NATO Developments in UAS Airworthiness and Sense & Avoid Functional Requirements

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Mission

• “To recommend and document NATO-wide guidelines to allow the cross-border operation of unmanned aerial vehicles (UAVs) in non-segregated airspace”
FINAS - Members by Nation

UK - Chair

FR – USAR ST Chair
DUO Training Requirements

- Designated UAV Operator
- Lists skills by
  - Subject knowledge areas
  - Task knowledge
  - Task performance
- Tailored to UAV type and role
- If majority Ratify then Promulgated as STANAG 4670
• UAV Systems Airworthiness Requirements (USAR)
• Fixed wing UAVs
• 150 to 20,000 kg
• Based on CS-23
• Minimum airworthiness standards
• Key component of national standards
• Ratification ends 1 Nov 07
• If majority agree Promulgated as STANAG 4671
• Public domain
STANAG 4671 Key to UAV Airspace Integration

International rules to integrate an aircraft in the airspace

Art 31
Airworthiness Requirements

Art 32
Flight Crew Licenses

Art 12
Operational Requirements "Rules of the air"

Civil Aviation

Military Aviation

Military Airworthiness Requirements
(e.g. MIL-HDBK-516B, JSSGs, STANAG 4671, etc.)

STANAG 4670 DUO Training Qualifications

NATO/Military/FAA/Eurocontrol SAA Requirements
Why STANAG 4671?

"If a National Certifying Authority states that a UAV System airworthiness is compliant with STANAG 4671... that UAV System should have streamlined approval to fly in the airspace of other NATO countries, if those countries have also ratified this STANAG." - excerpt

For US UAVs:
- Streamlines access to NATO non-segregated airspace by clearly defining UAV a/w requirements
- Provides PMA guidance on minimum airworthiness spec requirements
- Provides design guidance to industry and enhances FMS potential

For NATO UAVs to fly in US
- Provides minimum a/w standard in support of diplomatic clearances and FAA approvals for NATO partner UAVs
STANAG 4671 Scope Limitations

- The following issues are not addressed by STANAG 4671 and are subject to other forms of approval by the Certifying Authority:
  - Control station security
  - Security of the command and control data link from unlawful interference
  - Airspace integration and segregation of aircraft
  - The competence, training and licensing of UAV crew, maintenance and other staff
  - Approval of operating, maintenance and design organizations
  - Frequency spectrum allocation
  - Noise, emission, and other environmental certification
  - Operation of the useful payload (other than its potential to hazard the aircraft),
  - Non-deterministic flight (e.g. neural net)
  - Sea basing, Supersonic Flight, and carriage/release of stores
  - Remote piloting (i.e. direct control of flt surfaces) from an external or internal control box

- Sense and Avoid is a key enabling issue for UAS operations; however, derivation of ‘sense and avoid’ requirements is primarily an operational issue and hence outside the scope of this STANAG. Once the SAA requirements have been clarified, any system designed and installed to achieve these objectives is subject to “installed equipment” requirements.
01 Feb: Brief to AIR-4.0; NATO informed that Navy intends to ratify w/reservations

20 Jun: Comments from all L2’s received

20 Mar: Final NATO STANAG Development Meeting

04 Oct: JALC VTC

07 Aug: Ratification Brief to AIR-4.0

01 Nov: NATO Ratification Deadline

October 15: Final US position due to J6
Why should NATO write SAA Functional Requirements?

• “The CAA considers that, until such time as research and development work has been carried out to define potential system concepts and architectures, the parameters that will govern the performance characteristics of a sense and avoid system cannot be identified with any certainty, (and so cannot be agreed)”. UK CAP 722, Chap 9

• FINAS view:
  • Access difficult without common SAA standard
  • “Peg in the ground”
  • Exploit ATM principles
ATM Principles for Conflict Management
(Re: ICAO ATM Operational Concept Doc - AN-Conf/11 -WP/4 App)

• Conflict management 3 layers:
  • Strategic:
    – airspace organisation & management e.g charts, routes, traffic synchronisation
  • Separation Provision:
    – tactical process of keeping aircraft apart at (occasionally) prescribed minima (e.g 5 miles, 2000ft)
  • Collision Avoidance:
    – must activate when separation provision has failed. Last ditch manoeuvre necessary for survival
ATM Principles for Conflict Management
(Re: ICAO ATM Operational Concept Doc - AN-Conf/11 - WP/4 App)

• Separation Provision:
  – Who is the “separator”? ATC or Aircraft Cdr(UAV Cdr)?
  – Depends on class of airspace and flight rules in force

• Collision Avoidance:
  – Applies at all times, in any class of airspace under any flight rules. Independent from separation provision (e.g. TCAS II)

• Sense & Avoid System must consider both these 2 functions.

• Common misperception: a SAA system is an Airborne Collision Avoidance System (ACAS). It is not - the ACAS function is but one element of a SAA system.
FINAS SAA considerations

- Separation provision = "don’t scare others"
  - not all losses of separation result in a MAC
  - separation minima not defined for VFR flight
  - FINAS suggest 500ft vertical & 0.5nm lateral

- Collision Avoidance = "don’t scrape paint"
  - must be less than separation minima
  - FINAS suggest 350ft vertical & 500ft lateral
Probability of Mid-Air Collision ($P_{MAC}$)

Sequence of events:
- 2 a/c on collision course
- Failure of separation provision function by ATC, or UAV pilot (DUO)
- Failure of collision avoidance function in UAV and
- Simultaneous failure of collision avoidance function in other a/c, since both a/c are responsible for collision avoidance

$$P_{MAC} = P_{\text{collision course}} \times P_{\text{separation fail}} \times P_{\text{UAV Collision Avoid fail}} \times P_{\text{Conflicting A/C Collision Avoidance fail}}$$
Target Levels of Safety (TLOS) and $P_{MAC}$

$P_{MAC}$ equates to our desired TLOS:

$$P_{MAC} = P_{\text{collision course}} \times P_{\text{separation fail}} \times P_{\text{UAV Collision Avoid fail}} \times P_{\text{Conflicting A/C Collision Avoidance fail}}$$

- **Empirical Data (1995-2004, UK registered GA a/c):**
  - Average MAC rate = 1.47 collisions/million flt hrs.

- **However, FINAS suggest UAV and CAT collision so undesirable:**
  - TLOS = $1 \times 10^{-9}$ collisions/flight hr

- **Why so demanding?**
Pilots fear crash danger as drones prepare to take off

JASPER Copping

They can fly at more than 400mph and remain airborne for days at a time, monitoring traffic, searching for survivors lost at sea or even tracking suspected criminals 20,000ft below, all without a human on board.

Now plans to allow unmanned drones to fly alongside conventional aircraft in the skies over the UK by the end of the decade have prompted warnings from pilots who fear an increased risk of mid-air collisions.

Their warnings come as officials from the Civil Aviation Authority (CAA) and manufacturers of unmanned aerial vehicles (UAVs) are revamping the rules governing UK airspace to pave the way for a fleet of robotic drones to carry out a wide range of non-military roles.

These range from police surveillance and search and rescue to monitoring the health of crops over farm lands, checking on pipeline networks and tracking pollution after chemical spills.

Pilots say this would mean drones sharing the skies with passenger aircraft as well as light aircraft, gliders and hot air balloons, in areas where accidents - if they occur - are more likely to cause serious injury or death.

Dave Reynolds, a flight safety officer from the British Air Line Pilots Association (Balpa), said: "One major concern is safety. People need to realise it's not something that is far off in the future. We're very aware of the developments and are working closely with the CAA to ensure we are ready.

"There are also industry fears of problems near airports where air traffic controllers would have to deal with unmanned aircraft and some unmanned aircraft are currently banned from UK airspace - apart from a few, very short locations for test flights - for safety reasons.

But the rules are being overhauled as part of a £12million project, codenamed Astrosyn, which has been jointly funded by the Government and seven companies, including the weapons manufacturer BAE Systems and QinetiQ, to develop a new generation of drones within a variety of civilian roles flying pre-programmed routes.

Scientists are confident that they will be able to fit sensors to drones to help identify and avoid other aircraft.

Simon Jewell, chairman of the Astrosyn steering board, said: "It will be a challenge to avoid people's thinking but those systems will be far easier, not safer, than pilots.

The drones are expected to be far more cost-effective in a number of roles currently carried out by satellites, light aircraft or helicopters.

"They may even be fitted with facial recognition technology to follow the movements of specific people. Metropolitan police have expressed interest in using them to hover over problem areas to detect anti-social behaviour."

The most common drone is likely to be the Heron, which has a 7.5ft wingspan and can remain airborne for 25 hours.
Target Levels of Safety (TLOS) and $P_{MAC}$

$P_{MAC}$ equates to our desired overall TLOS=

$$P_{collision\ course} \times P_{separation\ fail} \times P_{UAV\ Collision\ Avoid\ fail} \times P_{Conflicting\ A/C\ Collision\ Avoidance\ fail}$$

Non-technical term
Depends on time and space
\(\propto\) air traffic density
\(\propto\) conops

Technical term = performance of collision avoidance system

Technical or non-technical term
Assume = 1

Technical or non-technical term
Depends on who is providing separation: ATC or DUO?
\(\propto\) conops
\[ A_{\text{exp}} = \text{Area of Exposure} \]

\[ D = \sum d_i \ldots d_n \]

Rate of potential collisions in time \( t \) = \[ \frac{A_{\text{exp}} D}{V t} \]

Given:

\[ A_{\text{exp}} (\text{757 size a/c}) \approx 560 \text{ ft}^2 \]

Then:

Rate (worst case) of potential collisions = \( 4 \times 10^{-5} \) collisions/hr
Target Levels of Safety (TLOS) and $P_{MAC}$

$P_{MAC}$ equates to our desired TLOS =

\[
P_{\text{collision course}} \times P_{\text{separation fail}} \times P_{\text{UAV Collision Avoid fail}} \times P_{\text{Conflicting A/C Collision Avoidance fail}}
\]

- Thus, if assume:
  - $P_{\text{collision course}} = \text{ambient probability of collision} = 4 \times 10^{-5}$
  - $\text{TLOS} = 10^{-9}$
  - $P_{\text{Conflicting A/C Collision Avoidance fail}} = 1$

- Then the combined probability of failure of separation provision and collision avoidance need only be $\approx 10^{-4}$
- But is this value realistic? How independent are these terms?
SAA - Issues

- What happens if we assign UAV a finite size?
- Does CPA minima (350ft & 500ft) have an affect
- $P_{MAC}$ expression - *are terms truly independent?*
- MAC rate $10^{-9} = TLOS$ - *is this realistic?*
- Ambient probability of collision - $4 \times 10^{-5}$ – *valid?*
- UAV’s concept of operations - *critical*
- VMC and/or IMC operation - *both or just VMC?*
- Where next? …………….*modelling!*
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Questions?

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US Participation To Date

• Over 400 US comments submitted to NATO from Government and Industry since July 2005:
  - Formal endorsement received from AIA
  - Socialization outside NATO/NAVAIR:
    - International Program Office
    - JALC Working Group
    - National Airworthiness Council
    - OSD, AT&L (UAS)
    - Aerospace Industries Association
    - FAA AIR-160
    - OSD Foreign Clearance Office