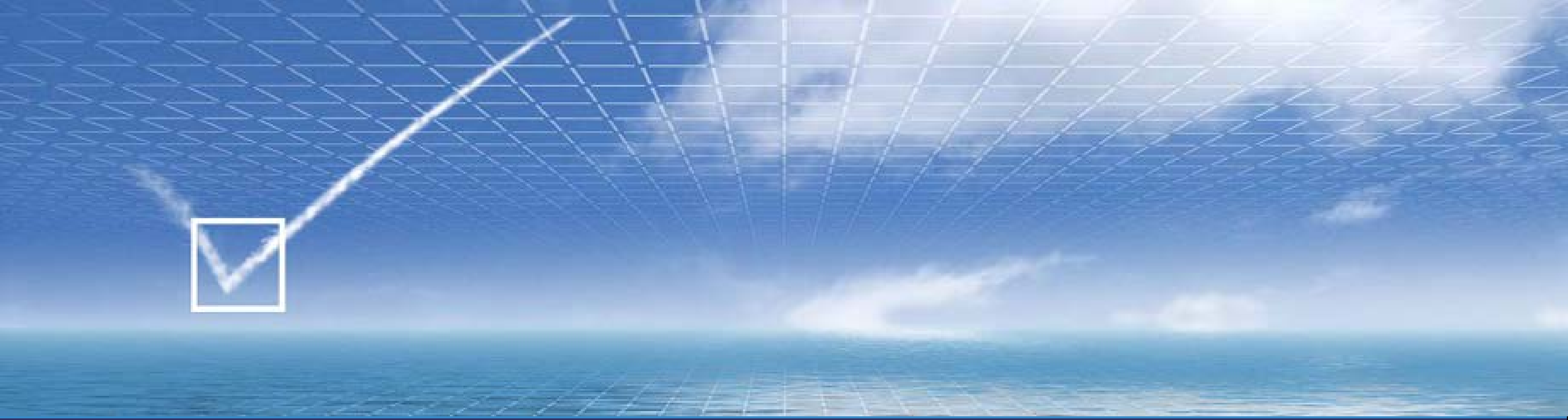

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Missions of civil RPAS in uncontrolled airspace

Present and Future of civil RPAS
AAE/3AF Conference, November 13th, 2014

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Member of 3AF CTD

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Agenda

- General principles
- RPAS missions in uncontrolled airspace
- Major associated risks
- Risk mitigation and potential solutions
- Conclusions

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RPAS missions in uncontrolled airspace

Uncontrolled airspace

- **Means Classes F (exceptional in Europe) and G in current classification**
- **Class G starts from ground and is up to 3000 ft throughout Europe, outside TMAs**

FL or Alt Band	France/ Monaco	FYROM	Germany	*Georgia*	*Greece*	Hungary	Ireland	Italy	Latvia	Lithuania	Malta	Moldova	Netherlands
Up Limit CAS	660	660	660	460	460	660	660	460	460	660	460	660	660
245-460	C	C	C	A	C	C	C	C	C	C	C	C	C
205-245													
195-205													
150-195	D	D		C				G			G / C		A / B
130*-150													
95*-130*	G		C / E										
3K*-95*		E	E	G		F	G		G	G			
SFC-3K*		G	G			G						G	G
Major TMA	A	D	C	C		C	C	A / E	C	C / D	C	C	A
Minor TMA	C / D / E	E	C / D / E					D / E					B / E
CTA/Airway	D / E	D / E								D			A
CTR*	A / D	D	D / F					A / C / D		C / D			C

Air Traffic Control Services

- **No ATC in Class G. Air Traffic Control cannot be responsible for Separation.**
- **If the RPAS is not taking off from or landing to an airport, no ATC support is available for T-O and Landing (most of the accidents in General Aviation occur at take-off and landing)**
- **Either in VFR/IFR or in BVLOS, the tele-pilot on the ground has no possibility to acquire potential dangers by direct vision: other aircraft, terrain, obstacles, bad weather, etc…**

> RPAS flight in uncontrolled airspace is a critical challenge for safety

Examples of civil RPAS missions

Potential Class G missions, in BVLOS , VLL (< 500 ft)

- Aerial photography
- Surveillance of buildings
- Police, surveillance of road traffic …
- Surveillance of long linear infrastructures
  - Pipe-lines and gas ducts
  - Power lines and rail tracks
- Support to agricultural activities
- Support to fishing
- Detection of pollution at sea
- Telecommunication relay
- Surveillance of industrial facilities
- Surveillance of forests and wild life
- Transport of freight
- Etc …

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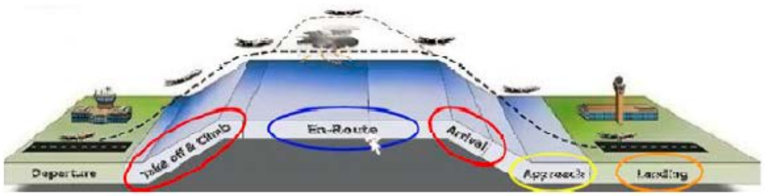
Typical Mission profile

- **Take-Off and climb**
  - **Manual (if very light) or catapult launched**
  - **Automatic T-O from runway for bigger RPAS**
  - **Climb phase can be either much shorter or longer than in manned aviation**
- **En-route**
  - **Variable transit to/from operational area**
  - **VLL or Class G IFR/VFR at different altitudes**
  - **In general, return to same point for landing**
- **Mission on operational area**
  - **Specific profile depending on mission:**
  - **Variable altitudes subject to points of interests for the specific performed mission**
- **Automatic Landing**
  - **Rugged landing for very light and rotorcraft**
  - **Parachutes, airbags or nets for medium**
  - **Runway for bigger air vehicles**



Manned Aviation (Air Transport)

RPAS specific operationnal mission

Major risks incurred

- Collision with another aircraft – Risk for other airspace users
  - Beyond line of sight and without any support from ATC, the operating pilot has *no possibility to see and avoid* a conflicting intruder and is not separated from other aircraft
  - At VLL, traffics are scarce but helicopters, parachutes, gliders, ULM can be met
  - At higher altitude general aviation and gliders can be met at any altitude within Class G
  - Take-off and Landing can be secured if local ATC from/to an airport but can be hazardous outside airport areas
  - The risk exists for any phase of flight and for any RPAS size or configuration (FW or RW)
  - A collision with another airspace user could have catastrophic consequences for the other user, even with a light RPAS.
- Collision with ground or ground obstacles – Risk for overflown population
  - Many ground obstacles can be found at very low altitude: buildings, poles, wires, cranes, ground hazards etc…
  - A collision with the ground could highly endanger people and/or affect the integrity of goods
  - Beyond line of sight and without any support from ATC (Uncontrolled Airspace), the operating pilot has no possibility to *see and avoid* an obstacle or the ground
  - The risk exists for any RPAS, but potential consequences increase with RPAS mass and velocity

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Particular sources of risk

Loss of Data Link

- **Loss of Data Link is an intrinsic risk for all RPAS, but it can particularly affect safety when flying in uncontrolled airspace and beyond visual line of sight, at any altitude**
- **Whatever the mitigations brought to previously mentioned major risks, a loss of data link, even temporary, can dramatically deteriorate the situation:**
  - Situation awareness from the RPAS pilot on the ground can be altered or suppressed
  - Mitigation actions and commands from the RPAS pilot may not be possible
- **This could in particular impact the RPAS capacity to avoid an uncontrolled crash**

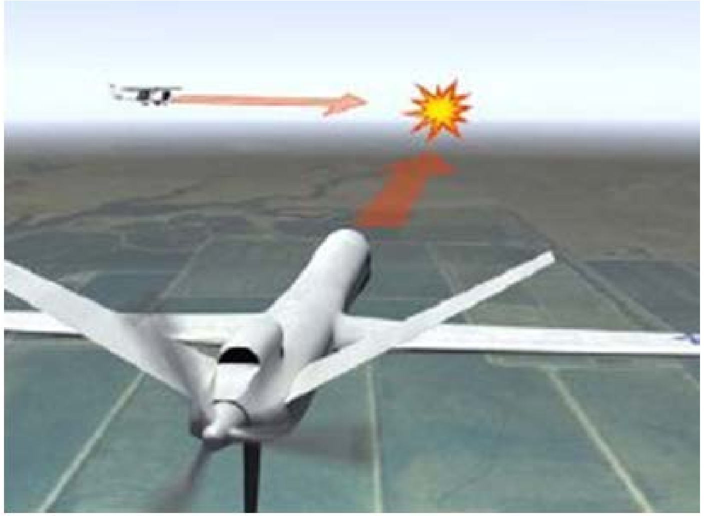
System failures

- **System failures can be detrimental to any RPAS safety, e.g. engine deficiencies, loss of electrical or hydraulic power, loss of navigation information, etc…**
- **The risk is increased in uncontrolled airspace if such failures affect the performance of the RPAS system at low altitude, or the equipment which will be used to mitigate major risks e.g. *Detect and Avoid, RPAS position*, vehicle altitude, distance to obstacles, etc…**
- **RPAS health status must be known by the pilot to mitigate a possible system failure**

Potential collision with another airspace user

Detect & Avoid

- **For RPAS, See & Avoid (Detect & Avoid) is replaced by Detect & Avoid**
- **Sensors, computers and (potentially) actuators are used to replace pilot's senses, decision making and (potentially) action to avoid as far as possible a possible collision**
- **Avoidance manoeuvre can be made at long / medium term ("traffic avoidance", or "self separation") and at short / very short term ("collision avoidance")**



Aviation Habitée
"Voir & Eviter"
"See & Avoid"

Unmanned Aircraft Systems
"Détecter & Eviter"
"Sense & Avoid"
"Detect & Avoid"

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Airborne Based Detect And Avoid

- All sensors and computers are aboard: detection, avoidance decision and execution are performed by on-board system
- Compatible with both cooperative (Transponder or ADS-B OUT equipped) and non-cooperative intruders, a necessity particularly in Class G
- Potential sensors

Transponder interrogator ADS-B IN receiver, FLARM	**Cooperative**
EO/IR sensors D&A radar	**Non-Cooperative**

- The pilot and the ATC can be permanently informed of the situation, prediction of the avoidance manoeuvre is permanently sent to the pilot who can decide to overtake the system. If no pilot action prevents it, the avoidance manoeuvre is automatically executed before the collision is deemed inevitable ("last ditch manoeuvre")
- Advantages:
  - Pilot and ATC possible interventions as far as possible
  - No time lag to execute manoeuvres
  - Resistant to Data Link loss

- Current status: many investigations in the world for a future technology
  - In the US: FAA/RTCA, NASA, DoD …
  - In Europe: EUROCAE WG 73, MIDCAS, ASTRAEA
    - Future developments to define standards and to miniaturize technology
  - The topic should be included in the future SESAR 2020 R&D

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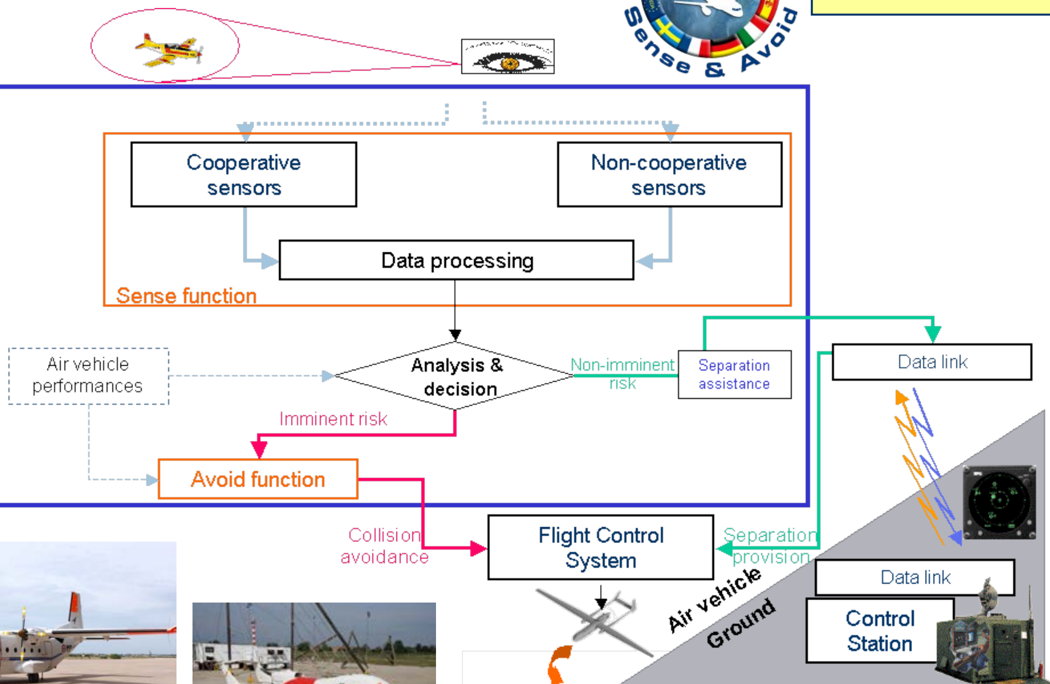
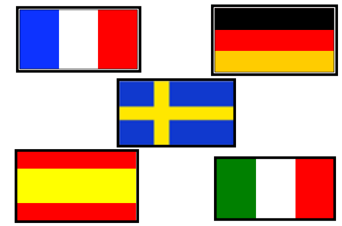
MIDCAS, the European answer

MID-air Collision Avoidance System



EDA



Basis for a standard
Generic system study
Extended simulation
Real flight tests

SAAB · AleniaAermacchi (A Finmeccanica Company) · CIRA · DIEHL BGT Defence · DLR · AIRBUS DEFENCE & SPACE · ESG · indra · SAFRAN Sagem · Selex ES (A Finmeccanica Company) · THALES

Other means of mitigation

ACAS II (T-CAS II)

- **Current Collision Avoidance “safety net” in civil aviation, but**
  - Not initially designed for RPAS performances
  - Limited to manoeuvres in the vertical plan
  - Usable only with cooperative intruders
- **Particularly efficient when explicitly coordinated with the other aircraft, not necessarily the case in Class G**

Ground Based D&A

- **A network of ground radars is sending information to the pilot to detect and avoid a potential collision**
- **Under investigation in some countries (Ge, SW, US in particular …)**
- **Advantages:**
  - No on-board system, particularly applicable to small RPAS
  - Use of existing infrastructures
- **Drawbacks:**
  - Sensitive to data link loss
  - Overland system

RPAS detectability

- **A reverse necessity for the RPAS to be detected by other aircraft (visual and electro-magnetic means), with the aim to reduce as far as possible other users equipment**

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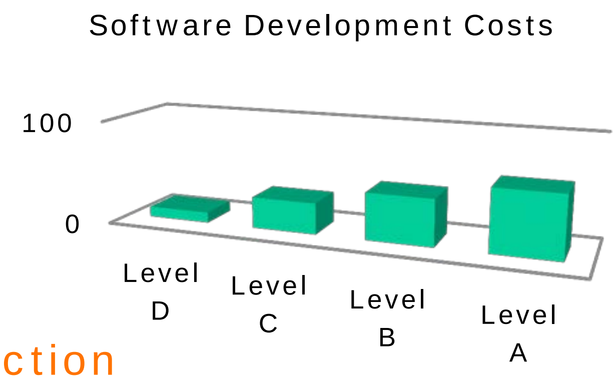
Potential collision with ground / ground obstacles

- Ground and ground obstacle avoidance
  - **Now taken into consideration for RPAS, in particular for VLL flights**
  - **Regulation can limit flights over specified densities of population**
- Currently used systems in civil aviation – Adaptation to RPAS
  - **Terrain Avoidance Warning Systems (TAWS) are based on embedded geographic information processed by a specific software**
  - **The avionics functionality is contained on a single PCB**
  - **Such devices do not currently include all the information relevant information for RPAS flight: a more detailed data base needs to be developed to incorporate all details useful for an RPAS flight at very low level**
    - Main issue is the update of such data base according to daily evolutions: works, crane installed, etc…
- Current status
  - **In Europe, EUROCAE WG-73 has started to elaborate a standard for civil RPAS**
  - **The topic should be included in the future SESAR 2020 R&D**

Prevention of system failures

- System Failure analysis
  - A failure analysis needs to be performed at system level in order to determine
    - All potential failure modes and their impact on safety
    - All potential degraded modes
    - All possible mitigations e.g. duplication of functional chains, targets of equipment reliability, etc…
  - Certified systems designed so as to meet safety requirements
  - Adequate safety targets need urgently to be defined, as a too high requirement could kill any economic perspective



3AF CTD – Juin 2013

- Data Link specific protection
  - Prevention of data link loss is part of such analysis, with specific measures
  - Use of internationally recognized protected radio-frequency bands for C2
  - Use of integrity protocols
  - Duplication of physical Data Link equipment
  - Redundancy between C2 and Mission

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Conclusions

- RPAS flight in uncontrolled airspace and outside airport is one of the most risky configurations
- However, many potential RPAS missions are embracing such a mission
- Major risks are collision with another airspace user and collision with ground / ground obstacle which might endanger population and goods on the ground
- Air collision avoidance technology is under investigation in many parts of the world and particularly in Europe with the MIDCAS project
- Ground based technology can be an interesting answer for small RPAS over land
- Standardization and technology miniaturization should enable innovation and adequate solutions to fly RPAS soon in uncontrolled airspace
- Other risks can be mitigated by using and adapting validated aviation processes and technologies, but with adequate and reasonable safety targets

Questions ?

- **Single European Sky Air Traffic Research (SESAR)**
  - Pan-European initiative aimed at modernising and harmonising European ATM systems
  - Safety & Efficiency are key drivers
  - Projects enable the validation of the SESAR concept of operation

- **Integrated RPAS Demonstration Activities**
  - Demonstrate how to integrate RPAS into non-segregated airspace in a multi-aircraft and manned flight environment
  - Focus on filling the operational and technical gaps identified
  - Provide synergies, risks and opportunities with the overall SESAR programme
  - Maintain coherence with and provide input to the EC RPAS Roadmap initiative

Project CLAIRE Demonstration Day 16 Oct 2014

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