iFly

# Airborne Separation in Advanced En-Route ATM

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Presented to the AP-23 Working Group

Honeywell

# Project Consortium

Honeywell

- National Aerospace Laboratory (NLR)
- Honeywell
- Isdefe
- University of Tartu
- Athens University of Economics And Business
- Eidgenossische Technische Hochschule Zurich
- University of l'Aquila
- Politecnico di Milano
- University of Cambridge
- National Technical University of Athens
- University of Twente
- Ecole National de l'Aviation Civile
- Dedale
- UK NATS En Route Ltd.
- Institut National de Recherche en Informatique et en Automatique
- Eurocontrol EEC
- DSNA-DTI-SDER
- University of Leicester

# iFly Objectives

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•Develop & Validate

**Highly automated ATM design for en-route traffic based on autonomous aircraft concept.**

## Key design aspects:

- Human responsibilities
- Traffic Complexity
- Safety Assessment using SESAR compliant safety targets

# Airborne Separation in Future ATM

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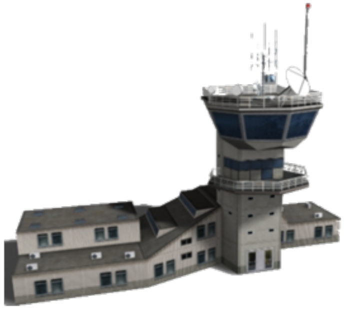
**SESAR/NextGen**

2025+



Merging & Spacing

Delegated Separation

Self Separation

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**iFly's Scope:**

- ✓ High Density Traffic
- ✓ Only Self Separation Capable Aircraft

# Research Questions

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**Two Design Cycles To Answer Two Main Research Questions:**

- Up to which en route traffic demands is (pure) Self Separation sufficiently safe? ($A^3$ design cycle)
- Which complementary support services from ground ATM are needed in order to accommodate higher traffic demands ? ($A^4$ design cycle)
  - $A^4$ = ATM-supported Autonomous Aircraft Advanced concept

# iFly Project Structure

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**Autonomous aircraft concept**

- ✓ Free Flight
- ✓ AFAS
- ✓ Gate-to-Gate
- ✓ CARE-ASAS
- ✓ MFF
- …

State-of-the-art

A3 Design Cycle — WP1

**Assessment:**

- Safety (WP7)
- Efficiency (WP7)
- Human factors (WP2)
- Capacity (WP7)
- Economy (WP6)

HYBRIDGE (2002-2005)

Distributed Control and Stochastic Analysis of Hybrid System

A4 Design Cycle — WP8

Complexity (WP3)

Situation Awareness (WP4)

Conflict Resolution (WP5)

Air and Ground Requirements

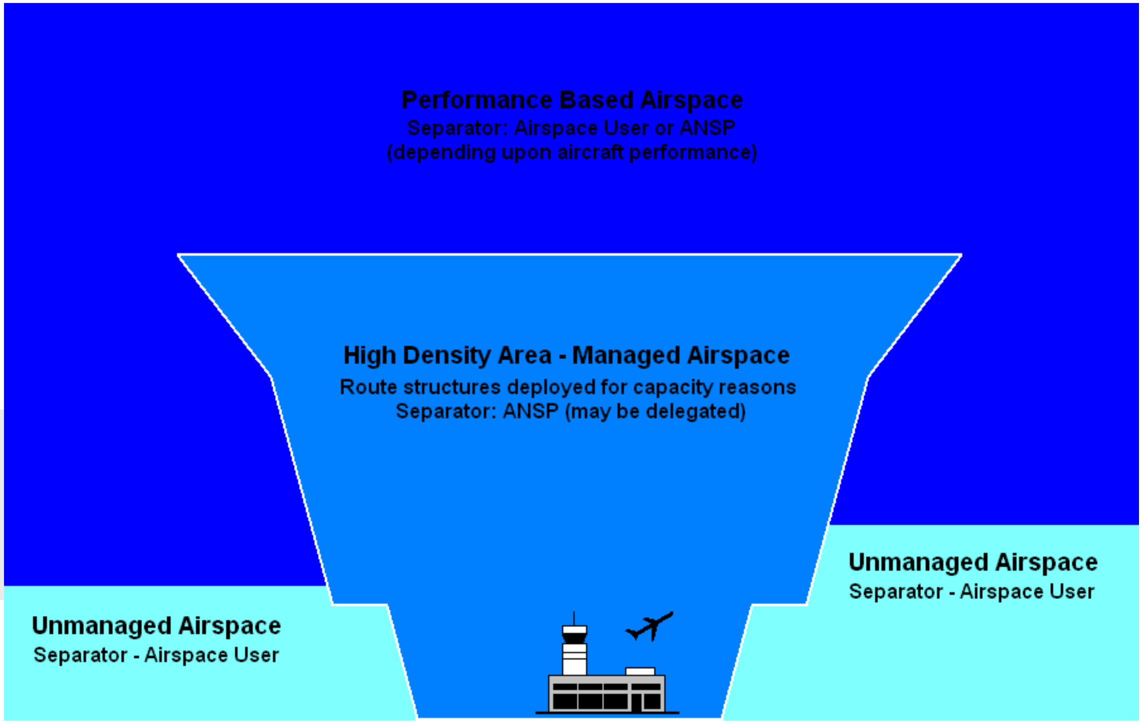
Advanced Operational Concept

Safety Assessment (WP9)

# A3 Design Cycle



- **iFLY ConOps Assumptions**
  - **Autonomous Flight Rules (AFR) operations within Performance Based Airspace (PBA)**
  - **Fully equipped Self Separation-capable aircraft considered only**
    - FMS, ASAS, ACAS, Cockpit Display of Traffic Information (CDTI), Communications Management Unit (CMU) able to communicate with SWIM and other aircraft via datalink (at least ADS-B In/Out).
  - **En-route phase of flight**
  - **Flight level structure not adhered to during AFR operations.**
  - **Self Separation trajectories end at RTA in BT.**
  - **No ATC ground support.**



# AC Separation

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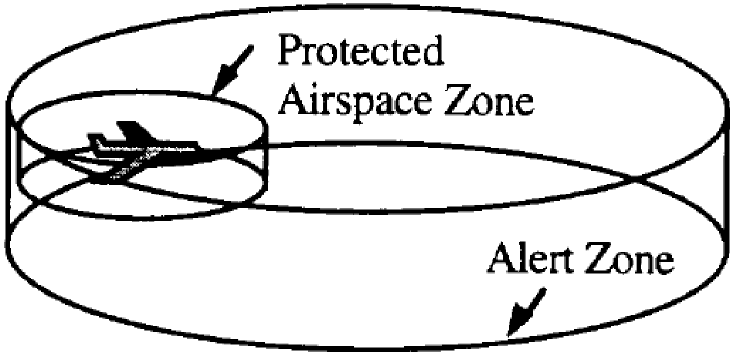
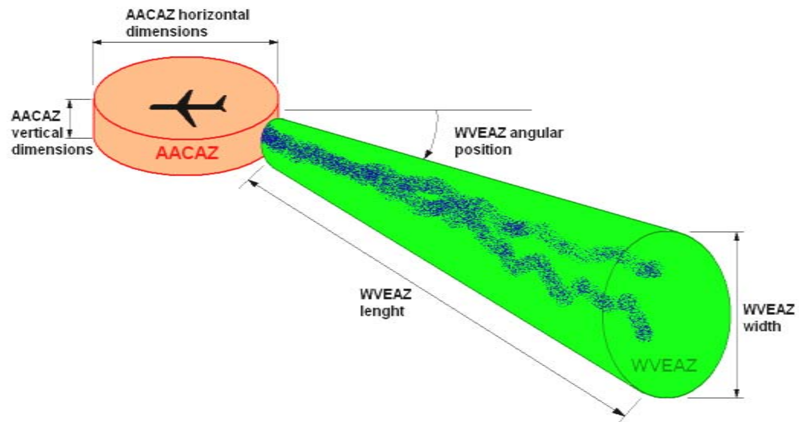
- **Protected Airspace Zone (PAZ)**
  - **Legal separation requirement.**
  - **Should not be penetrated to ensure safety**
  - **Dynamic PAZ with two real-time changing zones**
    - Aircraft – Aircraft Conflict Avoidance Zone (AACAZ)
    - Wake Vortex Encounter Avoidance Zone (WVEAZ)




- **Alert Zone (AZ)**
  - **When penetrated triggers an intervention by ATC.**
  - **May represent resolution zone for conflict resolution.**

- **Separation minima suitable for Autonomous Flight to be determined**
  - **RNP-1 capable AC enable reduction to 3NM**
  - **Dynamic PAZ may include Aircraft Conflict Avoidance Zone (AACAZ) and Wake Vortex Encounter Avoidance Zone (WVEAZ)**

- **Conflict situations: aircraft PAZ enters**
  - **A Restricted Airspace Area (RAA)**
  - **A Weather Hazard Area (WHA)**
  - **A Terrain/Obstacle restriction**
  - **Another aircraft's PAZ.**



# Flow & Trajectory & Management

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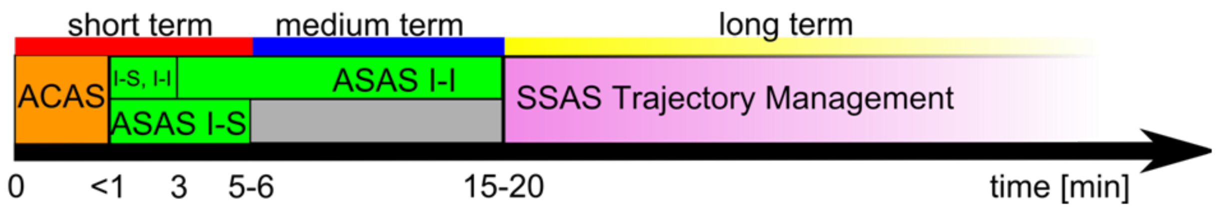


- **Strategic Flow Management provided to AC**
  1. **Ensure traffic complexity and density within safety and capacity limits**
  2. **Provide Transition Operations between IFR and AFR**
  3. **Provide Support Services for aircraft to achieve adequate Situation Awareness.**
  - **Uplink RBT, meteo & hazard data, traffic congestion, special use airspace.**

- **Trajectory Management**
  - **Generates optimal path across PBA, incl. Strategic deconfliction**
  - **FMS best suited for integrated airborne trajectory management within AFR ops.**
  - **TM trajectory modifications should only affect flight > 20 minutes ahead, otherwise might interfere with ASAS actions.**

# Functional System Architecture

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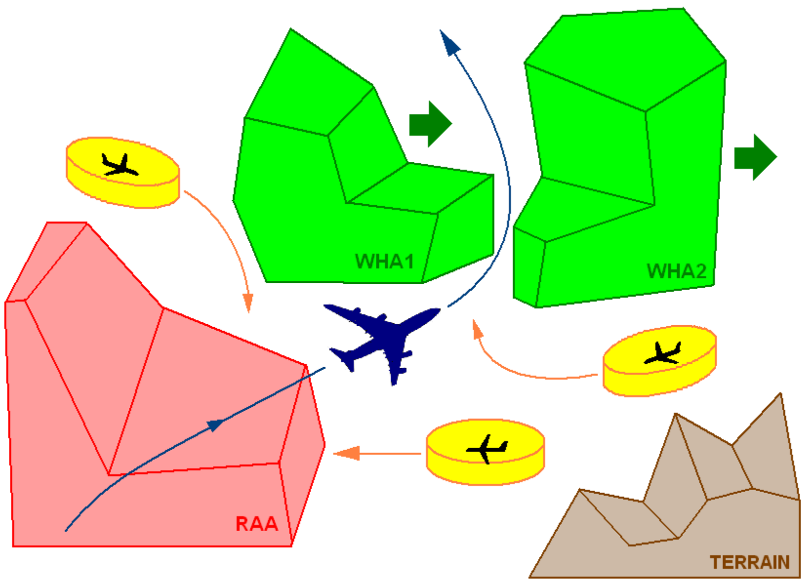
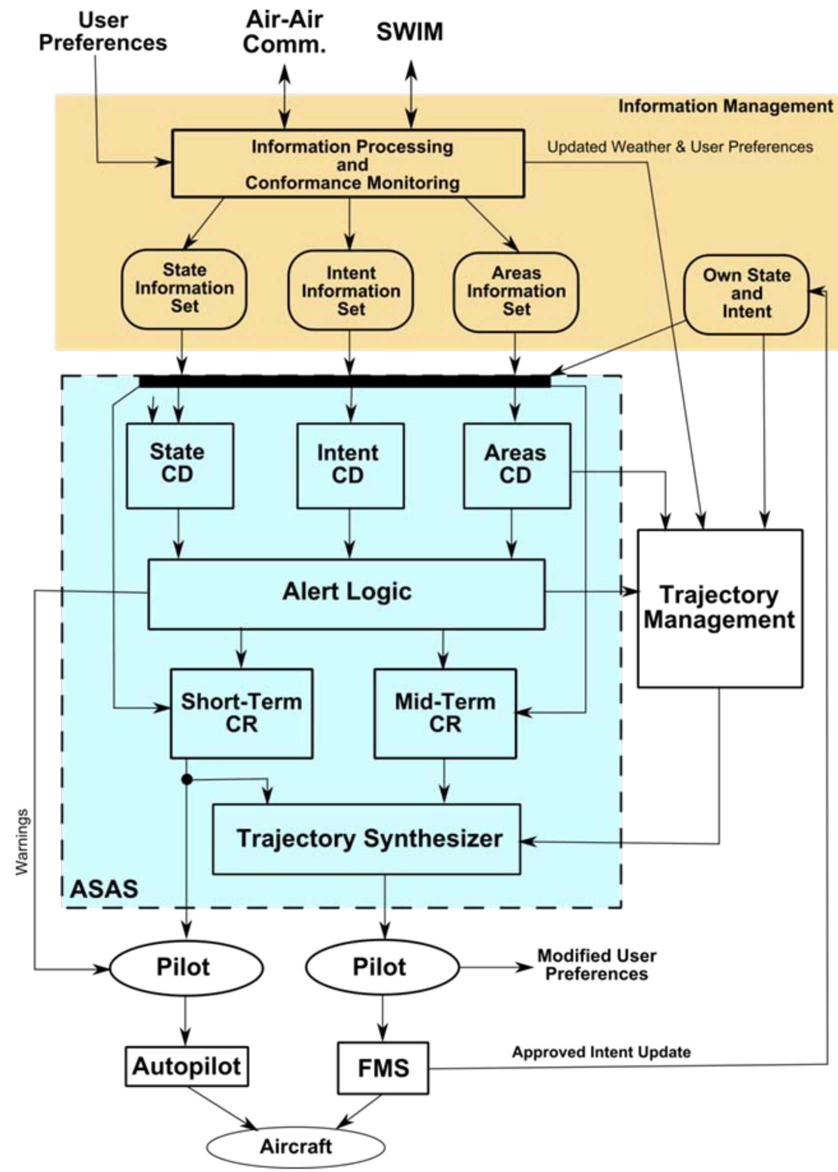
**Areas information data set – (weather, congested airspace, …)**

- Ground-air SWIM updates
- Onboard systems (Wx radar, EGPWS)




**Trajectory Synthesizer**

- Ensures that trajectory changes result into new consistent (complete) conflict free BT incl. AFR exit condition
- Inserts revised BT into FMS

# iFLY Program

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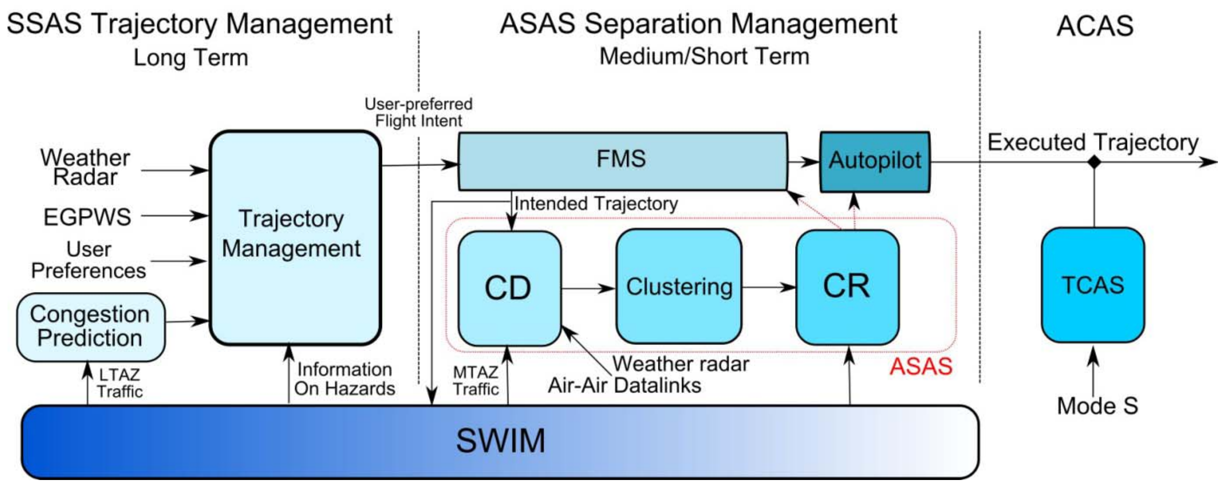
- **Main Research Areas**
  - **Safety simulations (rare event modelling)**
  - **Human factors**
  - **Complexity metrics and prediction**
  - **Situation awareness & modelling of complex hybrid systems**
  - **Conflict resolution methods**



# Safety Validation



- National Aerospace Laboratory (NLR) & Honeywell

1. **Hazard Identification**

2. **Safety Assessment – Rare event modelling based on the Hybridge project (TOPAZ)**

   **Complex System Modelling – Piecewise Deterministic Markov Processes represented by Dynamically Coloured Petri Nets**

   **Air Traffic Simulation – Sequential Monte Carlo Methods**

3. **RTCA/Eurocae ED78a Safety Assessment**

# Human factors



## Two Essential Tasks:



1. **Provide Input To Both Design Cycles**
2. **Analyze and Identify Bottlenecks of Designed Systems and Propose Solutions**

## Main Issues

- Analysis of pilots en-route tasks
- Cockpit crew responsibility analysis
- Pilot’s workload studies
- Situation awareness maintenance
- Identification of bottlenecks

# Conflict Resolution

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**Three iFly teams address 3 CR strategies**

- **Long Term CR** **(one hour or beyond)**
  - **Eidgenossische Technische Hochschule Zurich**
    - **Both centralized (ground-based) and distributed methods**
- **Mid Term CR** **(tens of minutes)**
  - **University of Cambridge**
    - **Distributed methods, questions of suitable intent information**
- **Short Term CR** **(minutes)**
  - **National Technical University of Athens**
    - **Distributed methods, interface with TCAS**

## Main Issues

- **Choice of suitable CR maneuvers**
  - **E.g., Geometrical CR algorithms well suited for implicit coordination.**
- **Coordination of CR maneuvers between conflicting aircraft**
- **TP uncertainty handling**
- **Conflict of multiple aircraft (clustering)**
- **Optimization (selection) criteria**

# Situation Awareness & Hybrid Systems

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- University of l'Aquila

## Two parallel approaches:

**Conventional**

**Vs.**

**Theoretical (formal)**

**Based on the expert assessment and subsequently validated – used in both design cycles.**

**Based on complex hybrid system modelling and subsequent analysis of critical observability.**

# Some Questions of Interest

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- WHAT ARE THE MOST SUITABLE CR ALGORITHM(S) FOR ASAS OPERATIONS?
- SHOULD CR MANOEUVRES BE CONSIDERED SEPARATELY IN THE VERTICAL AND HORIZONTAL PLANES?
- SHOULD THE CR ALGORITHMS BE PART OF THE FMS, TCAS OR AN INDEPENDENT BOX?
- WHAT ARE THE CHANGES NECESSARY IN CURRENT AVIONIC SYSTEMS (ESP. FMS) TO ENSURE AUTONOMOUS FLIGHT TRAJECTORY MANAGEMENT?
- HOW CAN AIR TRAFFIC COMPLEXITY FOR AIRBORNE SELF SEPARATION BE DEFINED?
- WHICH INFORMATION MUST BE PROVIDED TO THE AIRCREW TO ENSURE HIGH SITUATION AWARENESS?
- HOW MANY CR ADVISORIES SHOULD BE PROVIDED TO THE PILOT?
- HOW SHOULD THE ASAS-TCAS INTERFACE BE DESIGNED TO ENSURE THE CONTINUATION OF CR ADVISORIES?
- HOW SHOULD PAZ FOR AIRBORNE SELF SEPARATION BE DEFINED ?
- WHAT BENEFITS WOULD REDUCED SEPARATION STANDARDS BRING?

# In Conclusion

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- **iFLY Progress to Date**
  - **Completed first phase of (A3) design cycle and state-of-the-art research.**
- **Submitted Deliverables**
  - **WP1.1: Autonomous Aircraft Advanced (A3) High Level ConOps**
  - **WP2.1: Description of airborne human responsibilities in autonomous aircraft operations**
  - **WP3.1: Complexity metrics applicable to autonomous aircraft**
  - **WP4.1: Hybrid models and critical observer synthesis for multi-agent situation awareness**
  - **WP5.1: Comparative Study of Conflict Resolution Methods**
  - **WP7.1: Accident risk and flight efficiency of A3 operation - Scoping and safety target -**
- **Upcoming Meeting**
  - **2nd PMC: May 28-29, 2008, Tartu, Estonia**

**Web site: http://iFLY.nlr.nl**
**Coordinator: Henk Blom (NLR)**