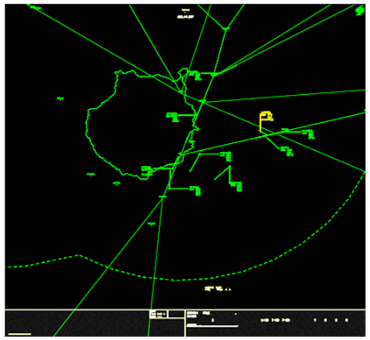
E4U Workshop #2
7 April 2011

Work Package 1
UAS Air Traffic Insertion



WP1 Team: Henk Hesselink (NLR),
Christoph Roos (NLR) Sebastien Defoort (ONERA),
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Task 1 Air Traffic Insertion - intro

This task is concerned with the insertion of UAS in the air traffic management system.

The *Air4All roadmap* describes the steps for integration in airspace classes A to G in a number of steps towards full integration in international cross border operations.

Task 1 Air Traffic Insertion - intro

- Air4All
  - **Step 1**: Fly experimental UAS within national borders in segregated airspace (regular, at short timescale) – Unpopulated range
  - **Step 1a**: Fly experimental UAS within national borders in segregated airspace (regular, at short timescale) - overflown sparse population
  - **Step 2**: Fly an experimental UAS as IFR traffic within national borders in controlled, non segregated airspace (airspace classes A, B and C)
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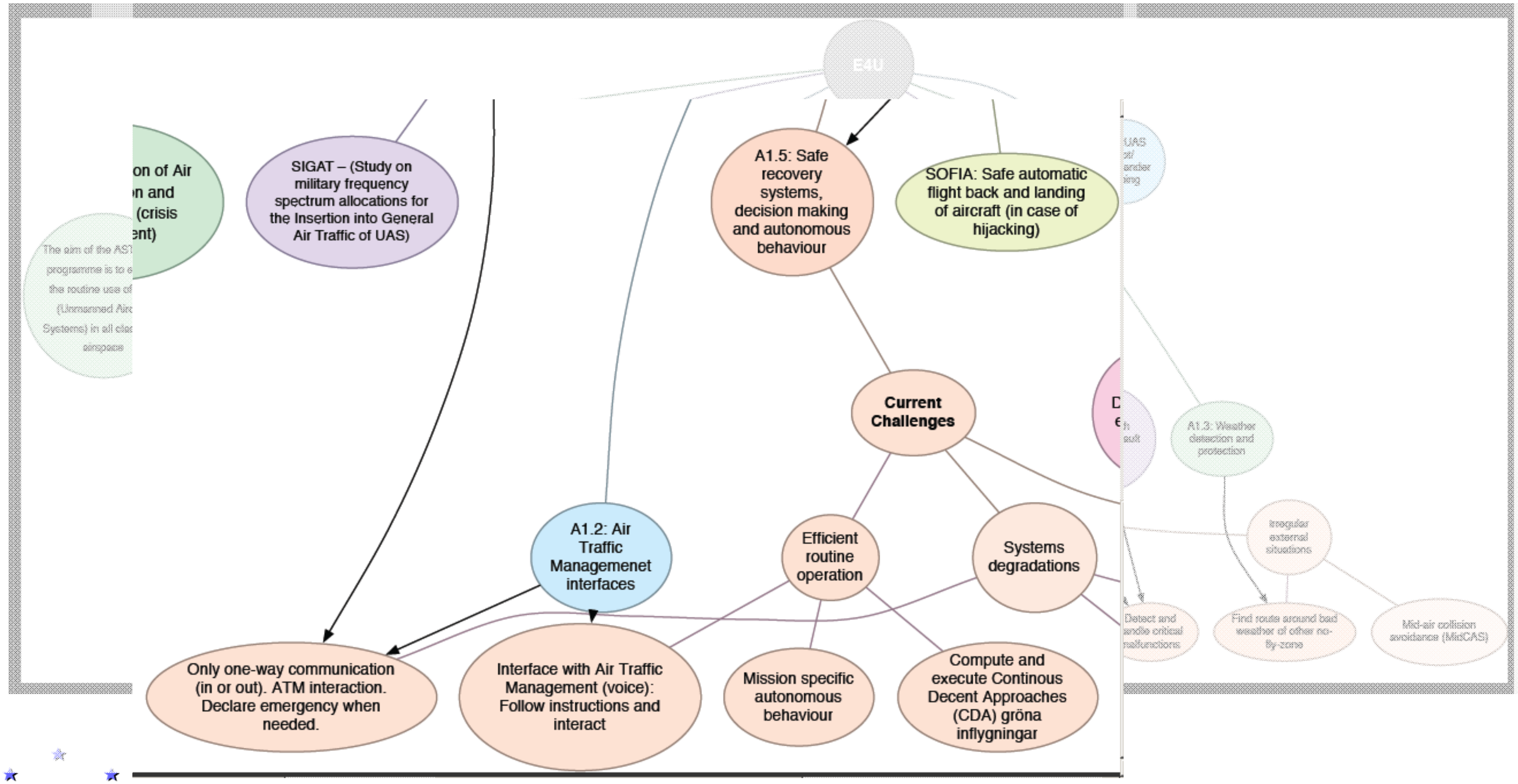
Task 1 Air Traffic Insertion - intro

Air4All Roadmap

Non Type Certificated UAVs		*Type Certificated UAVs*		
Experimental UAVs		*State UAVs*	*Civil/State UAVs*	
Step 1 Segregated Airspace	**Step 2 Non Segregated Airspace**	**Step 3 Non Segregated Airspace**	**Step 4 Non Segregated Airspace**	**Step 5 Non Segregated Airspace**
Fly within National Borders National Competence				*Worldwide ICAO*

Step 2
- separation and collision avoidance
- secure and sustainable communication
- radio bandwidth allocation
- ATC interface
- dependable emergency recovery
- health monitoring / fault detection
- UAS pilot / commander training

Relationship



Approach

Air4All steps

	1	1a	2	3	4	5	6
E4U							
T1.1 project A	0	0	0	1	1	1	1
T1.1 project B	0	0	0	0	1	1	1

⇒ Projects A and B will both tackle the issues concerned with T1.1 and will solve the problem in step 3 resp. 4.

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- The list of projects that have been identified in E4U can be mapped on the Air4All steps and can be depicted in time
- This will give us a first hint towards identification of priorities for UAS insertion

Approach (advanced)

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Leftovers from WS1

E4U

UAS Air Traffic Insertion

EDA

- T1.1 Secure C2 systems and links
- T1.2 Air traffic management interface
- T1.3 Weather detection and protection
- T1.4 Taxi, automatic take off, and landing
- T1.5 Safe recovery systems, decision making, and autonomous systems
- T1.6 Dependable emergency recovery
- T1.7 Health monitoring detection
- T1.8 UAS pilot/commander training

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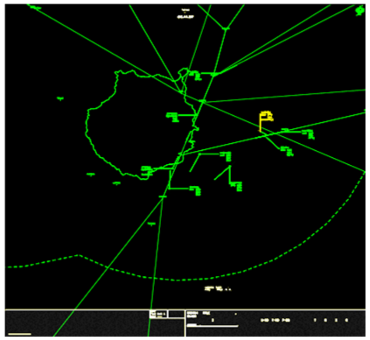

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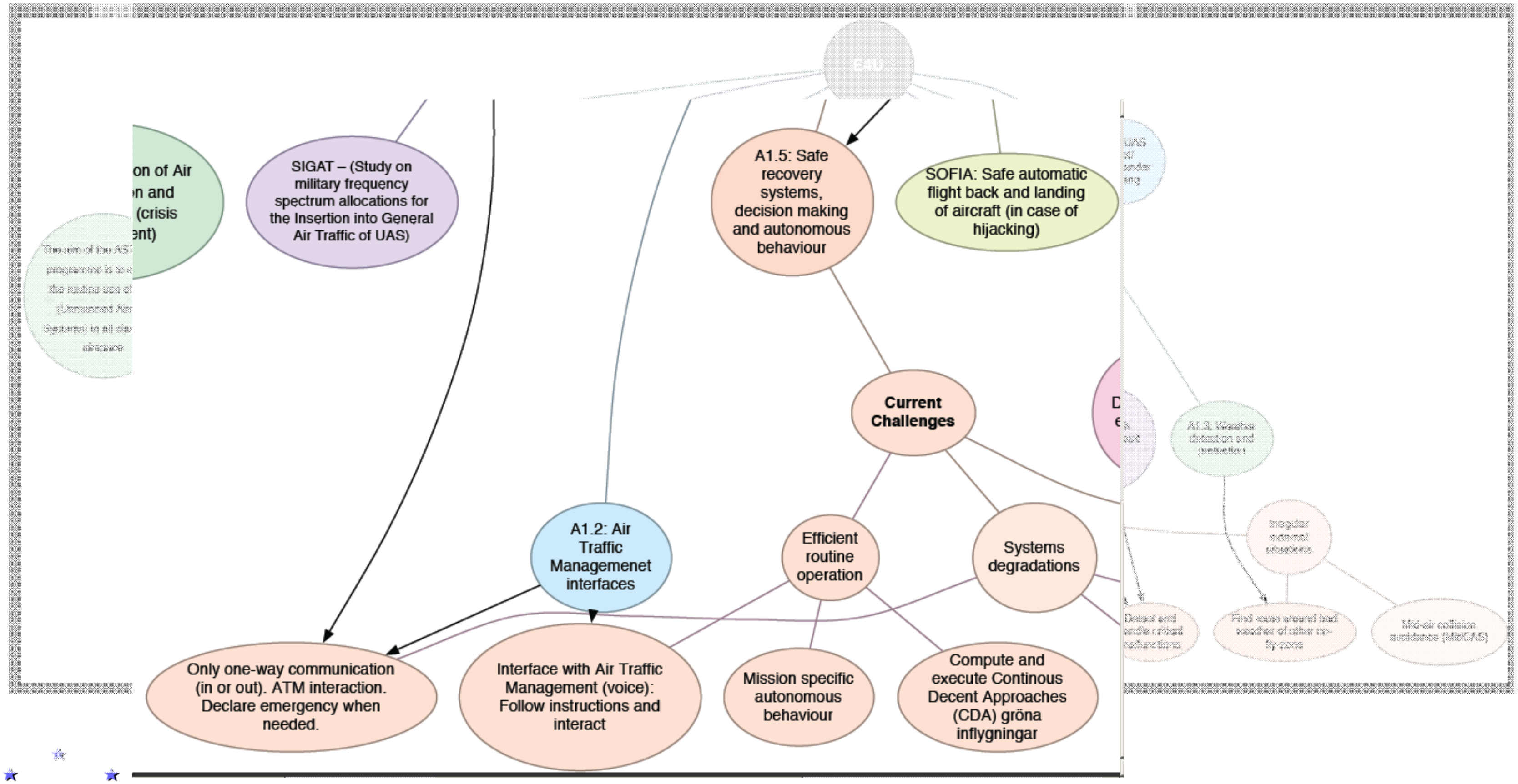

- Assumptions
  - Steps as defined by Air4All
  - Challenges as provided by Air4All
  - Topics by Air4All + EDA + WS1
- Parameters
  - Challenges (per topic, per step)
  - Projects
    - Shall provide input to standardization / regulation
    - TRL (shall be 9?)
    - Relevance (per challenge, per step)
    - End date
- Outcome
  - Challenges that are missing (emergency procedures?)
  - Challenges that are not (sufficiently) addressed by projects
  - Challenges that are not addressed timely
  - Challenges that depend on other topics

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Approach (alternative)

Air4All steps

	1	1a	2	3	4	5	6	
E4U								
T1.1 project A	N	N	N	Y	Y	N/A	N/A	2017
T1.1 project B	N	N	N	N	P	P	P	2016

⇒ Different representation, without the numbers, now with "codes"

⇒ N=Not; Y=Yes; P=Partly; N/A=Not Applicable

Approach (alternative)

Air4All steps

	1	1a	2	3	4	5	6	
E4U								
T1.1 project A	Y	Y	Y	Y	Y	N/A	N/A	2017
T1.1 project B	Y	Y	Y	Y	P	P	P	2016

⇒ N=Not; Y=Yes; P=Partly; N/A=Not Applicable

⇒ Maybe, items solved for level three, will implicitly solve an issue for the earlier levels as well

Prioritisation

JUST EXAMPLE

			air4All step						coverage	TRL
			1	2	3	4	5	6		
T1.2 Interface	ASTRAEA	2013	N	Y	n/a	n/a	n/a	n/a	0.5	5
T1.2 Interface	SINUE	2010	N	Y	Y	Y	Y	n/a	0.5	3

Conclusions may be:

⇒ Should we want to got to TRL 8, priority must be given to T1.2 to solve step 2

⇒ Should we want to go towards step 3, priority must be given to T1.2

⇒ Should we want step 2 to be solved before 2013, priority must be given to T1.2

Leftovers from WS1

UAS Air Traffic Insertion

T1.1 Secure C2 systems and links

T1.2 Air traffic management interface

T1.3 Weather detection and protection

T1.4 Taxi, automatic take off, and landing

T1.5 Safe recovery systems, decision making, and autonomous systems

T1.6 Dependable emergency recovery

T1.7 Health monitoring detection

T1.8 UAS pilot/commander training

T1.1 Secure C2 Systems and Links

UAS system has inbuilt critical vulnerabilities within

- communications links between the remote pilot station and the aircraft
- Communication links between the aircraft and ATC
- to the relay stations and external networks.
- positioning of satellite systems

Every single part of the complete system is sensitive to

- jamming and spoofing (intentional disturbances)
- dazzling and interruption activities (unintentional disturbances)
- electromagnetic pulses

T1.1 Secure C2 Systems and Links

Secure links concerns many UAS functions and represents a key challenge

- Command and control
- Sense and avoid information sent to the pilot
- Connection to ATC
- Payload and sensor control functions
- Secure data sharing
- Electronic warfare

T1.1 relevant projects

Secure C2 systems and links

- MidCAS = Mid Air Collision Avoidance System
- SIGAT = Military spectrum requirements for the insertion into General Air Traffic for the UAS
- INOUI = Innovative Operational UAS Insertion
- IDEAS = Integrated Deployment of UAS in the European Airspace using Satellites Air4All
- National projects
- Workgroups in EUROCAE, EASE, WRC2012

T1.1 relevant results (so far)

Secure C2 systems and links

- Ongoing discussions in radio bandwidth allocation (WRC2012, see task 4.2)
- National studies on vulnerability of existing links certified for civil aviation
- Preliminary analysis on requirements on h1 architectures for secure communication

Folie 34

h1 where is this analysis?
hessel; 14.03.2011

T1.1 Current challenges

Secure C2 systems and links

- Certification procedures of safe and secure links for UAS in civil aviation
- C2 system/link loss strategy (autonomous behaviour)
- C2 redundancy (payload link?)
- Overall system integrity
- Radio bandwidth allocation

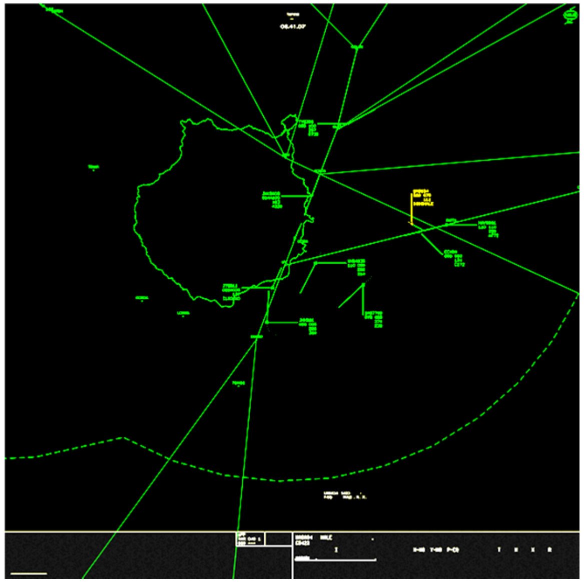
This covers T1.1 so far

T1.2 Air Traffic Management interface

ATM Interface

The air traffic management (ATM) interface concerns those aspects of interfacing the UAS with the air traffic controller (ATCo) and with other traffic/pilots.

- Common situational awareness
- Awareness of UAS traffic
- ATC symbology
- Dedicated routes
- Required separation
- Human factors
- Emergency procedures
- Emergency route design



T1.2 relevant projects

ATM Interface

- SINUE = Satellites enabling the integration in Non-segregated airspace of UAS in Europe
- SIGAT = Military spectrum requirements for the insertion into General Air Traffic for the UAS
- INOUI = Innovative Operational UAS Insertion
- Air4All
- USICO = Unmanned Aerial Vehicle Safety Issues for Civil Operations
- IDEAS = Integrated Deployment of UAS in the European Airspace using Satellites
- MINERVA = Demonstration project from the Spanish Guardia Civil
- Study from LFV, Saab and Lund University on ATM/UAS real time simulation issues h2

h2 hessel; 14.03.2011

T1.2 Relevant working groups

ATM Interface

- WG73 of EUROCAE
- UAVNet
- NATO FINAS specifications

T1.2 relevant results (so far)

ATM Interface

- Little real practical experience
  - Military (mostly corridors)
  - MINERVA
- Simulations
  - SINUE
  - IDEAS
  - LFV, Saab, Lund
  - INOUI
  - USICO
- ATCo HMI, situational awareness
  - do not distinguish the UAS too much
  - use of special emergency transponder codes
  - phraseology for informing other traffic

T1.2 relevant results
(so far)

ATM Interface

- Emergency routes and procedures
  - diversion procedures (fly home, destroy, go to safe area)
  - emergency routes
  - special transponder codes
  - other means of communication (back up telephone, internet)

T1.2 Current challenges

ATM Interface

- Knowledge of UAS flight characteristics by ATCo's
- Phraseology for ATCo's to inform traffic
- UAS (emergency) procedures
- ATCo training
- Reduction of time for detection of an emergency case

This covers T1.2 so far

T1.3 Weather Detection and Protection

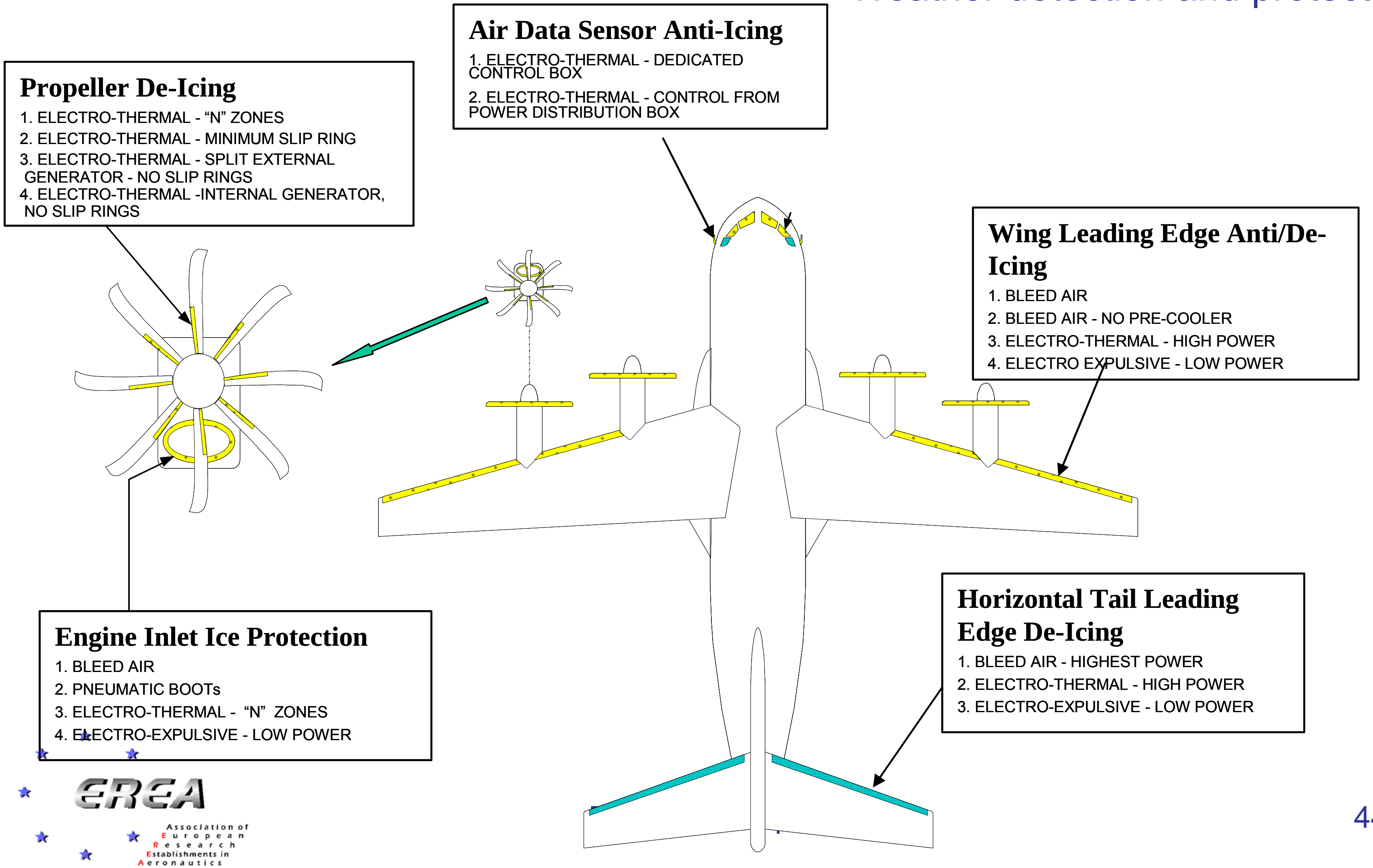
- In-flight atmospheric hazard avoidance through remote sensing systems
- Technology for detection and avoidance of atmospheric hazard
- Technology for icing protection systems

Strategic elements investigated in recent studies:

- Identifying the operational needs of pilots, operators, manufacturers, system utilization, aircraft integration, regulators and human factors
- Identifying sensing requirements
- Identifying technologies, and their state of development, for an integrated sensing system

T1.3 Weather Detection and Protection

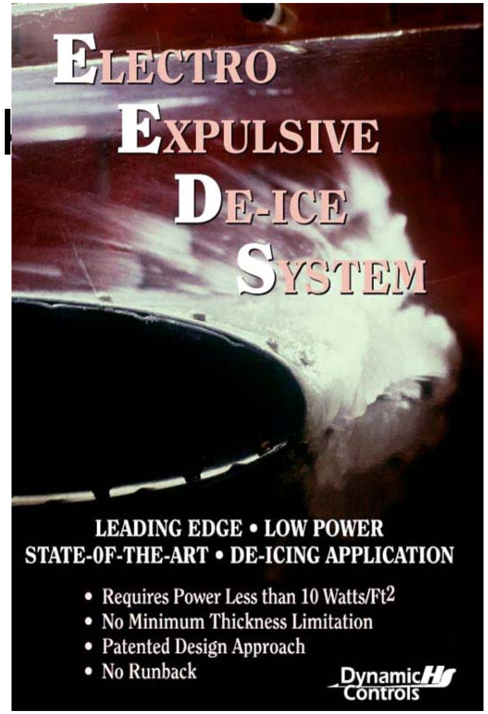
Weather detection and protection



T1.3 relevant projects

Weather detection and protection

- FLYSAFE
- AEROMUCO = Aerodynamic surfaces by advanced Multi-functional Coatings
- IIFD = Integrated Intelligent Flight Deck
- EEDS



T1.3 results (so far)

Weather detection and protection

- Ground-based remote sensing development to provide accurate detection and warning of in-flight icing conditions
- Airborne remote sensing development
- Terrain and obstacle presentations tailored to each flight phase
- More precise and detailed information on atmospheric disturbances such as thunderstorms, icing conditions and clear air turbulence

This covers T1.3 so far

T1.4 Taxi, Automatic Take off and Landing

Interoperability within the EDA adopted protocols, use of VTOL capabilities, all weather conditions, obstacle avoidance, collision avoidance.

ATM regulatory boundaries currently used for ground and take-off and landing operations in civil airports;

Technology needed to allow a routinely ground operation of UAS based on existing A-SMGCS (Advanced Surface Movement and Guidance System) procedures and know-how;

T1.4 relevant projects

Taxi, automatic take off and landing

- INOUI = Innovative Operational UAS Insertion
- Air4All
- TECVOL project (funded at National Level - Italy)
- EUROCAE WG-73
- EUROCONTROL - Specifications for the Use of Military Unmanned Aerial Vehicles as Operational Air Traffic Outside Segregated Airspace

T1.4 relevant results (so far)

Taxi, automatic take off and landing

- AL algorithm:
  - on line landing trajectory re-planning
  - fully autonomy from pilot inputs
  - weakly instrumented landing runway
  - ability to land starting from any point in the space
  - autonomous management of failures and/or adverse atmospheric conditions

T1.4 Current challenges

Taxi, automatic take off and landing

- Situational Awareness
  - Adaptation to UAS of Cockpit Displays of Traffic Information and Advanced Human Machine Interfaces to enhance the situational awareness of UA pilots
- Regulation and procedures
  - to be issued
- Sense/detect and avoid
  - technology development
- FMS and ACAS
  - enabling technologies for taxiing and automatic take-off &landing

This covers T1.4 so far

Recovery systems, decision support and autonomy of UAS needs to handle

- Efficient routine operation: ATM interactions, follow orders
- Irregular situations: Collision avoidance, weather avoidance
- System degradations: Communication link failures, Emergency behavior

T1.5 relevant projects

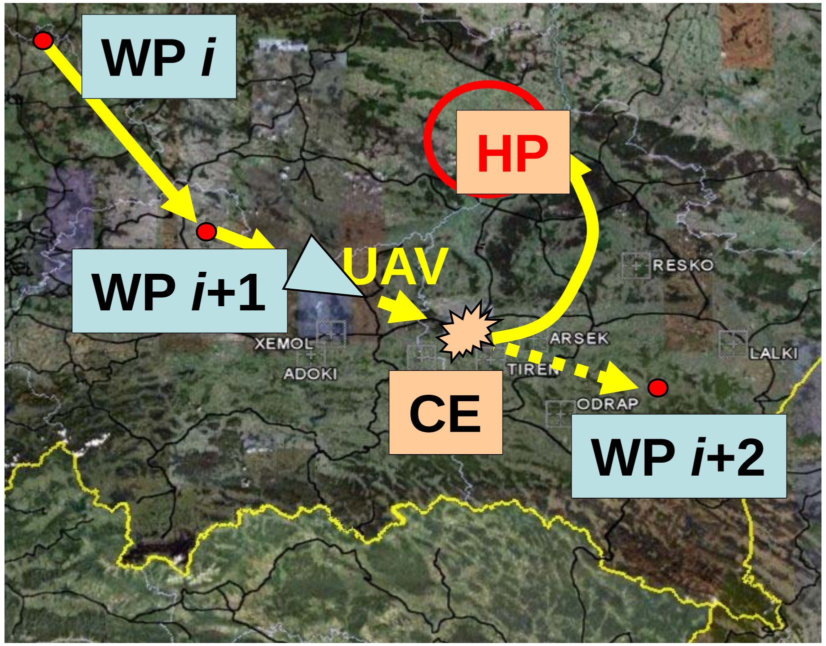
Safe recovery systems, decision making, and autonomous systems

- Sofia (EC)
- Wimaas (EC)
- Airbeam (EC)
- Patin (EC)
- Air4all
- MidCAS = Mid Air Collision Avoidance System
- SESAR Definition phase (SESAR ConOps, 4D trajectory, ATM Master plan)
- National studies, e.g. Astraea (UK), Safer (GE), Aura, Phoenix, Lot (Pl)

T1.5 relevant results (so far)

Safe recovery systems, decision making, and autonomous systems

- Robotics and Artificial Intelligence literature is full of results on UAS
- Safe, traffic rule obeying, robust, fault tolerant unmanned driving
- Path planning relative to bad weather, no-fly zones, alternate/emergency airfield, and continuous decent approach



T1.5 Current challenges

Safe recovery systems, decision making, and autonomous systems

- Collision avoidance systems
- Detect and handle critical malfunctions
- Interact with ATM (T1.2) by voice
  - Interchange information / follow orders
  - One-way (in or out) in case of link failure
  - Declare emergency
- Mission specific autonomous behaviour

This covers T1.5 so far

T1.6 Dependable Emergency Recovery

Emergency recovery (Assumed that a reliable failure detection and isolation was in place) may have several levels depending on the failure case :

- Hold on and return to nominal mission
- some mitigation action to reduce the severity of its effects
- Mission abort and safe landing in non-nominal flight configuration
- In extreme case, emergency procedure to protect on-ground populations and properties (eg crash zone, safety parachute,...)

A safety assessment concerns:

- Reliability definition of nominal components, redundancies
- Implemented logic of decision making
- Dedicated recovery equipments (eg parachute) and its (separate) activation chain

T1.6 relevant projects

Dependable emergency recovery

Safety analyses (or steps towards) have been performed in

- INOUI = Innovative Operational UAS Insertion
- Air4All
- NACRE (EC)
- SIGAT = Military spectrum requirements for the insertion into General Air Traffic for the UAS
- IDEAS = Integrated Deployment of UAS in the European Airspace using Satellites
- WG73 SG1
- SESAR : safety nets analysis, aircraft equipment projects
- National projects :
  - Cnes EOLE air-launch demonstrator (< 150 kg) : dedicated safety hardware

T1.6 relevant results (so far)

Dependable emergency recovery

- Functional hazard assessment, FMECA, Fault Tree Analysis, decision trees
- Definition of an emergency procedure based on an autonomous safety chain (watchdog + parachute system)
- Definition of a gradual approach (Air4All): first to tests emergency procedures for experimental vehicles in national, segregated airspace, unpopulated area, then populated, then non-segregated, then “file and fly”, then across borders/

T1.6 Current challenges

Dependable emergency recovery

- Regulation issues : define the cases when the aircraft should (depending on failure effects, FMECA, Fault Tree Analysis) :
  – Continue the mission
  – Switch to a hold-on procedure and try to fix
  – Switch to a return-to-base procedure
  – Switch to extreme emergency procedure with likely loss of the aircraft (eg parachute opening, ditching in the sea or in secured land,…
- Technical issues (based on safety assessments):
  – Define robust decision making process : redundancies, function separations, dedicated emergency item
  – Ensure controllability in non-nominal cases
  – Ensure sufficient unlikeliness of the “crash on populated areas” extreme case.

This covers T1.6 so far

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T1.7 Health Monitoring/ Fault Detection

The new paradigm consists in the ability to plan/decide/perform maintenance interventions based on the actual condition of the aircraft (condition based maintenance – CBM),

Health monitoring has to go through a RAMS (Reliability Availability, Maintainability, Safety) approach

The UAS HM system depends upon:

- the interaction of vehicle, engine and communication systems to provide data and information
- information processing and analysis
- understanding during the operational life of vehicles, engines and systems

T1.7 relevant projects

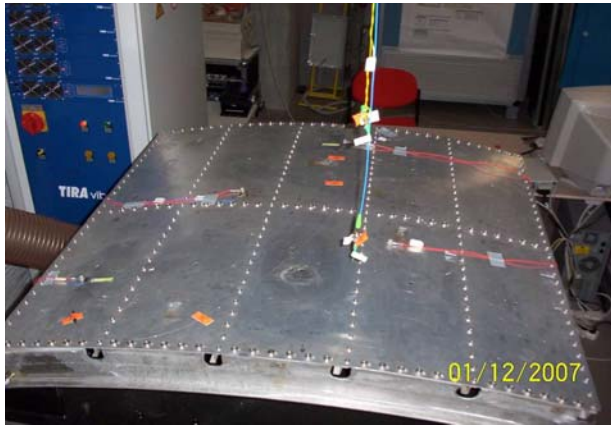
Health monitoring / fault detection

- **PON SMART (MIUR program)**
- **AHMOS (EDA)**
- **CESAR (EC)**
- **JTI Clean Sky (EU JTI program)**

T1.7 – Results (so far)

Health monitoring / fault detection

- **Structural Health Monitoring available for aeronautical components through use of traditional sensors (strain gages, accelerometers) and FBG fibre optics.**
- **Demonstration of sensing systems and in flight tests for SHM on military and civil aircraft.**
- **Numerical modelling of a complete SHM system (structure and sensor network) for impact identification damages.**



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T1.7 Current challenges for Health Monitoring and CBM

Health monitoring / fault detection

- **Condition based maintenance**
  - early degradation/damage detection
  - unambiguous health assessment at component level
  - enhanced prognostic assessment taking into account engine usage and operations.
- **To this extent, typical Key Performance Indicators would be**
  - accuracy of degradation/damage detection
  - false alarm and no detection rates for component level localisation
  - fidelity of prognostic regarding time remaining before control or maintenance action
- **For structural health monitoring**
  - Multi-scale modelling of materials and structures for design tools development
  - Validation of the developed SHM systems on relevant environments
  - Sensor embedding or integration within the structure: Fiber Optic Bragg Grating (FOBG) appear a promising technology, alternative to conventional sensors.

This covers T1.7 so far

T1.8 UAS Pilot/ Commander Training

- A situational awareness level comparable to that of on-board pilots must be aimed for in the design of the ground control station.
- Current solutions and research directions indicate a human machine interface that significantly differs from that of manned aircraft cockpit design.
- Research directions
  - pilot selection
  - education
  - training
  - qualification

T1.8 relevant projects

UAS pilot / commander training

- NATO FINAS (Flight In Non-Segregated Air Space)
  - Recommended Guidance for the Training of Designated UAV Operator (DUO) work strand
- EUROCAE WG 73 SG3
- Several national studies
- Eurocontrol OAT TF
  - (Among others) certification for training and licensing
- NATO / CEAC Guidance for unmanned aerial vehicles (UAV) operations, design specification, maintenance and training of human resources

T1.8 relevant projects

UAS pilot / commander training

- FAA Unmanned aircraft operator qualification and training requirements
- USICO
  - 5th framework research programme on (among others) recommendations for UAV operations regulations
- IMPRINT: Improved Performance Research Integration Tool (USA)
  - Human Systems integration tool (incl. training and human factors)
- WASLA-HALE

T1.8 relevant results (so far)

UAS pilot / commander training

- Initial certification efforts
- Dedicated UAS training programmes (DoDs and industry)
- Increased maturity level of training environments and evaluation tools

T1.8 Current challenges

UAS pilot / commander training

- More agreement and coordination among different partners/organisations is needed
- Certification of selection, training and (rules of) operation for a huge array of UAS operators still needs development
- Concept of operation (in ATM) is needed
- Deadlock between industry waiting for certification standards and certification authorities waiting for more experience in UAS operation
- RPS design and training for Human Machine Interaction is insufficient
- EU still lags behind on UAS theatre

This covers T1.8 so far
and my part

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