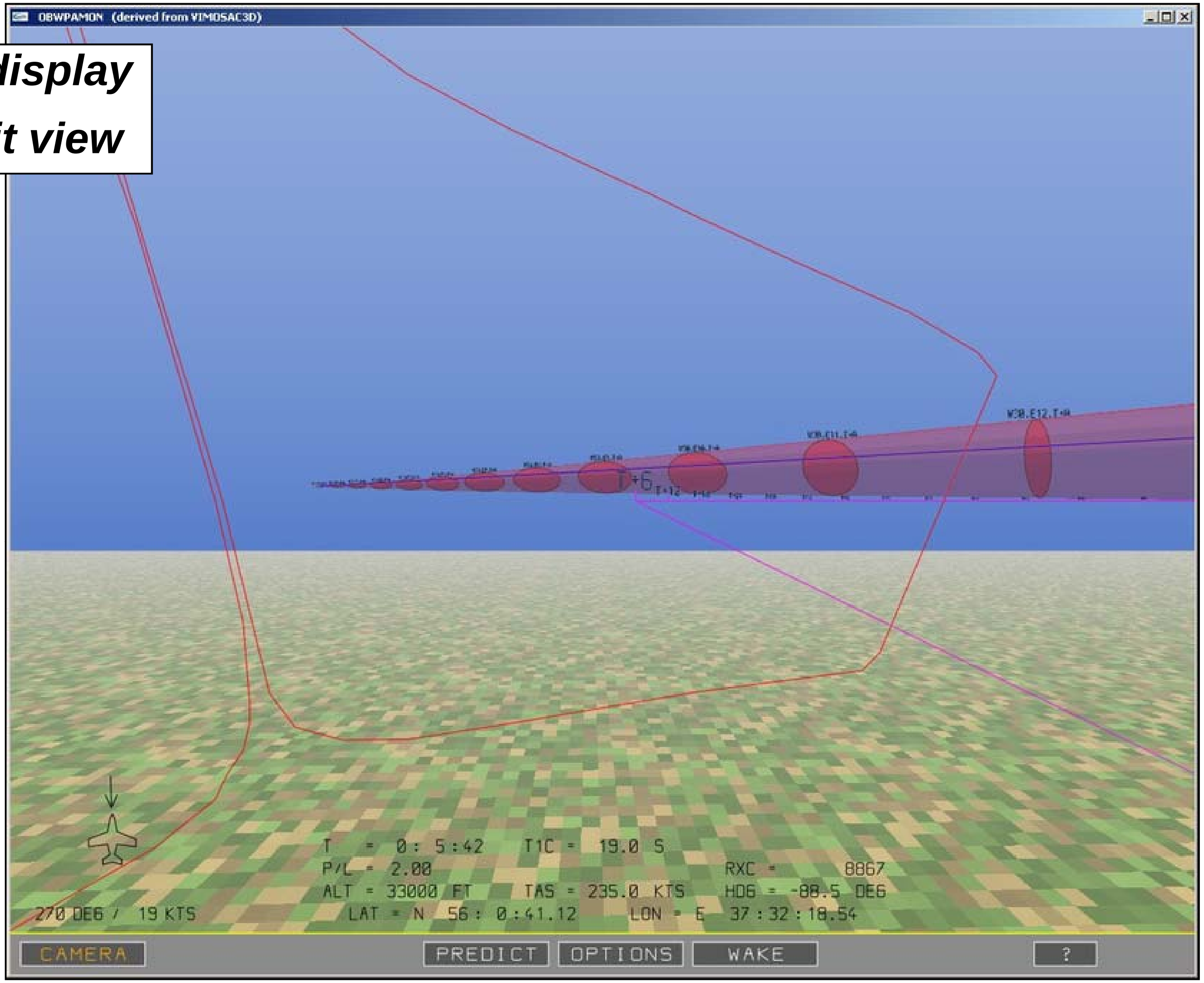
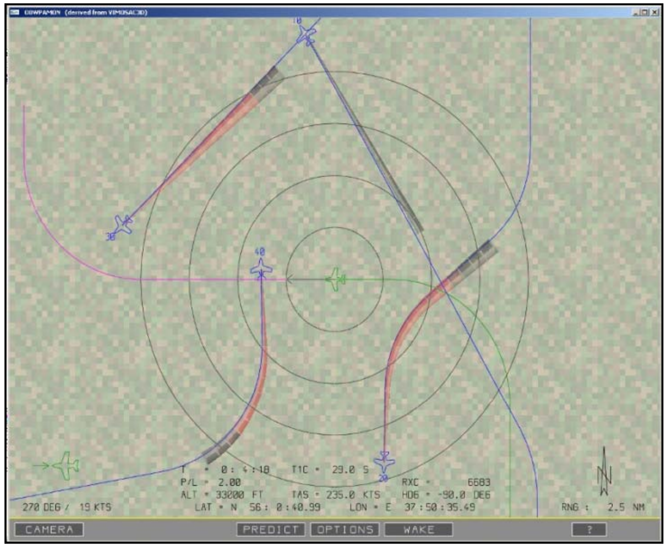
Engineering display

Out-of-cockpit view

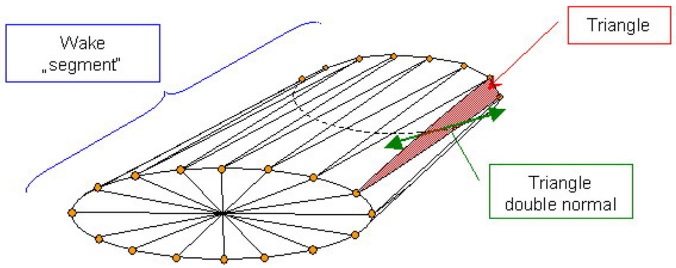


WEPS-P – Specific sub-functions

- **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



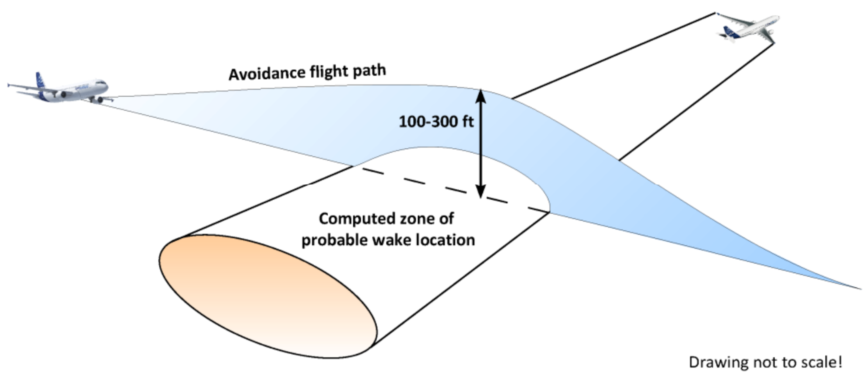
- **Conflict Detection**
  - Detection of conflict between intended flight path and predicted zone of wake location
  - Decision for Alerting/Avoidance using encounter severity metrics developed and validated in P6.8.1



WEPS-P – Specific sub-functions

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

Vertical Avoidance Maneuver



- **Human Machine Interface & Human Factors**
  - Presentation of information to the pilots
  - Alerting logic

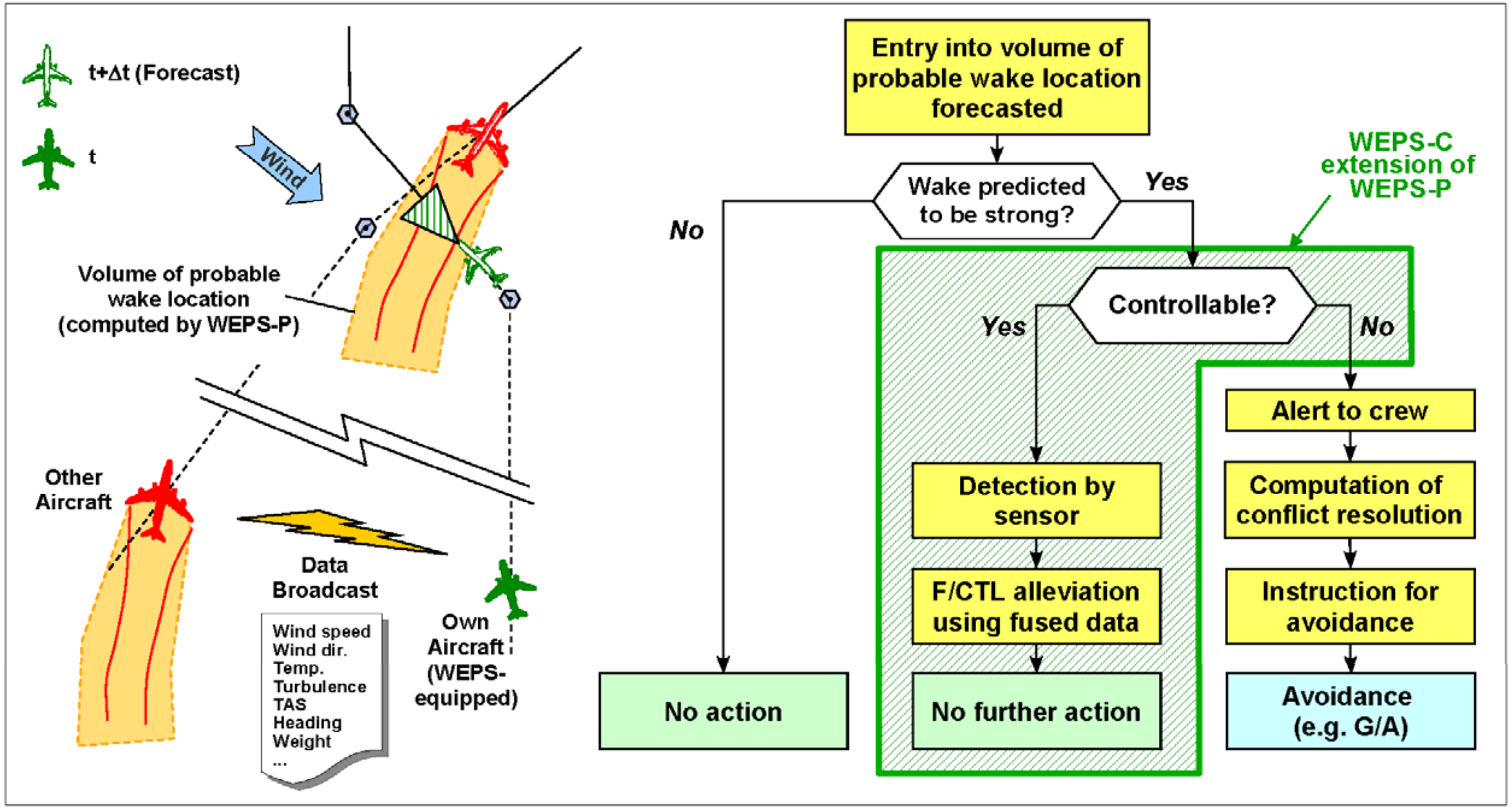
- **System interfaces**
  - Interaction with existing surveillance systems
  - Inputs from other airborne systems

Wake Encounter Prevention System (WEPS)

WEPS-C (Control to Alleviate) P9.30

WEPS-C – Scetch of operational principle

- **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

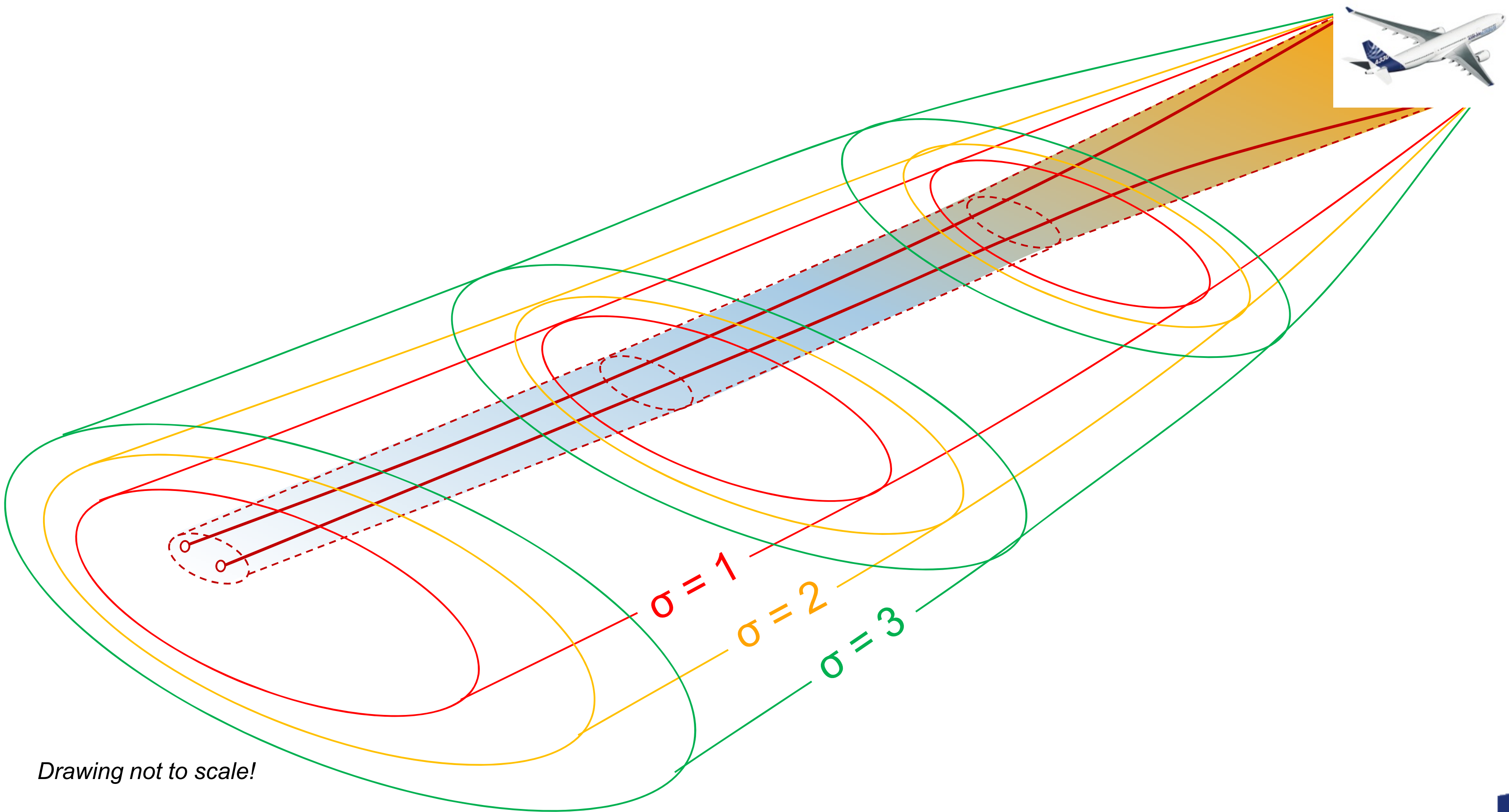
- **Solution delivers benefits in two main areas:**

  - 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.

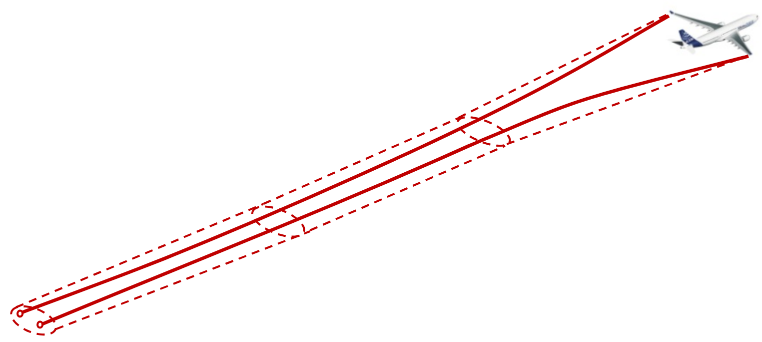
WEPS – Expected Benefits

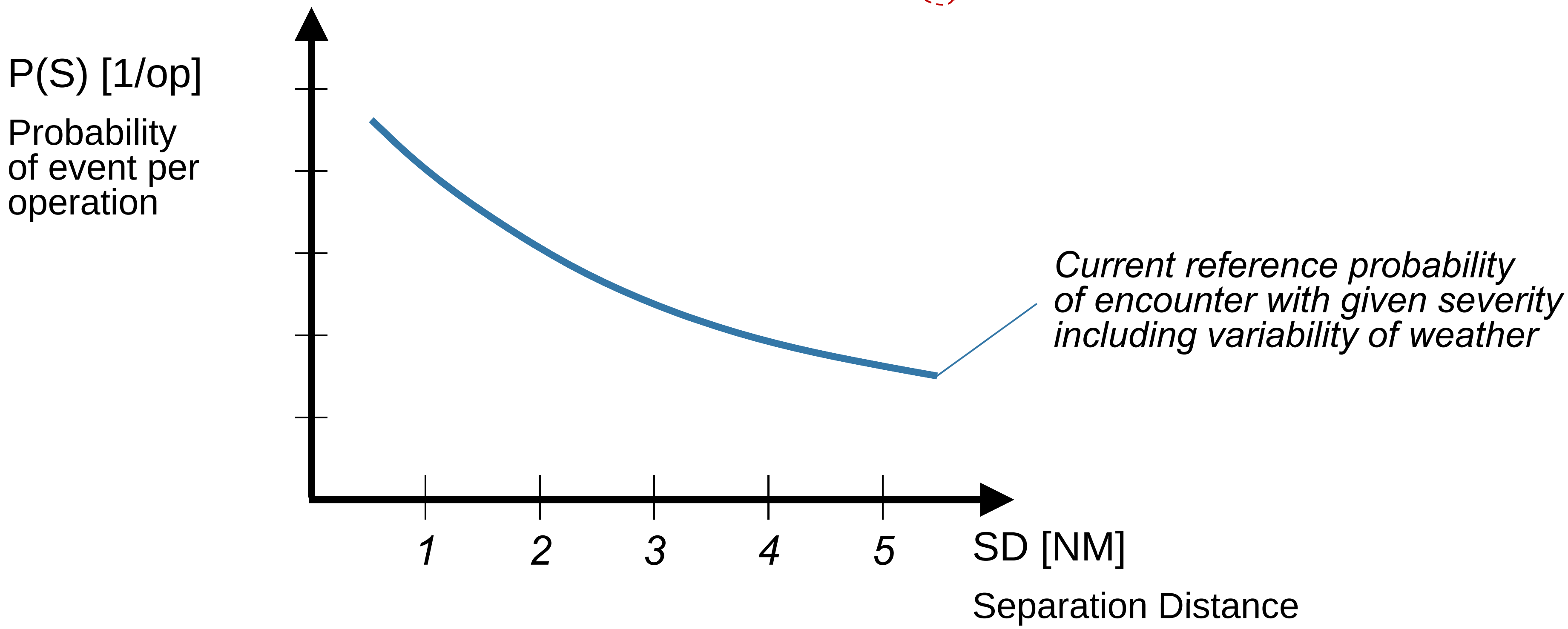
- **WEPS-P (prediction to avoid):**
  - Probabilistic prediction with uncertainty



WEPS – Expected Benefits

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





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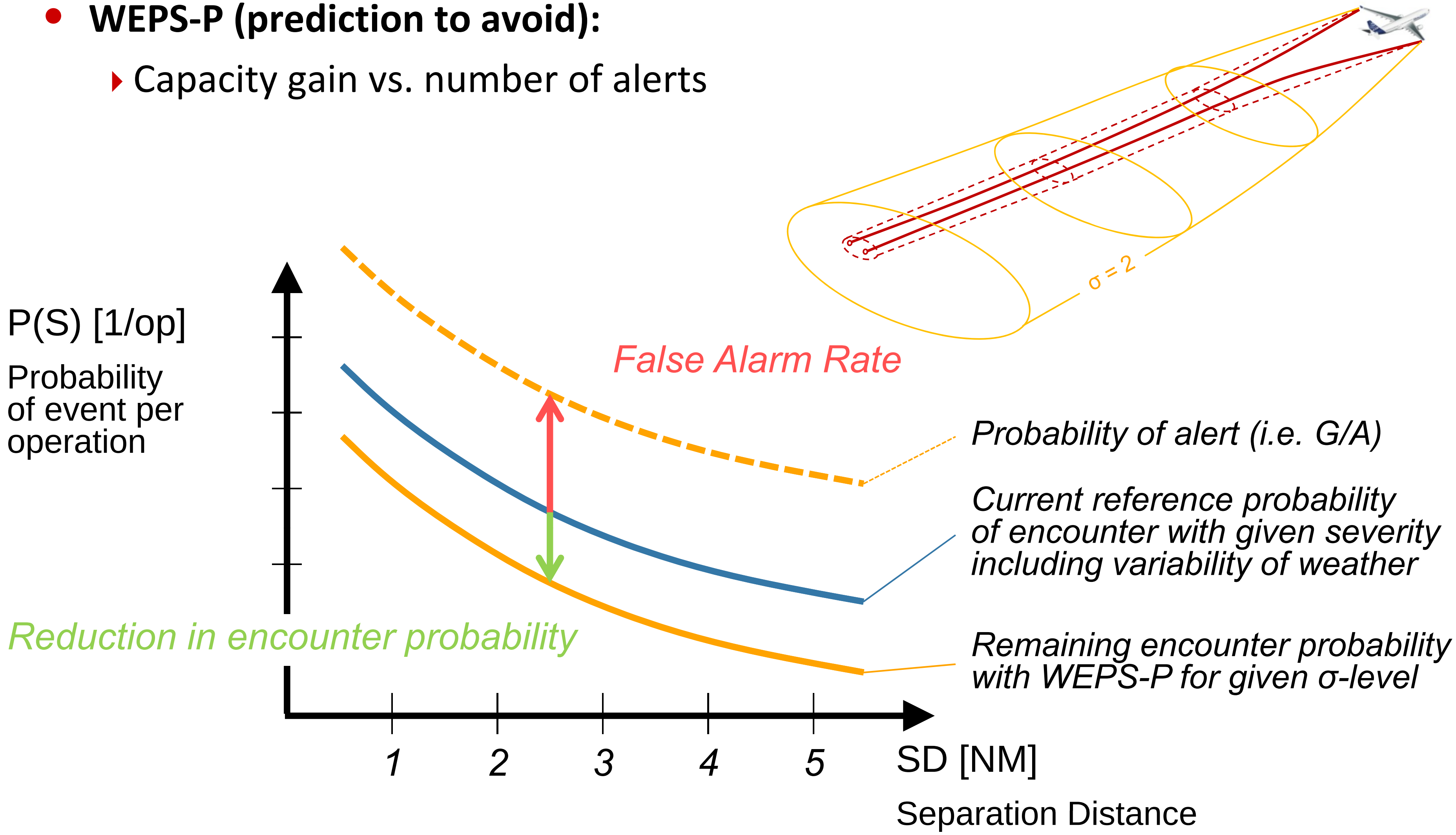

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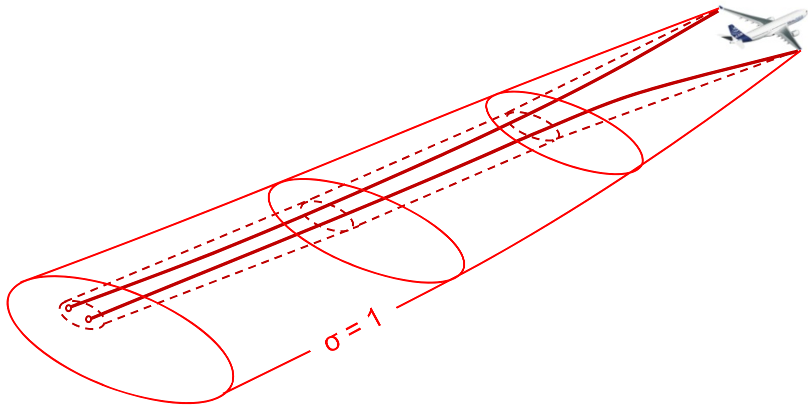

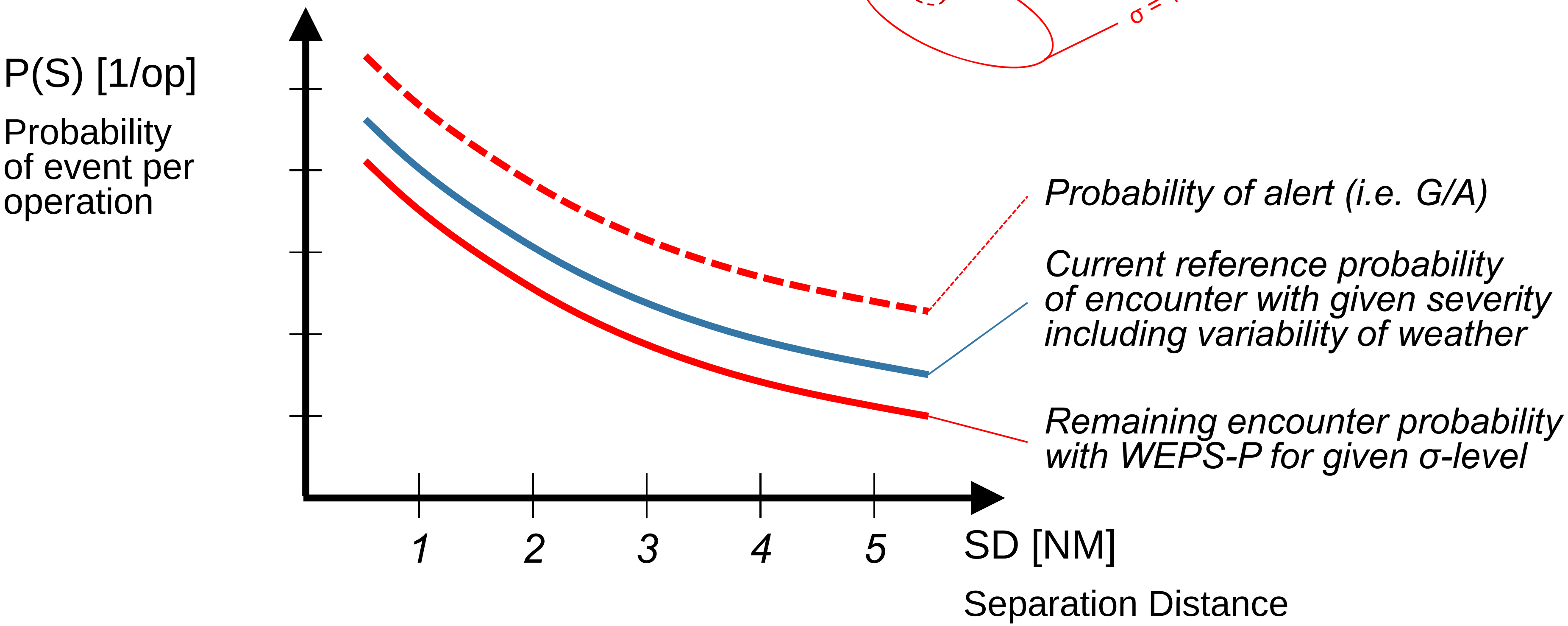

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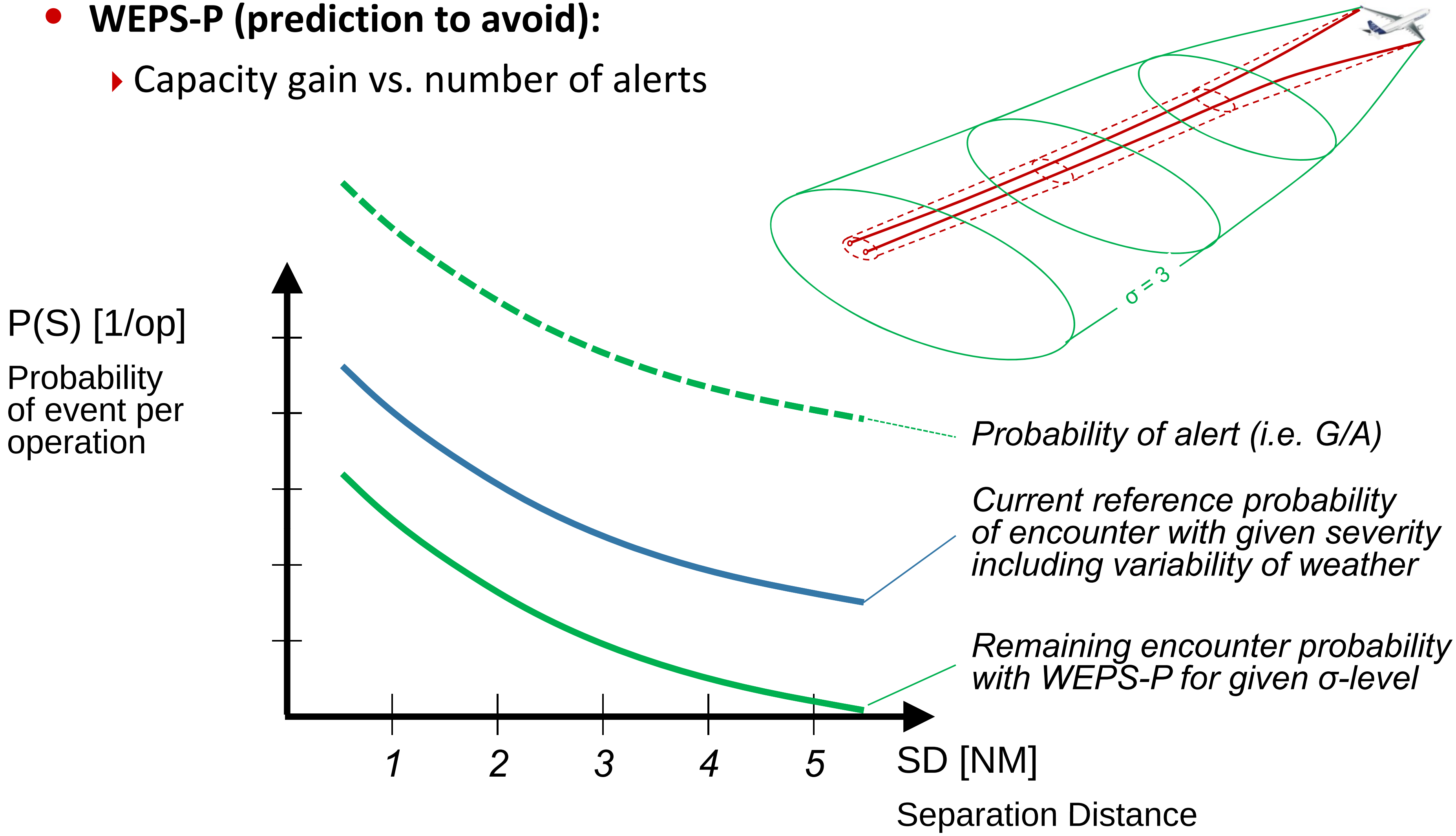

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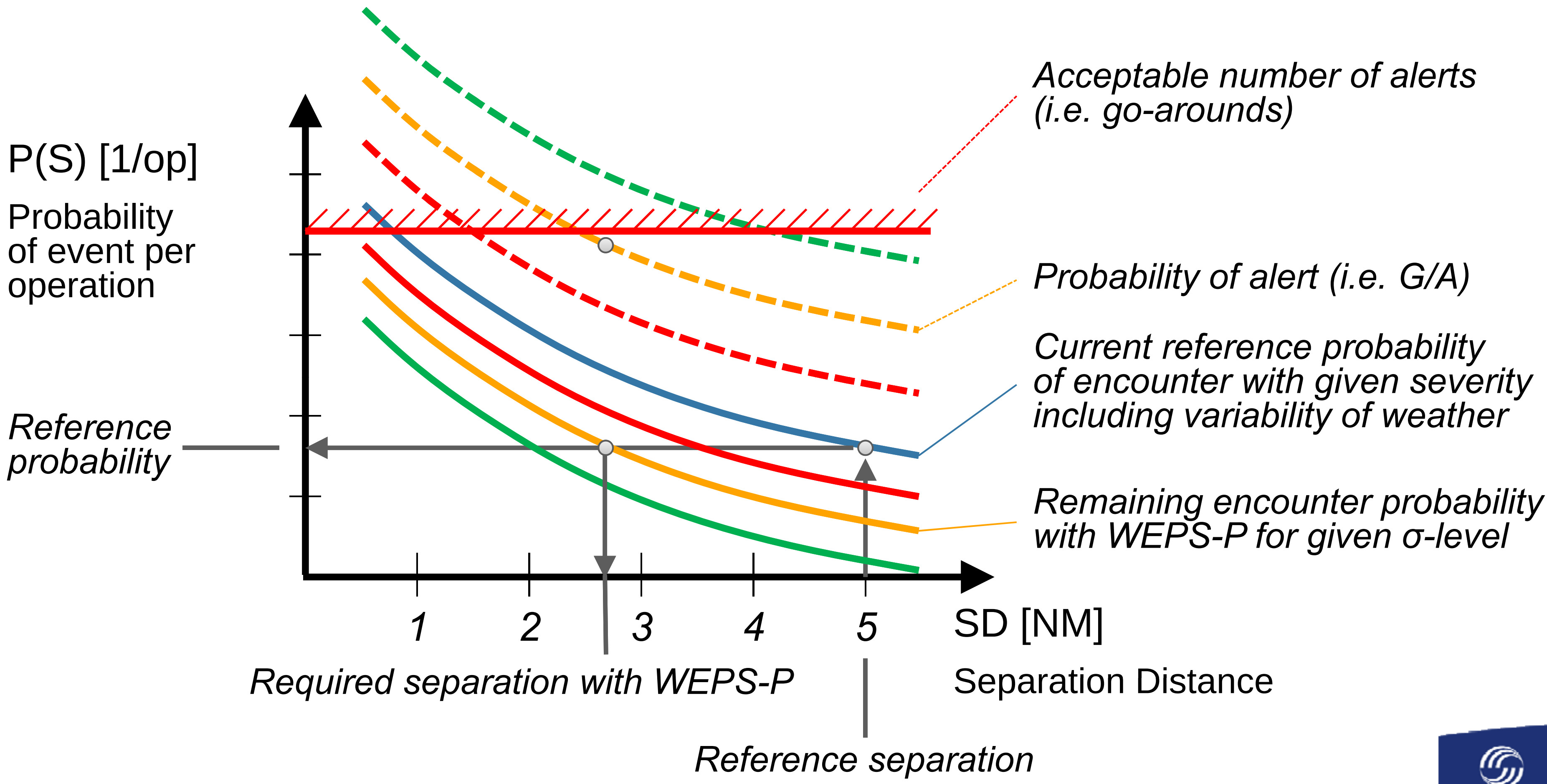
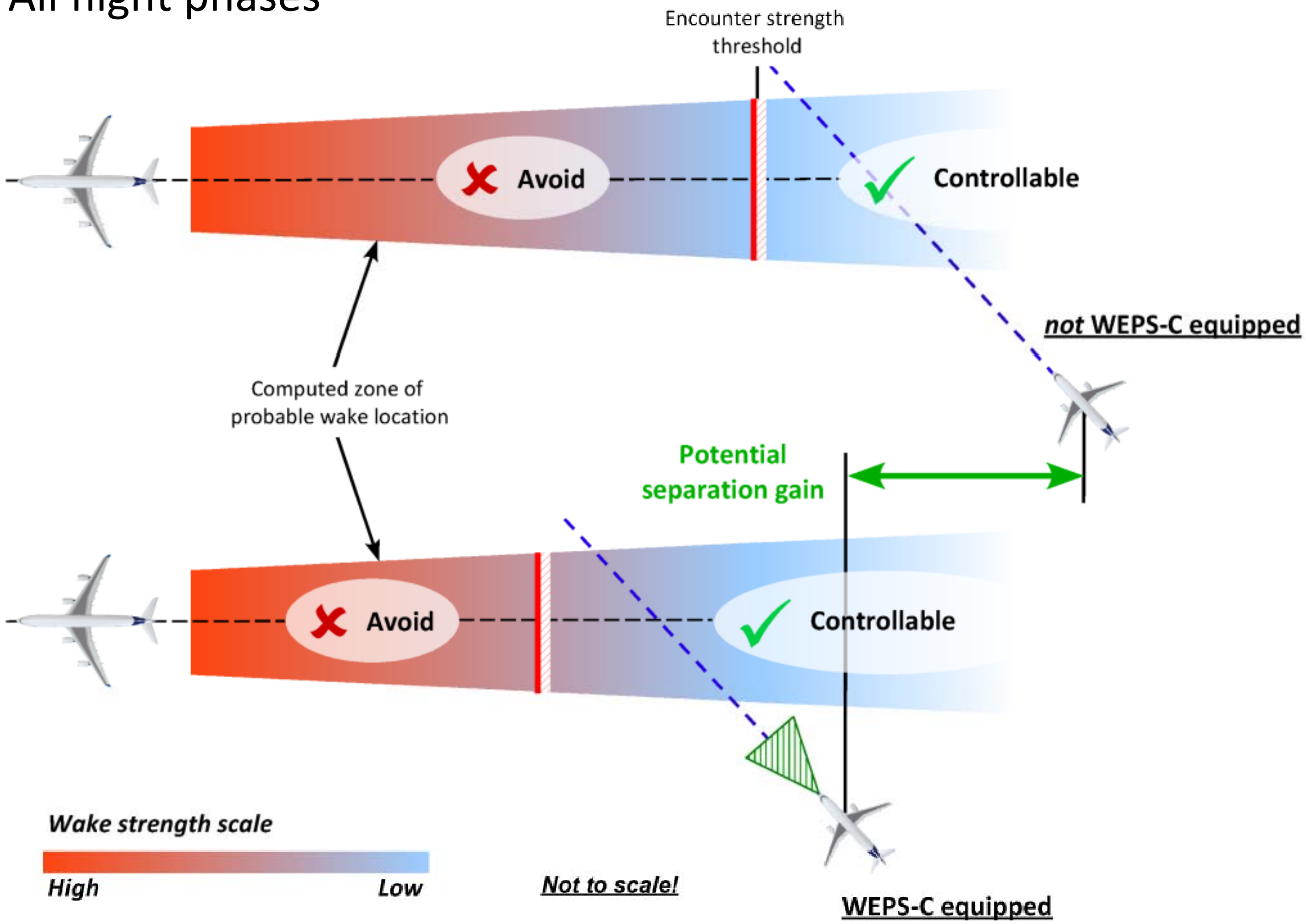


WEPS – Expected Benefits

- **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

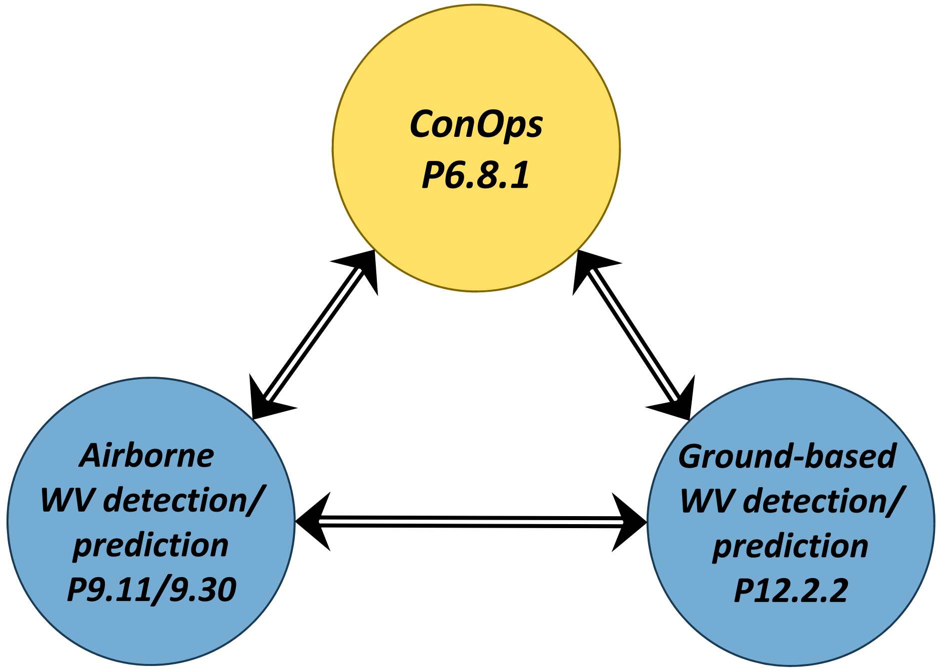
SESAR 9.11 & 9.30 – Scope

- **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

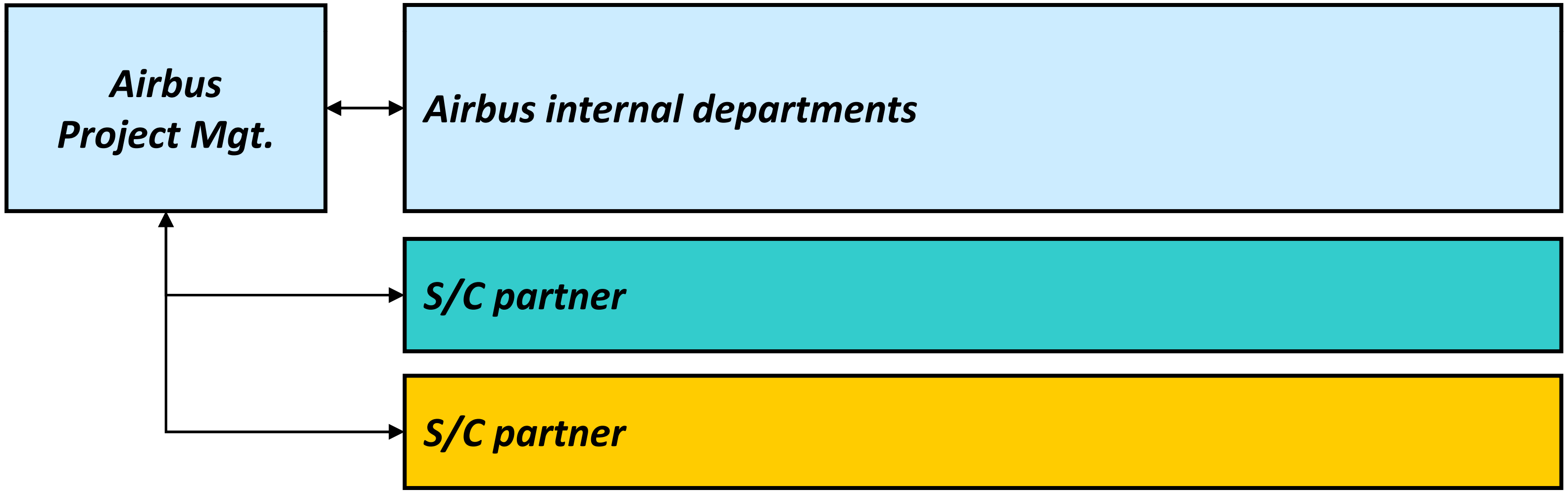
- **Additional interdependencies with other SESAR projects, e.g:**
  - P9.21/9.22 ADS-B capabilities evolution
  - P9.47 New TCAS evolution
  - WP 4/5 Consideration of solution in high-level en-route and TMA concepts

- **Links outside SESAR include:**
  - Standardization bodies (RTCA, EUROCAE)
  - ICAO Wake Vortex Study Group
  - LiDAR sensor manufacturers
  - WakeNet
  - GreenWake project

SESAR 9.11 & 9.30 – Workshare

- **Airbus is sole project member in both projects**
- **Several Airbus departments contributing to projects**
  - Cockpit Functions
  - Human Factors
  - Communication/Navigation/Surveillance
  - Flight & Integrations tests ...

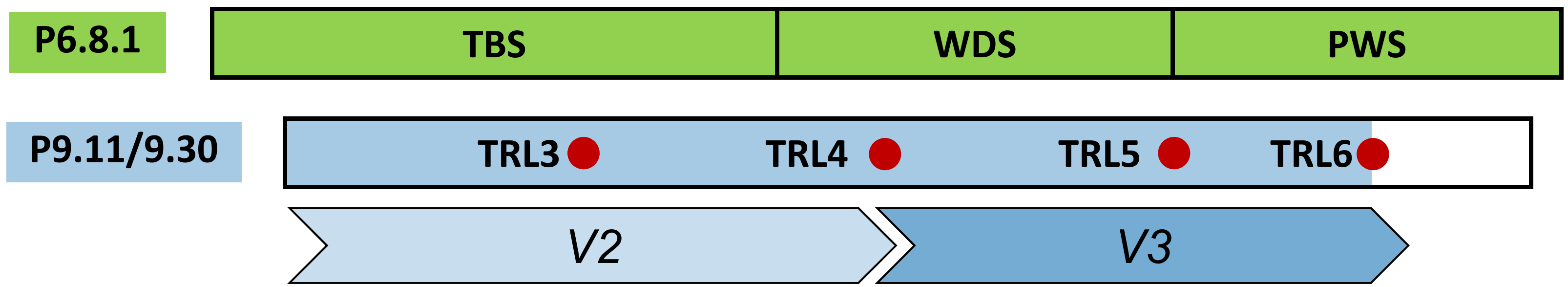
- **Some specific tasks will be subcontracted to external partners**



SESAR 9.11 & 9.30 – Global schedule

- **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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