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

CA

SW

GE

US

IT

NL

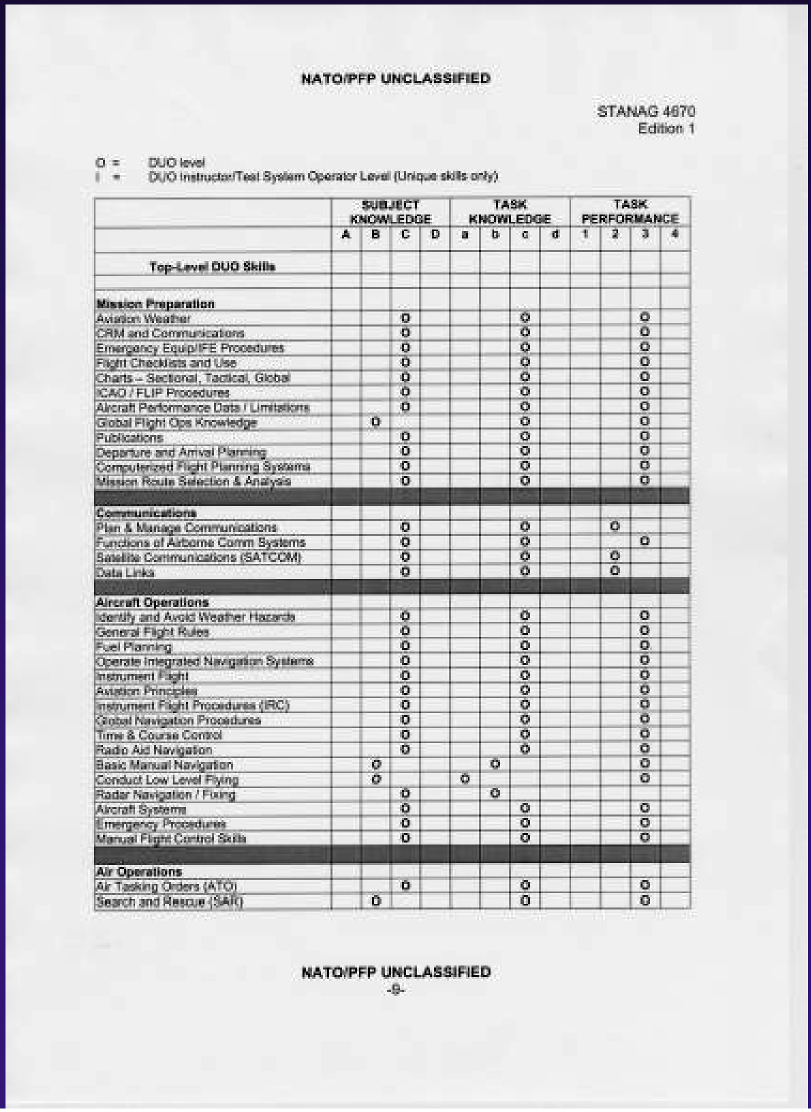
SP

TU

PO

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



NATO/PFP UNCLASSIFIED

STANAG 4670
Edition 1

O = DUO level
I = DUO Instructor/Test System Operator Level (Unique skills only)

	SUBJECT KNOWLEDGE				TASK KNOWLEDGE				TASK PERFORMANCE			
	A	B	C	D	a	b	c	d	1	2	3	4
Top-Level DUO Skills												
Mission Preparation												
Aviation Weather			O				O				O	
CRM and Communications			O				O				O	
Emergency Equip/IFE Procedures			O				O				O	
Flight Checklists and Use			O				O				O	
Charts – Sectional, Tactical, Global			O				O				O	
ICAO / FLIP Procedures			O				O				O	
Aircraft Performance Data / Limitations			O				O				O	
Global Flight Ops Knowledge		O					O				O	
Publications			O				O				O	
Departure and Arrival Planning			O				O				O	
Computerized Flight Planning Systems			O				O				O	
Mission Route Selection & Analysis			O				O				O	
Communications												
Plan & Manage Communications			O				O			O		
Functions of Airborne Comm Systems			O				O				O	
Satellite Communications (SATCOM)			O				O			O		
Data Links			O				O			O		
Aircraft Operations												
Identify and Avoid Weather Hazards			O				O				O	
General Flight Rules			O				O				O	
Fuel Planning			O				O				O	
Operate Integrated Navigation Systems			O				O				O	
Instrument Flight			O				O				O	
Aviation Principles			O				O				O	
Instrument Flight Procedures (IRC)			O				O				O	
Global Navigation Procedures			O				O				O	
Time & Course Control			O				O				O	
Radio Aid Navigation			O				O				O	
Basic Manual Navigation		O				O					O	
Conduct Low Level Flying		O			O						O	
Radar Navigation / Fixing			O			O						
Aircraft Systems			O				O				O	
Emergency Procedures			O				O				O	
Manual Flight Control Skills			O				O				O	
Air Operations												
Air Tasking Orders (ATO)			O				O				O	
Search and Rescue (SAR)		O					O				O	

NATO/PFP UNCLASSIFIED
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USAR

- 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
(Edition 1)

NATO STANDARDIZATION AGREEMENT
(STANAG)

DRAFT STANAG 4671 - UNMANNED AERIAL VEHICLE SYSTEMS AIRWORTHINESS REQUIREMENTS (USAR)

Annex A. UAV Systems Airworthiness Requirements

Related documents: None

AIM

1. The aim of this agreement is to establish a baseline set of airworthiness standards in relation to the design and construction of military UAVs.

AGREEMENT

2. Participating nations agree to adopt the USAR in their national certification standards for military UAVs, recording national reservations where appropriate.

TERMS AND DEFINITIONS

3. Terms used in this document are defined in the Glossary for the purpose of this document only.

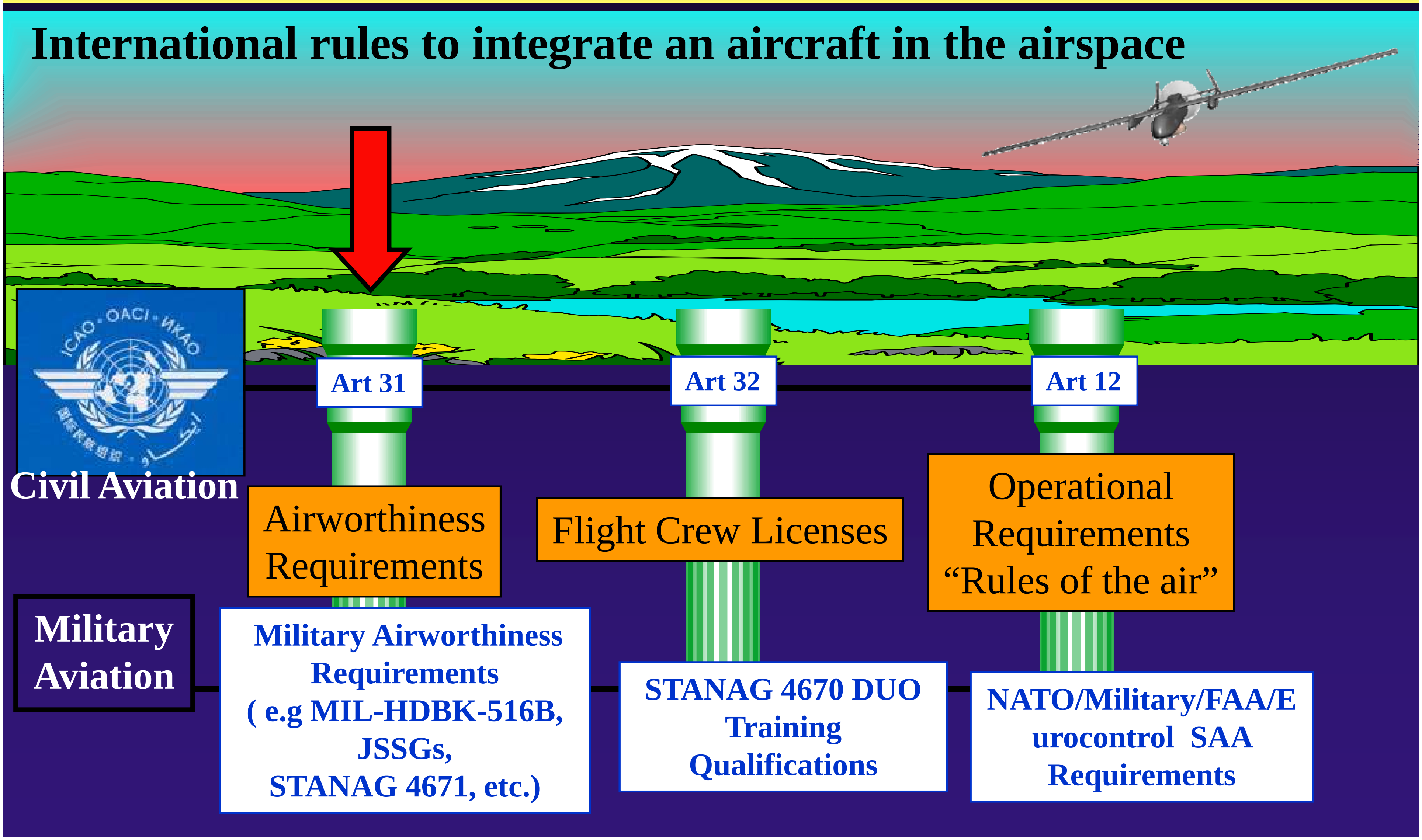
DETAILS OF AGREEMENT

4. **General**. If a National Certifying Authority states that a UAV System airworthiness is compliant with STANAG 4671 (and any appropriate national reservations), then, from an airworthiness perspective, that UAV System should have streamlined approval to fly in the airspace of other NATO countries, if those countries have also ratified this STANAG.

5. By definition, national ratification means that the contents of this STANAG have been enacted in national orders and regulations, together with national reservations. Promulgation of this STANAG will record verbatim differences from the STANAG by way of national reservations (if any) that will be clearly visible to all readers of the STANAG.

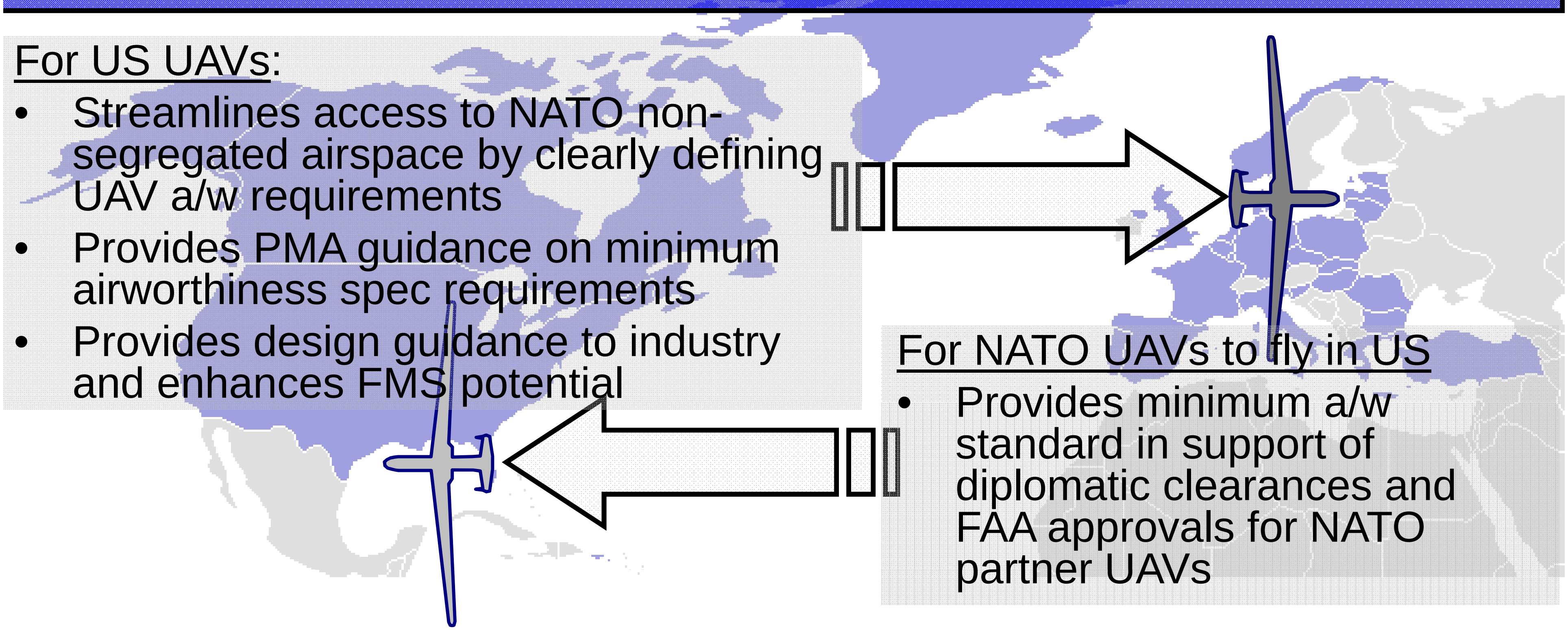
6. Along with immediate improvements in UAV interoperability and mission effectiveness, the USAR will provide a common starting datum for the long-term assessment of UAV airworthiness by allowing the comparison of systems designed and built to common standards.

STANAG 4671 Key to UAV Airspace Integration



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

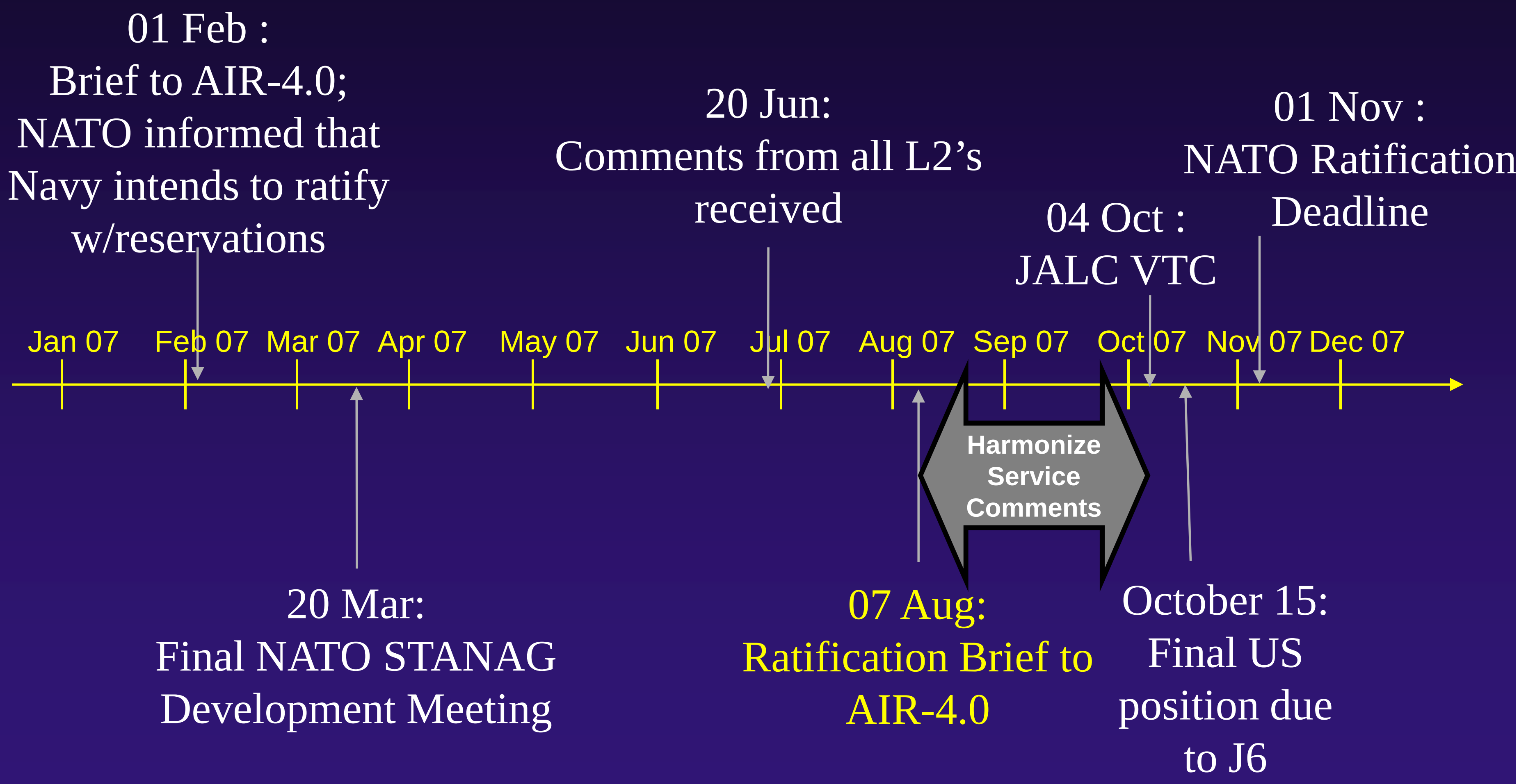
- Provides minimum a/w standard in support of diplomatic clearances and FAA approvals for NATO partner UAVs

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.

STANAG ratification timeline



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 <u>must consider</u> 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

Probability of Mid-Air Collision ,P_{MAC} =

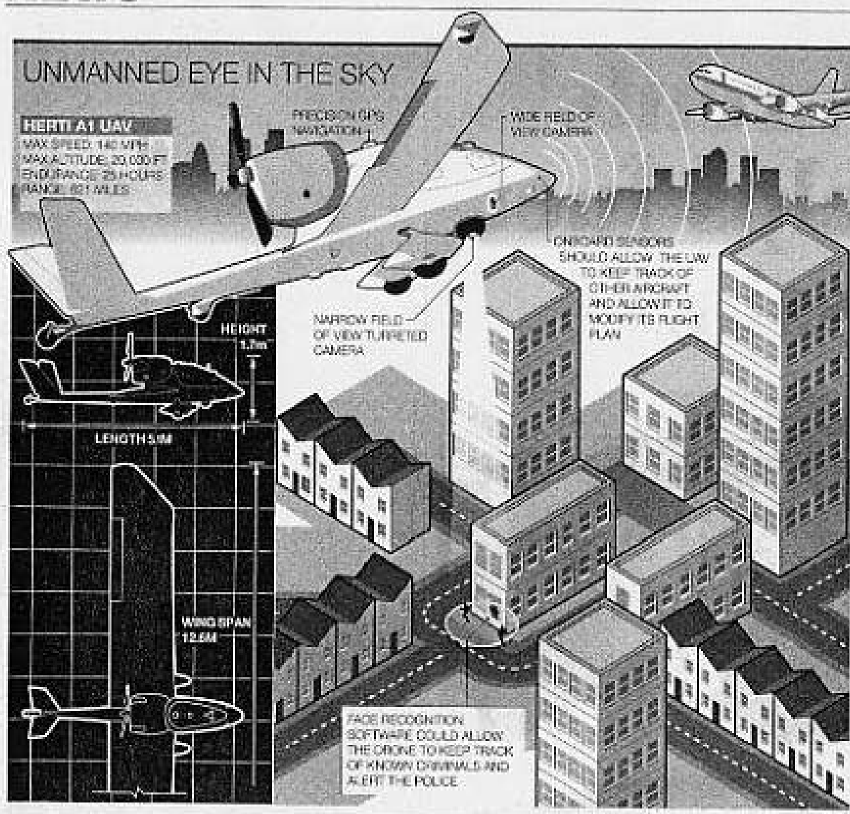
$$P_{\text{collision course}} \times P_{\text{separation fail}} \times P_{\text{UAV Collision Avoid fail}} \times P_{\text{Conflicting A/C Collision Avoidance fail}}$$

Target Levels of Safety(TLOS) and P_{MAC}

P_{MAC} equates to our desired TLOS=

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

- 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 = 1×10^{-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 100mph and remain airborne for a day at a time, monitoring traffic, searching for sailors 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 warning comes as officials from the Civil Aviation Authority (CAA) and manufacturers of unmanned aerial vehicles (UAVs) are rewriting 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 farmlands, checking on pipeline networks and tracking pollution after chemical spills.

Pilots say this would mean drones sharing the skies with passenger airlines as well as light aircraft, gliders and hot air balloons, in areas where aviators rely, ultimately, on line of sight – and emergency action – to avoid each other.

Dave Reynolds, a flight safety officer from the British Air Line Pilots Association (Balpa), said: "Although modern manned aircraft spend a lot of time under automatic control, they have the pilot on board to respond to mechanical or technical failure. It's not going to be very easy to replicate that.

"Technology has existed for many years to have trains running without drivers. But not many do so because there's a psychological aspect of reassurance from having a human in control."

Keith Auchterlonie, from the British Gliding Association, said: "Our 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 on any decisions."

There are also industry fears of problems near airports where air traffic controllers would have to deal with some manned aircraft and some unmanned.

UAVs are currently banned from UK airspace – apart from a few, remote locations for test flights – for safety reasons.

But the rules are being overhauled as part of a £32 million project, codenamed Astraea, which has been jointly funded by the Government and seven companies, including the weapons manufacturers BAE Systems and QinetiQ, to develop a new generation of drones with 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 Astraea steering board, said: "It will be a challenge to evolve people's thinking but these systems will be just as safe, if 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 face recognition technology to follow the movements of particular people. Merseyside police have expressed an interest in using them to hover over problem estates to tackle anti-social behaviour.

The most common drone is likely to be the Herti, which has a 13yard wingspan and can remain airborne for 25 hours.

The Sunday Telegraph – 5 May 5 2007

Target Levels of Safety(TLOS) and P_{MAC}

P_{MAC} equates to our desired <u>overall</u> TLOS=

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

Non-technical term
Depends on time and space

$\propto$ **air traffic density**

$\propto$ **conops**

Technical or non-technical term
Depends on who is providing separation: ATC or DUO ?

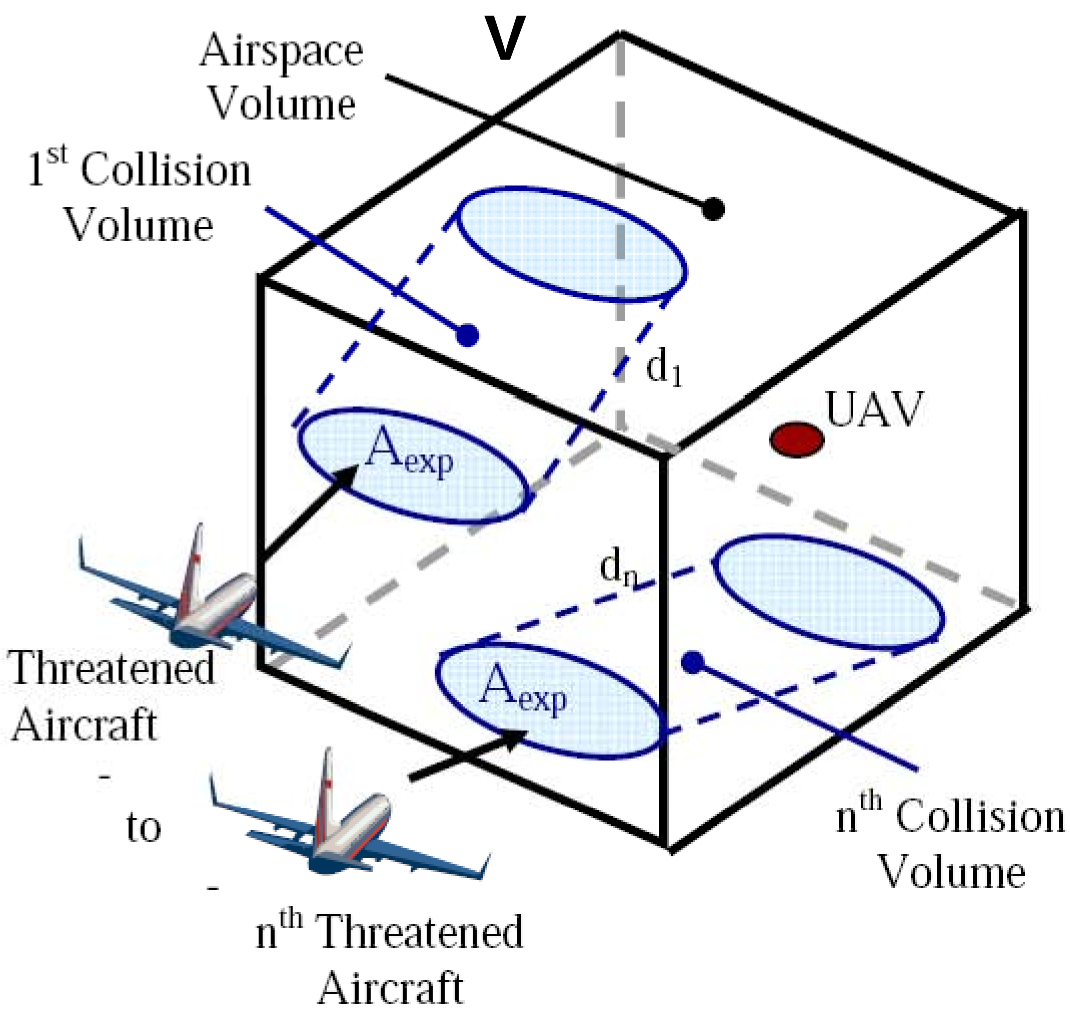
$\propto$ **conops**

Technical term = performance of collision avoidance system

Technical or non-technical term

Assume = 1

Acrobat Standard - [Report_UAV_Safety.pdf]



A_{exp} = Area of Exposure

$D = \Sigma\, d_i \ldots\ldots d_n$

Rate of potential collisions in time t = $\dfrac{\mathbf{A_{exp}\ D}}{\mathbf{V\ t}}$

Given:

A_{exp} (757 size a/c) ≈ 560 ft^2

Then:

Rate (worst case) of potential collisions = 4 x 10^{-5} collisions/hr

SAFETY CONSIDERATIONS FOR OPERATION OF UNMANNED AERIAL VEHICLES IN THE NATIONAL AIRSPACE SYSTEM Roland E. Weibel and R. John Hansman, **MIT Report No. ICAT-2005-1, March 2005**

Target Levels of Safety(TLOS) and P_{MAC}

P_{MAC} equates to our desired TLOS=

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

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

- 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 x 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