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• Safety layers in manned aviation
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MID-AIR COLLISIONS – A REAL THREAT
3.2 Avoidance of collisions

Nothing in these rules shall relieve the pilot-in-command of an aircraft from the responsibility of taking such action, including collision avoidance manoeuvres based on resolution advisories provided by ACAS equipment, as will best avert collision.

Note 1.— It is important that vigilance for the purpose of detecting potential collisions be exercised on board an aircraft, regardless of the type of flight or the class of airspace in which the aircraft is operating, and while operating on the movement area of an aerodrome.
MAIN LAYERS OF PROTECTION AGAINST MID-AIR COLLISIONS

**Strategic Conflict Management**
- Airspace design
- Procedures and Regulations
- Flight plans

**Separation Provision**
- Responsibility of ATC or the Pilot depending on airspace class and flight rules (IFR/VFR)
- "Don't scare others!"

**Collision Avoidance**
- This ultimate responsibility for avoiding collisions always remains with the pilot
- Mainly performed by the pilots ability to “See & Avoid”, i.e. the pilots eyes and ability to perform the correct decision and correct action
- “Don't scrape paint”
AIRSPACE CLASSES A-G

• Airliners
  – Operates in class A-C
  – Flying according to Instrument Flight Rules (IFR)
  – Equipped with Transponder/ADS-B, i.e. are Cooperative
  – Equipped with TCAS collision avoidance system
  – Separated from all other traffic by ATC
  – **Pilot responsible for Collision Avoidance** (aided by TCAS)

• General Aviation aircraft
  – Operates mainly in the "lower" airspace classes incl uncontrolled
  – Operates at lower altitudes below 10 000 ft (max speed 250 kts)
  – Large portion of flights according to Visual Flight Rules (VFR)
  – Many without Transponders/ADS-B, i.e. Non-cooperative
  – Limited or no ATC separation
  – **Pilot responsible for Remaining Well Clear and Collision Avoidance**
DAA FOR RPAS

• Removing the pilot from the aircraft requires a capability to detect and avoid other aircraft – Detect and Avoid system (DAA) for conflicting traffic

• Note that full DAA includes to avoid several hazards (according to ICAO definition):
  a) conflicting traffic
  b) terrain and obstacles
  c) hazardous meteorological conditions (i.e. thunderstorms, icing, turbulence)
  d) ground operations (aircraft, vehicles, structures or people on the ground)
  e) other airborne hazards, including wake turbulence, wind shear, birds or volcanic ash

• Some of these hazards can be mitigated with procedures and planning, i.e. may not require systems
OPERATIONAL CATEGORIES FOR RPAS

- Three different categories of RPAS operations are foreseen:
  - **Open**: VLOS, low altitude (500 ft AGL)
  - **Specific**: Operation based on risk assessment
  - **Certified**: ATM operation, mixing with manned aviation

- DAA for conflicting traffic is mainly applicable for the Certified category but also to some extent for Specific category depending on the risk assessment.
Detect and Avoid (conflicting traffic) consists of three main capabilities

- Traffic Awareness ("be informed")
- Remain Well Clear ("don't scare")
- Collision Avoidance ("don't scrape paint")

DAA OPERATIONAL SCENARIO
DAA TIMELINE

- **Surveillance phase**
- **Remain Well Clear phase**
- **Escape phase**
- **Collision Avoidance phase**

- **RWC Alert**
  Up to 120 s before Conflict

- **RWC Threshold**

- **CA Alert**
  ~10 s before last chance

- **Auto CA**

- **CPA**

- **Well Clear boundary**

- **Collision Volume**

- Communication with ATC for amended clearance
DAA COLLISION AVOIDANCE CONCEPT

When the manoeuvre prediction indicates last chance to resolve the situation without CV breach (incl margins) the manoeuvre is activated automatically.

A manoeuvre is continuously calculated and evaluated against the Collision Volume.
MAIN TOP REQUIREMENTS

• Be at least as safe as manned flights (low MAC probability)
  – Historical rates for MAC
    – $3.67 \times 10^8$ per flight hour for Large aeroplanes (airliners) ($\sim 1 \times 10^{-9}$ fh)
    – $7.15 \times 10^7$ per flight hour for GA under IFR ($\sim 1 \times 10^{-7}$ fh)
    – $1.41 \times 10^7$ per flight hour for GA under VFR, filing flight plan ($\sim 1 \times 10^{-7}$ fh)
    – $1.47 \times 10^6$ per flight hour for GA not filing flight plan ($\sim 1 \times 10^{-6}$ fh)

  => Acceptable risk for MAC depends on intruder type and possibly airspace class

• Not impair safety to other airspace users
  – Maneuvers performed due to DAA system needs to be safe relating to all other airspace users.

• Be seamlessly integrated in the airspace
  – Limit unjustified avoidance maneuvers
  – Not increase workload for ATCo, e.g. not increase communication
  – Follow Right of way rules

• Be interoperable
  – The DAA system shall be interoperable with established collision avoidance systems
DAA STANDARDS

- Work to define standards for DAA is ongoing in several different groups

- ICAO RPAS Panel
  - Updating ICAO Annexes to integrate RPAS (e.g. Airworthiness, C2 Link, DAA, …)

- EUROCAE and RTCA
  - Developing industry standards, MASPS/MOPS

- JARUS
  - Defining technical, safety and operational requirements

In parallel to developing standards there are several projects developing technology to ensure e.g. feasibility
If we have a Detect & Avoid system onboard? Why do you ask?

DAA SYSTEMS ARE RELEVANT ALSO FOR MANNED AVIATION …

Thank you for your attention!