Towards a Wake Encounter Advisory & Avoidance System – Recent work at DLR

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Content

[Photo: Hahn]

- **Background:**
  DLR Internal Project “Wetter und Fliegen”
- **Motivation and Objectives:**
  Wake Encounter Advisory & Avoidance (WEAA) System
- WEAA **System Architecture**
- **Existing System Components**
- **Recent Work**
  - Trajectory Generation
  - (E)GPWS Alert Avoidance
  - Human Machine Interface
- **Future Work**

DLR Project Wetter & Fliegen (Weather and Flying)

Objective: Increased safety and efficiency of air traffic with
weather information in the TMA and **optimised aircraft behaviour**

Time frame: 2008 - 2011

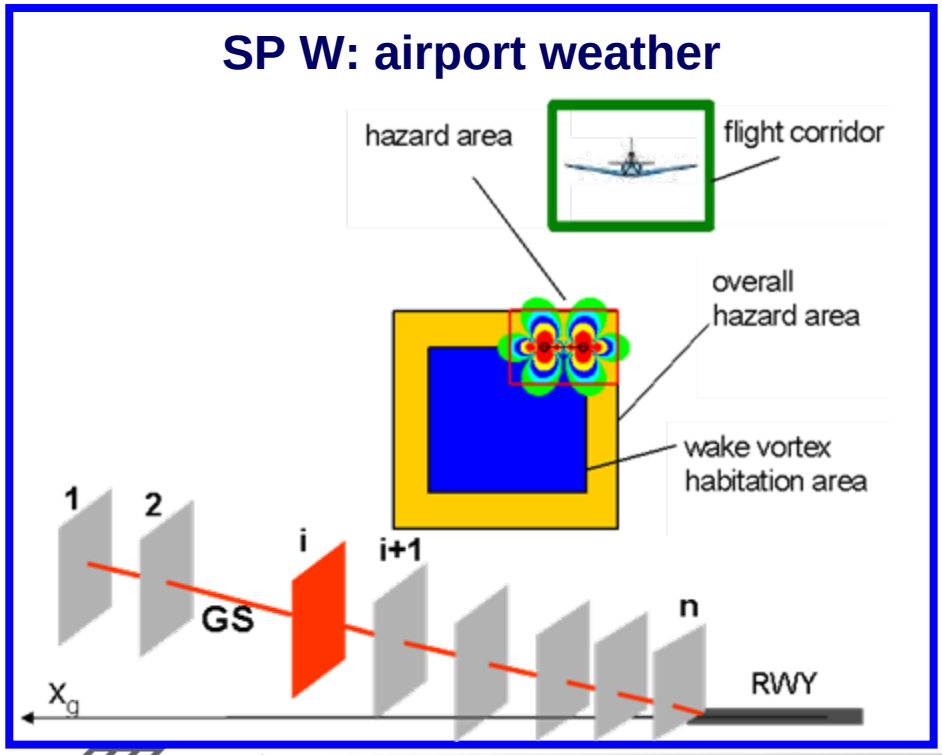
DLR & partners: DWD, HYDS, EADS

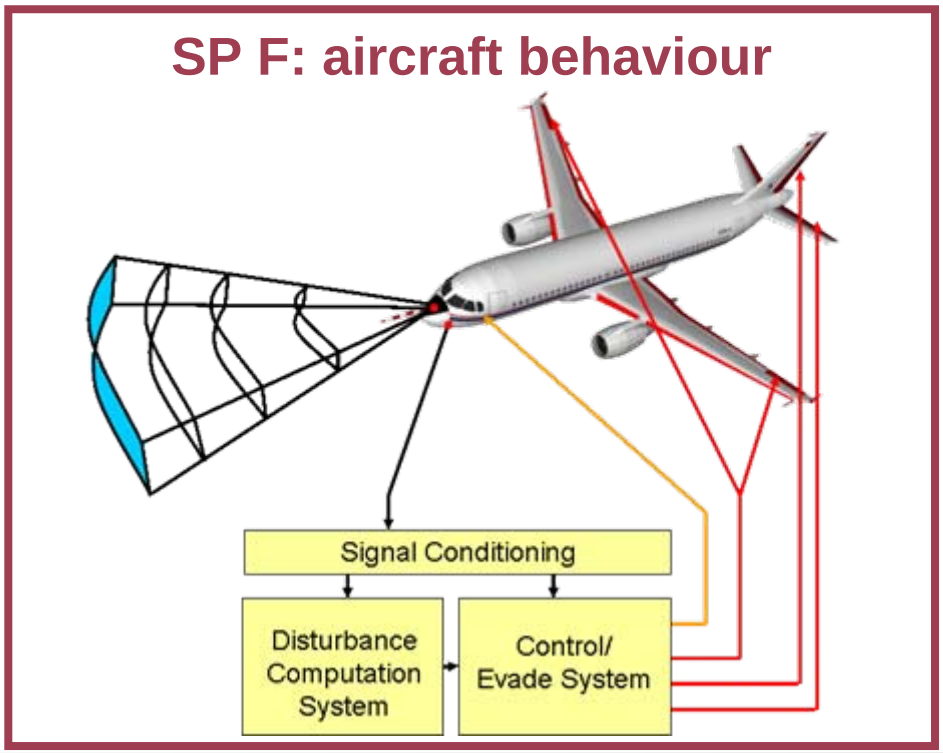
SP W: airport weather

integrated airport weather systems for wake vortex, thunderstorms and winter weather

SP F: aircraft behaviour

systems for control, monitoring and information for improved aircraft behaviour in gusts, wake vortices and thunderstorms





Motivation: Wake Encounter Advisory & Avoidance (WEAA)

- 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)
  - ⇒ stay within navigation limits
- <u>DLR objectives:</u>
  system proof-of-concept,
  in-depth investigation of selected components


[Drawing: FLYSAFE / Airbus; Photo: airliners.net]

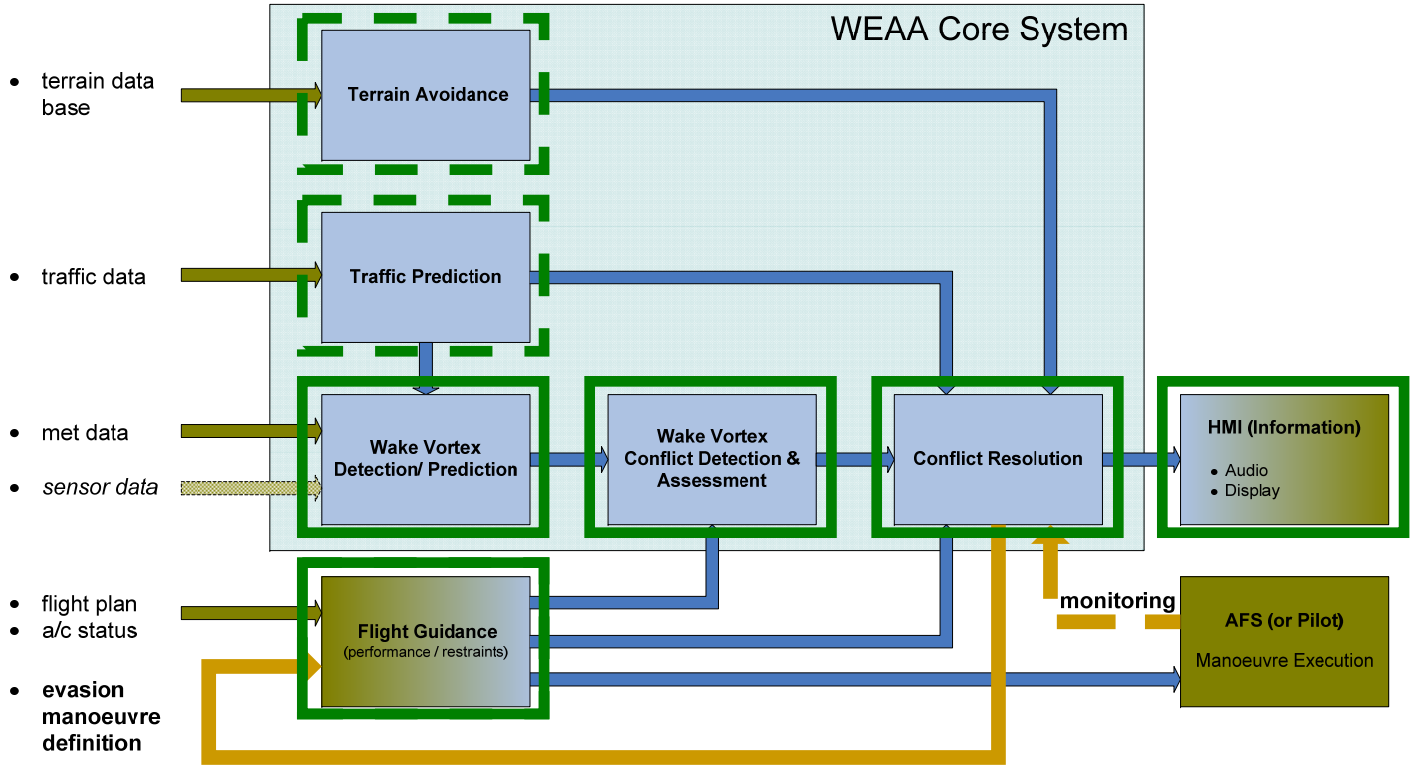
WEAA Objectives and Constraints

- **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)
  - NB: wake alleviation is not part of WEAA but can be integrated

- **Manoeuvre Design Constraints**
  - evasion without ATC request (similar to TCAS), i.e. 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)

System Architecture: Functions

- **predict wake vortices** from performance data and planned trajectories of surrounding aircraft using meteorological data
- perform a **conflict detection**, using prediction of own trajectory, in connection with **hazard assessment** where required
- **generate evasion trajectory**, taking into account terrain data and surrounding traffic
- **define and display** required **evasive manoeuvres** to the pilots on PFD (and VSI)
- generate **overview display** on ND (and VSD) **to increase** pilots' **situational awareness**

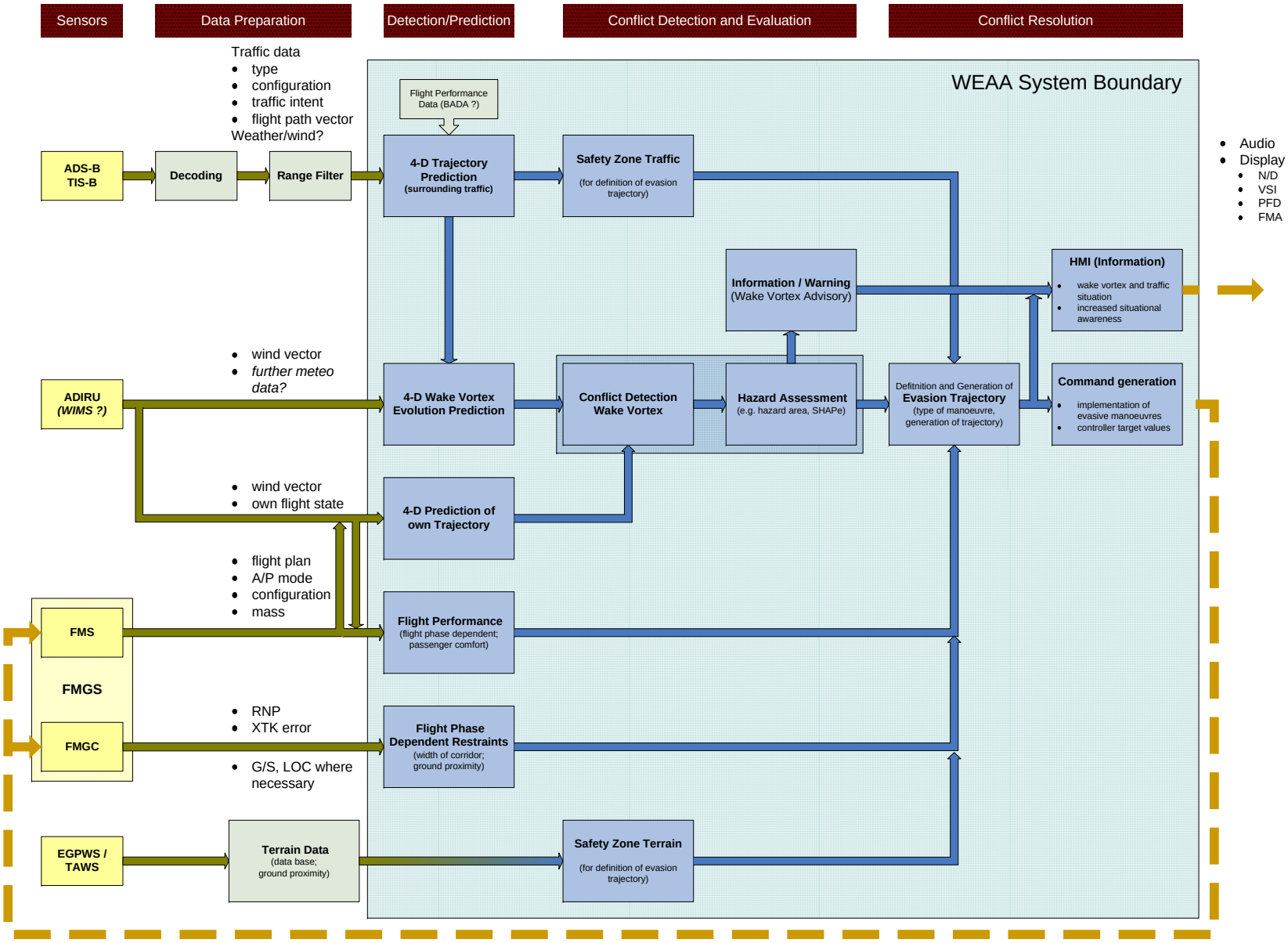


WEAA System Architecture

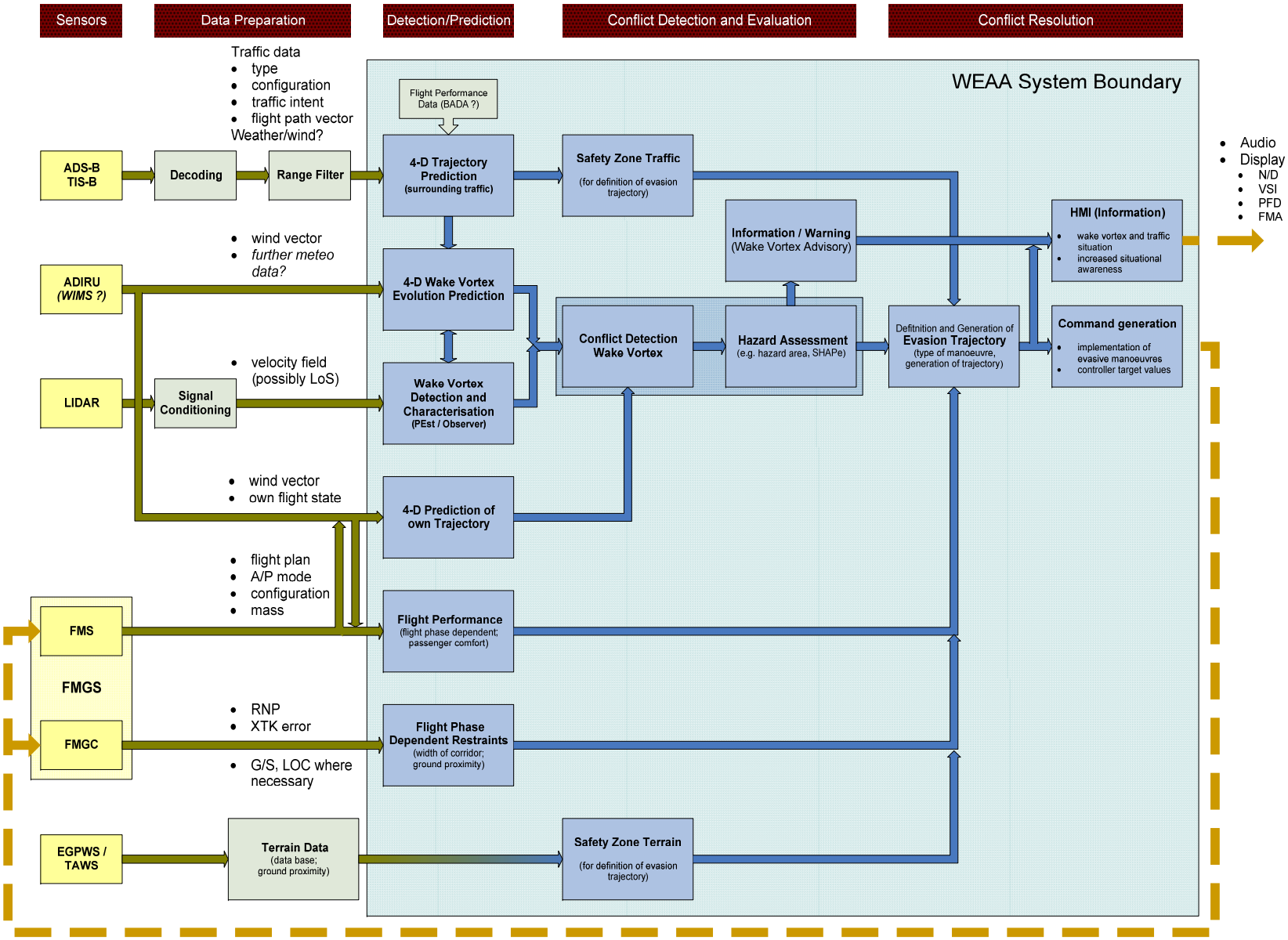
- **Modular architecture** gives possibility to
  - adapt single components without changing the whole system
  - combine components for different system architectures

- **Two design options**
  - evasion purely based on *wake prediction*
    - vortex habitation volumes grow significantly with vortex age
  - evasion based on combined *wake prediction and detection*
    - detection likely by LIDAR
    - most LIDARs deliver only line-of-sight measurements
      $\Rightarrow$ vortex characterisation necessary
    - long-term perspective (sensor availability critical)

WEAA Functional System Breakdown (WV Prediction Only)



WEAA Functional System Breakdown (with WV Detection)



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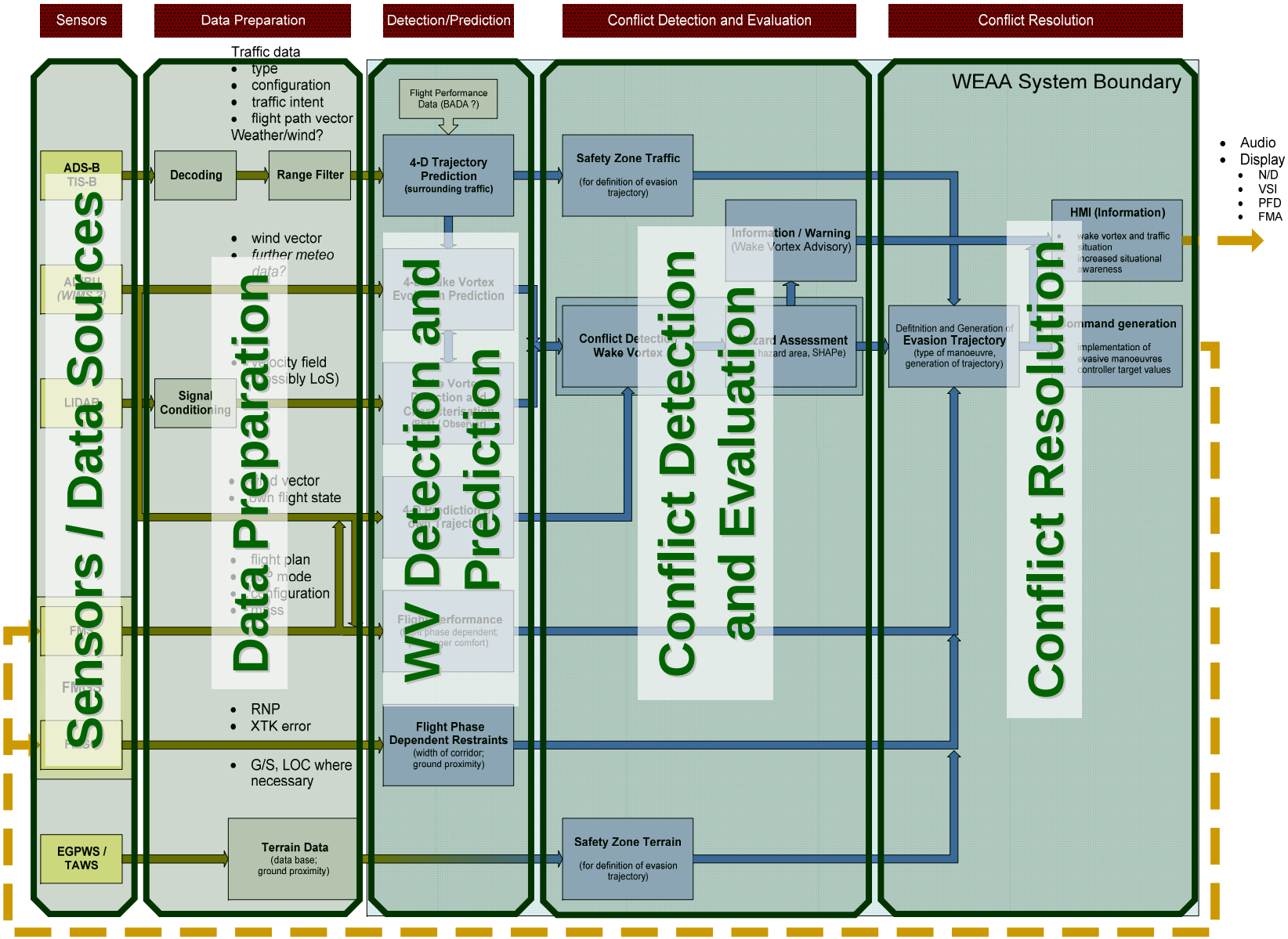
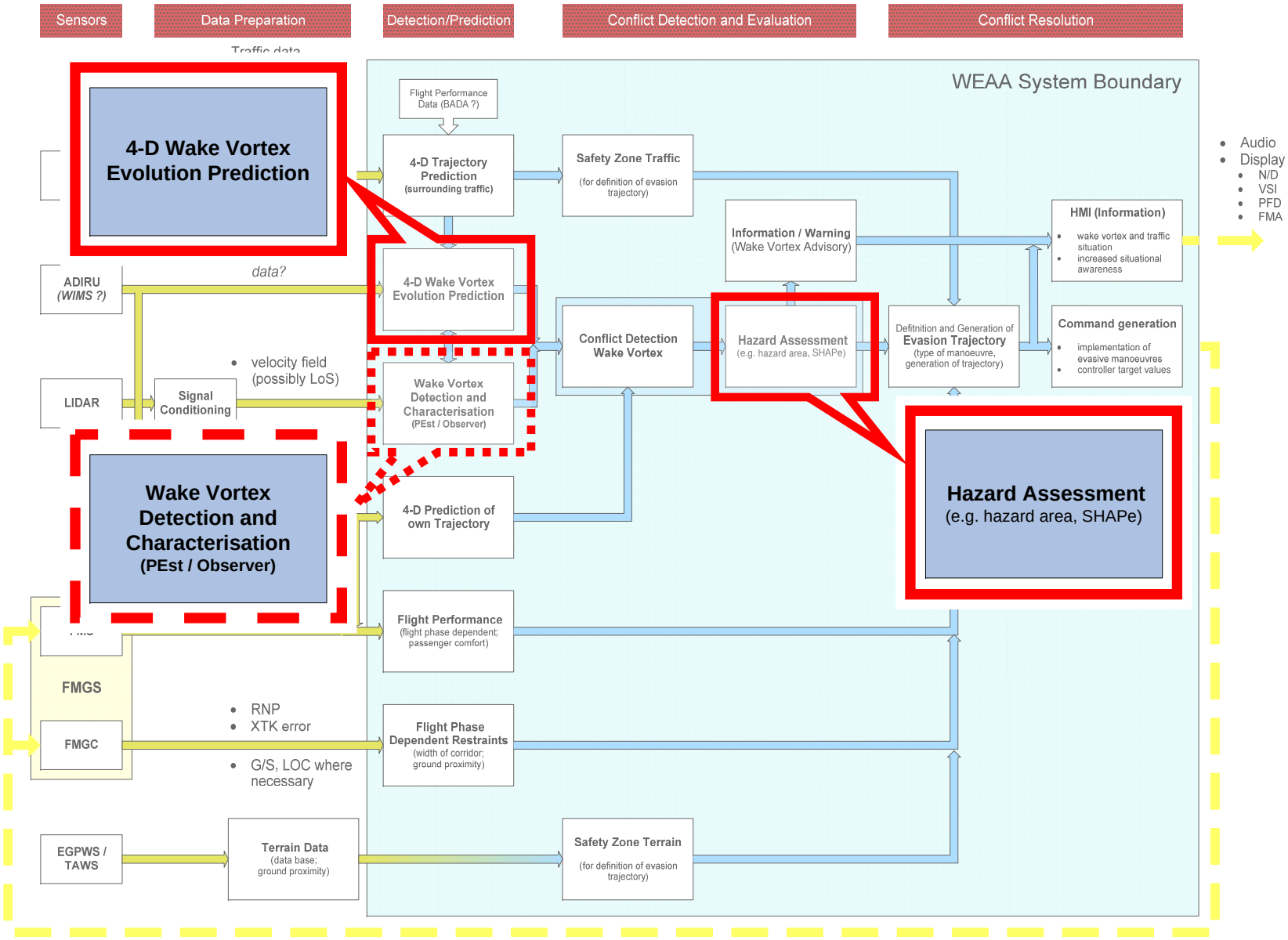
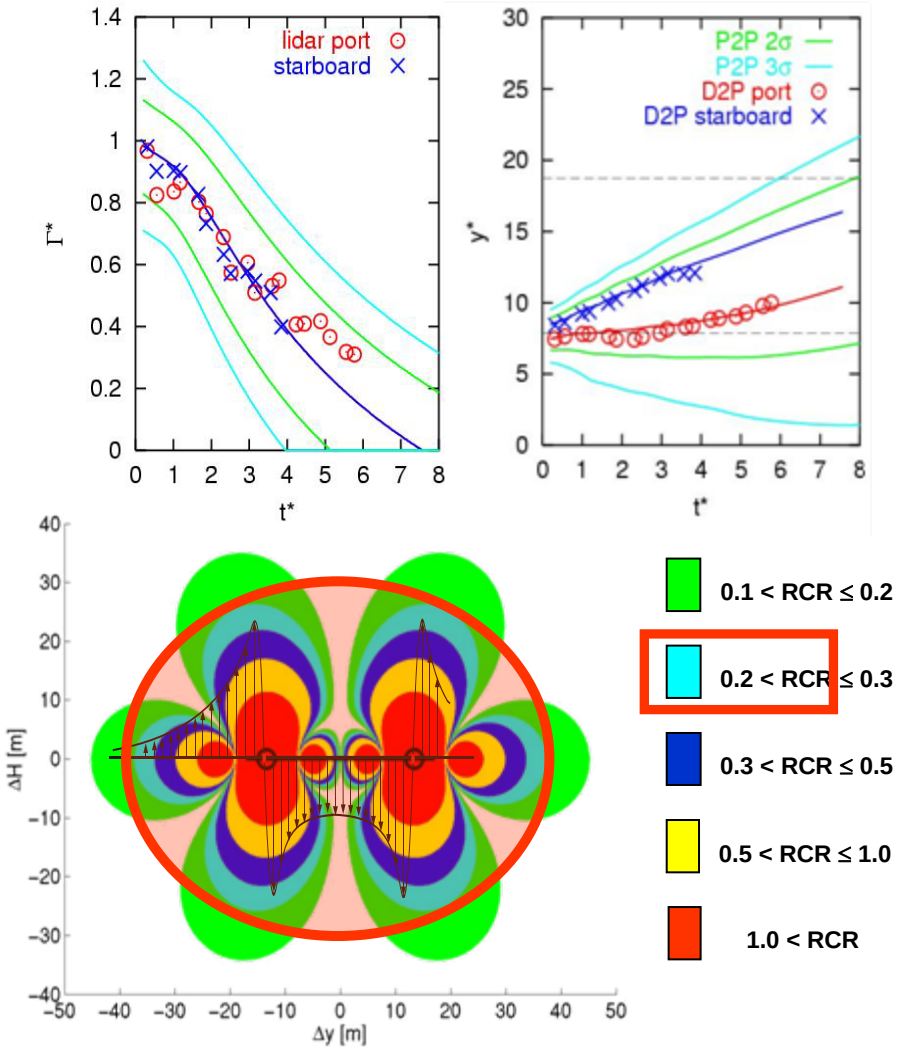


WEAA FBS: Existing Functions

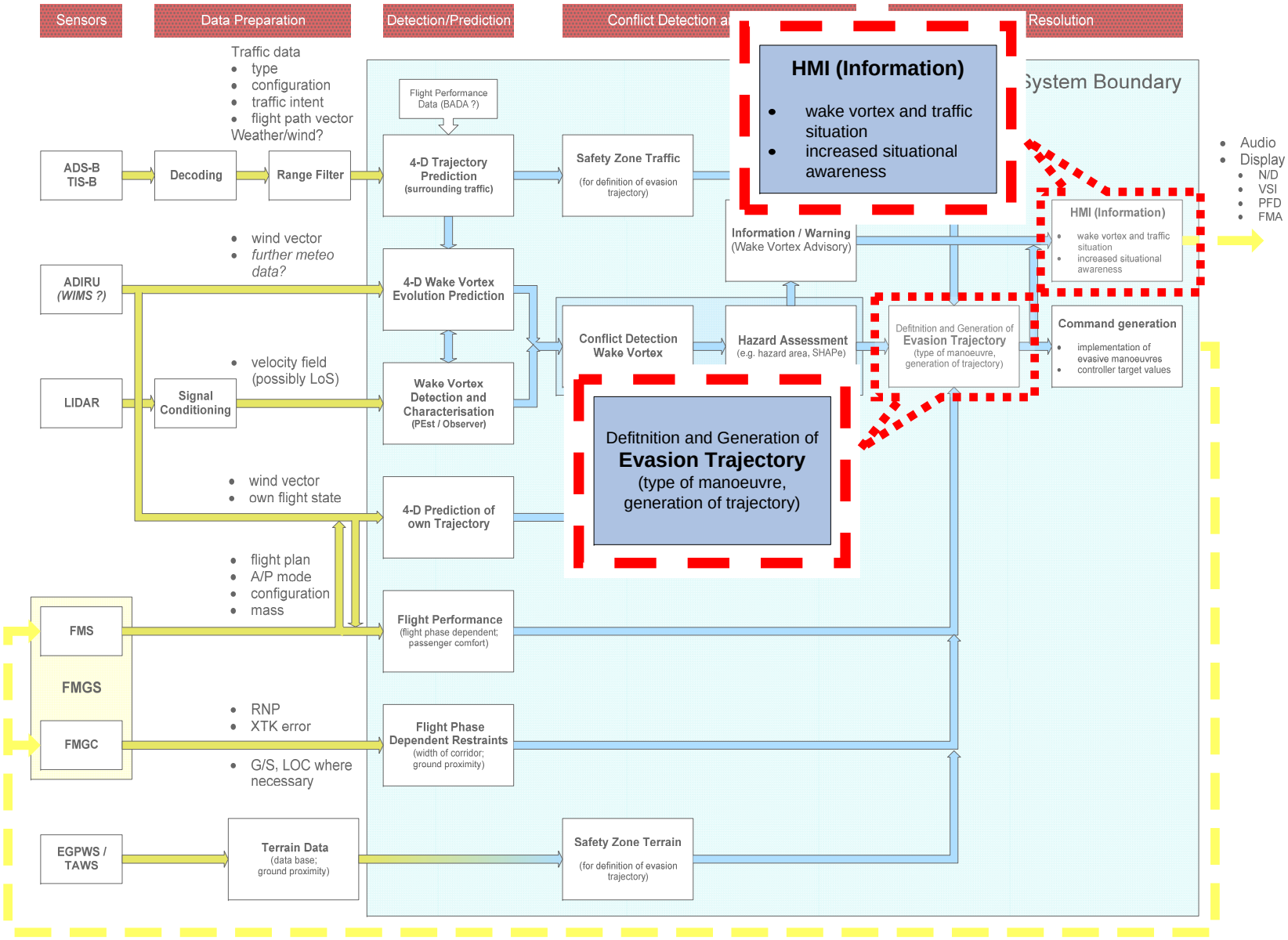


WEAA: Exploitation of Existing DLR Knowledge

- **Vortex Prediction Model: *P2P***
  (HOLZÄPFEL)
  - probabilistic two phase model
  - effects of a/c configuration, wind, wind shear, turbulence, stratification and ground proximity
  - real-time capability
  - extensively validated on LIDAR measurements and LES
- **Severity Assessment: *SHAPe***
  (HAHN, SCHWARZ)
  - simplified hazard areas (rectangular or elliptical)
  - hazard rating by means of roll control ratio RCR
- **Wake Parameter Estimation: *Online-ID***
  (FISCHENBERG)



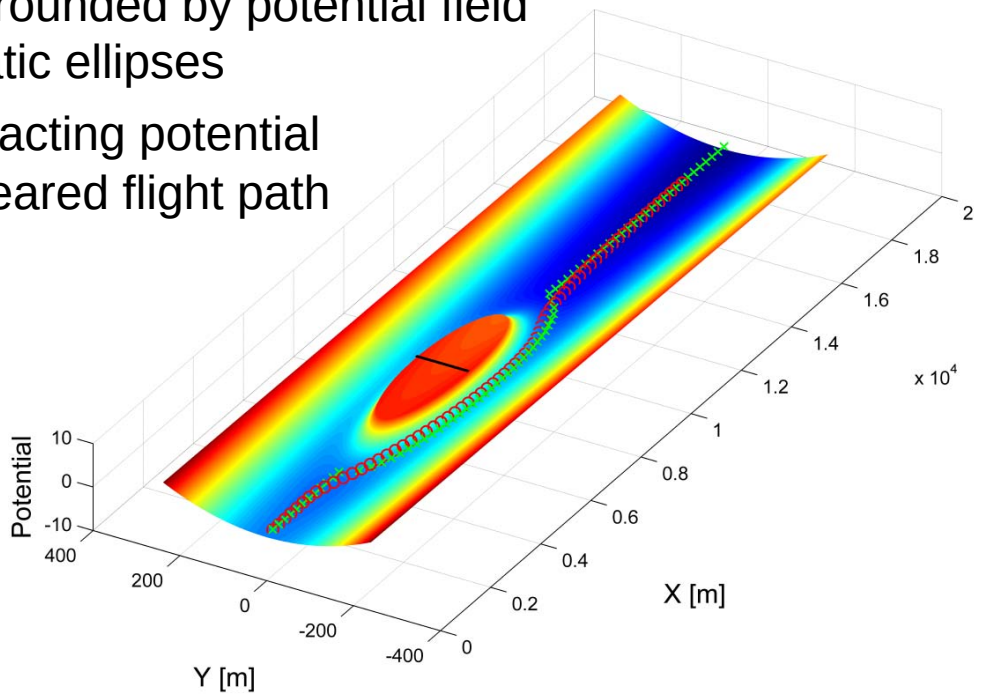
WEAA FBS: Recent Work



Recent Work

Trajectory Generation

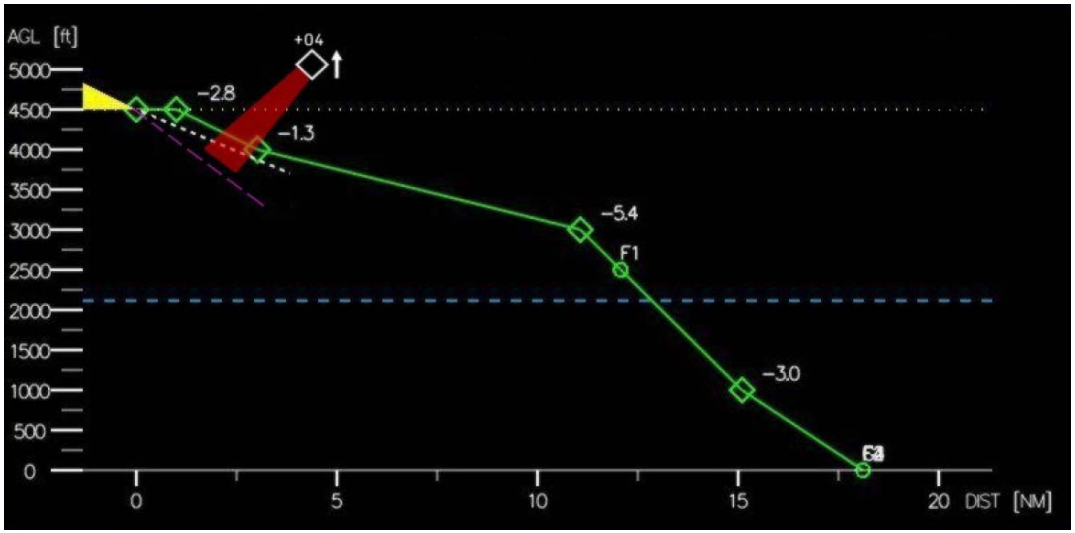
- trajectory generation using **potential field approach** (from robotics)
  - obstacles, boundaries surrounded by potential field modelled by super-quadratic ellipses
  - intended flight path as attracting potential
    ⇒ “automatic” return to cleared flight path
- trajectory smoothing
- lateral or vertical evasion
  ⇒ decision algorithm using encounter geometry
- status:
  - tested offline with A/P in cruise
  - simulator implementation in progress
- next step: (E)GPWS interoperability (inverted alerting boundary as limit)



Recent Work

Display Concepts

- simulator study conducted with **display concept similar to FLYSAFE** project (Airbus development, PFD + ND)
  - simplified evasion algorithm
  - visual and aural warnings
- wake **visualisation extended to vertical situation display** (VSD)
  - enhanced situational awareness



Summary: Objectives, Work So Far

- DLR is developing a Wake Encounter Advisory and Avoidance System (WEAA)
  - **tactical small-scale evasion** to avoid possibly hazardous wake encounters
  - **pure safety net** function
  - **interoperability with TCAS and (E)GPWS** / TWAS assured

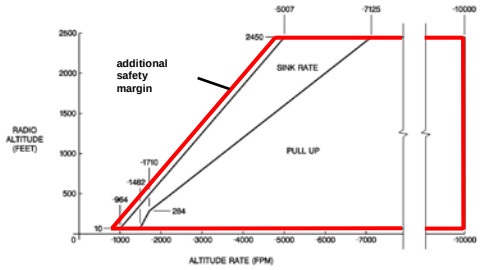
- two design options
  - pure wake prediction
  - prediction + wake detection/characterisation (long term)

- existing DLR knowledge exploited:
  - WV prediction model
  - wake characterisation from forward-looking measurements
  - severity assessment

- on-going development of new system functions:
  - evasion trajectory generation using potential field approach
  - ground and traffic collision avoidance interoperability
  - pilot displays for **situational awareness**

Future Work: Where Do We Want to Go?

- **Component Function Development**
  - conflict detection concept and algorithms
  - refinement of conflict resolution algorithms taking into account
    - (E)GPWS & TCAS interoperability
    - passenger comfort
    - aircraft performance
  - ConOps for additional flight phases
  - analysis of different concepts for pilot assistance w.r.t. work load and situational awareness
  - enhanced severity assessment
  - enhanced wake characterisation with (LiDAR) measurement
- **System Proof of Concept**
  - implementation in engineering flight simulator
  - perspective: motion based simulator and flight test
- **Benefit Analysis**




[Photo: DLR]

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