UNMANNED AIRCRAFT SYSTEM ACCESS TO NATIONAL AIRSPACE

BACKGROUND PAPER

Integrating unmanned aircraft into national airspace requires significant efforts on numerous fronts. Developing standards will lead to international regulations that permit aircraft and system certification. UAS pilot training will follow, along with the production of relevant Concepts of Operation. Technological advances in Sense & Avoid and Command & Control security will bridge the gap between manned and unmanned flight procedures. As these lines of development converge, the opening of the National Airspace to unmanned aerial systems will follow.

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1.0. INTRODUCTION

1.1. Unmanned Aircraft Systems (UAS) have reached a critical mass in the global aviation community such that their undertaking of Flight in Non-Segregated Air Space (FINAS) is a matter of 'when', not 'if', it occurs. For example, 2009 saw approximately 20,000 Unmanned Air Vehicle (UAV) flights occurred in civilian airspace, accumulating over 2,500 hours, and representing a tripling of UAV operations since 2007[1]. This paper is designed to inform members of the public about the issues and most recent developments in the field and to assist them in making a positive contribution to this pressing aviation problem.

1.2. Widely held principles for UAS access to National Airspace (NAS) include 'do no harm' and 'conform not create' and as such this paper will be framed in the context of the current (and near-future) manned aviation system[2]. This approach should assist aircrew in their understanding of the issues and in their contributions towards the proposed solutions.

1.3. The scope of this paper is to assess how current and in-development UAS might gain access to unsegregated airspace under the assumption that the UAS community is driving for their pilots to be able to 'file and fly' as any other General Aviation (GA) aircrew member currently does. Each of these Unmanned systems is envisioned to have a human pilot in direct and continuous control with the unmanned air vehicle (UAV) in all but certain, emergency, conditions (i.e. Loss of Command Link). The future prospect of purely autonomous 'drones' or multi-aircraft control systems are not covered herein. Both of these aspects may become prevalent in the medium term, but can be considered step-changes in the UAS development cycle, and their contemplation is impractical at this stage.

1.4. Additionally, the prospect of unmanned passenger airliners is not within the scope. The driving forces behind 'de-piloting' the current fare-paying air transport system differ considerably from those attempting to bring new capabilities into the NAS, and the public acceptance of such is an emotionally-fraught topic. However, unmanned cargo aircraft are considered within the purview of the paper.

1.5. The paper will follow the 'most likely' course for successfully undertaking FINAS:

1.5.1. Classification and naming of the various unmanned systems.

1.5.2. The development of standards for each aspect of a UAS, to include airframe, datalinks etc.

1.5.3. The production of Regulations, preferably global, for UAS Certification.

1.5.4. Aircraft and aircrew certification, including technological items (i.e. 'Sense & Avoid' systems).

1.5.5. Finally, operational concepts for UAS use and the issues of public acceptance are covered.

1.6. This paper will not provide an introduction to UAS, nor detail the history or background of the issues covered. Suggestions for further reading are highlighted in the Bibliography appendix. A 'Suggested Position' is used to close each Section.

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[1] Timothy Ravich, "The Integration of UAVs into National Airspace" North Dakota Law Review, Vol 85:597 (Mar 10): 597-620

[2] Department of Defense, Office of the Secretary of Defense, "UAS Airspace Integration" (Washington DC, 2007), 82

2.0. UAS CIVILIAN MISSION SETS

2.1. Although not strictly pertinent to the 'how' question of UAS gaining access to NAS, a brief description of the 'why' should frame debate and explain the significant pressure for such a move. The current lack of available operating areas is considered a prime reason why UAS have not been fully exploited for many potential civilian roles[3].

2.2. Recent studies[4] have drawn up over 53 different mission types for civilian UAS. With some generalization, these can be grouped into 5 mission sets as listed in Table 2.1 and depicted in Diagram 2.2. The UAS Classes referenced in Table 2.1 are explained in later sections, but roughly equate to increasing size and complexity, from Class 1 to 3.

Mission Set	UAS Class	Mission Types
Survey, Maintenance, and Management	1, 2, 3	Agricultural, Mineral, Fisheries, Comms lines, Wildlife, Weather / Atmospheric, Ice flow, Aerosols, Aerial Photo (multispectral & LIDAR), Power & Pipeline, Imagery, Mapping, Pollution, Oceanography
Law Enforcement	1, 2	Policing, Surveillance, Traffic, Missing persons, Sensitive sites
Border / Coastal Patrol	2, 3	Counter smuggling, Anti-terrorism, Port security, ISR
Communications	2, 3	Comms relay, Media, News, Advertising, Surrogate satellite ('Stratellites')
Disaster Relief	1, 2, 3	Forest fires, Flood, Search & Rescue, Nuclear-Bio-Chemical, Extreme weather

Table 2.1: Civilian Mission Sets

2.3. The traditional strengths of UAS over manned platforms are epitomized by the phrase: 'The 3 Ds: Dull, Dirty and Dangerous'. This characterizes their incredible persistence, up to 5 days and beyond for some systems ('Dull'). Their ability to go into harm's way either in polluted / contaminated environments, such as radioactive scenarios ('Dirty') or into adverse weather conditions, such as hurricanes ('Dangerous'), give the UAS their other distinct advantages over manned platforms.

Diagram 2.2: UAS Advantages and Roles

[3] Saurabh Anand, "Domestic use of UAS: Evaluation of Policy Constraints", WISE Paper, Aug 2007. p. 2
[4] Timothy H. Cox et al, "Civil UAV Capability Assessment", NASA Briefing Paper, Dec 2004. p. 4

2.4. Just as the success of early military UAS led to their rapid expansion into non-traditional roles (e.g. close air support, armed escort, cargo resupply etc.), increasing usage of UAS in the civilian arena is expected to lead to a dramatic increase in their roles and mission sets[5]. In some respects it is this anticipated exponential growth of UAS usage of NAS that is the main reason to ensure robust procedures and regulations are in place.

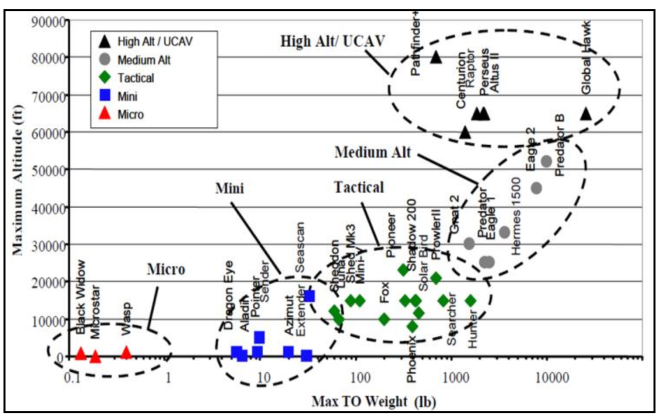
2.5. Numerous cost-benefit analyses[6] have come to differing conclusions about the financial operating advantages of UAS vs. manned platforms in many of these roles. Extraneous costs, including Air Vehicle and Ground Control Station (GCS) certification, manning overheads and insurance could all tip the balance to the status quo. Current NASA flight testing estimates that 24% of operating funds go towards insurance costs alone[7]. Alternate figures price typical Small UAS (SUAS) costs in a law enforcement scenario at $50,000 versus over $1 million for a manned rotary wing operation[8].

2.6. **Suggested Position.** The utility for UAS in the civilian sector can currently only be estimated, due primarily to the lack of airspace for operations to be conducted. The roles and mission types foreseen for UAS suggest tremendous utility in many civilian sectors, especially surveying, climatology, disaster relief and law enforcement. It is reasonable to expect even greater benefits to be realized, as has been seen in the growth of military UAS applications, assuming a reasonable regulatory environment. Robust procedures and regulations need to be developed to facilitate future needs as well as the current status quo.

3.0. UAS CLASSIFICATION

3.1. A classification system is needed to stratify the required levels of airworthiness, equipage and aircrew training standards. This would reduce the burden of NAS entry on lower-level systems, but mandate a significantly higher entry requirement for UAS wishing to conduct FINAS.

3.2. There are numerous classification systems in use within the UAS field, most commonly based on Max All Up Weight (AUW), ceiling, or kinetic energy levels (for impact damage estimations). Typical designations are Micro, Mini (together Small - SUAS), Tactical (TUAV), Medium Altitude - Long Endurance (MALE) and High Altitude - Long Endurance (HALE). Additional groupings include Combat (UCAV), lighter-than-air (LTA) and vertical take-off (VTUAV).This is classically illustrated in Chart 3.1.



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[5] Matt DeGarmo, "Issues concerning Integration of UAVs in civil airspace", MITRE CAASD Paper, Nov 2004. p. 13-17

[6] Op. cit. Cox. p.33-36

[7] Op. cit. Anand, p. 22

[8] Ibid., p. 22

Chart 3.1: Current Typical UAS Classification scheme: Max AUW vs. Ceiling.

3.3. One significant classification problem is the proliferation of smaller, but very capable, systems such as the Boeing Insitu ScanEagle. The ScanEagle would be a Mini UAV by weight, but is capable of loitering at 15,000ft for 15 hours, making it more capable than some Tactical UAS. As technologies such as fuel cells and payload miniaturization advance, the blurring of size vs. capability will make this classification relatively worthless. Unfortunately, AUW is still a major legal delineator in current CAA (generically used to denote national Civil Aviation Authorities, e.g. Australian CASA, U.S. FAA, UK CAA etc.) legislation[9].

3.4. Manned aircraft utilize a system of seven Categories (i.e. airplane, rotorcraft, lighter-than-air - LTA, etc.) subdivided into Classes (e.g. single or multi-engine, land or sea, airship or balloon etc.) for which an aircrew rating is required. This is shown in Diagram 3.2. An additional Type rating is required to operate certain aircraft that are deemed to need specialist training (e.g. Piper Malibu).Further groupings include Light Sports Aircraft (LSAs).

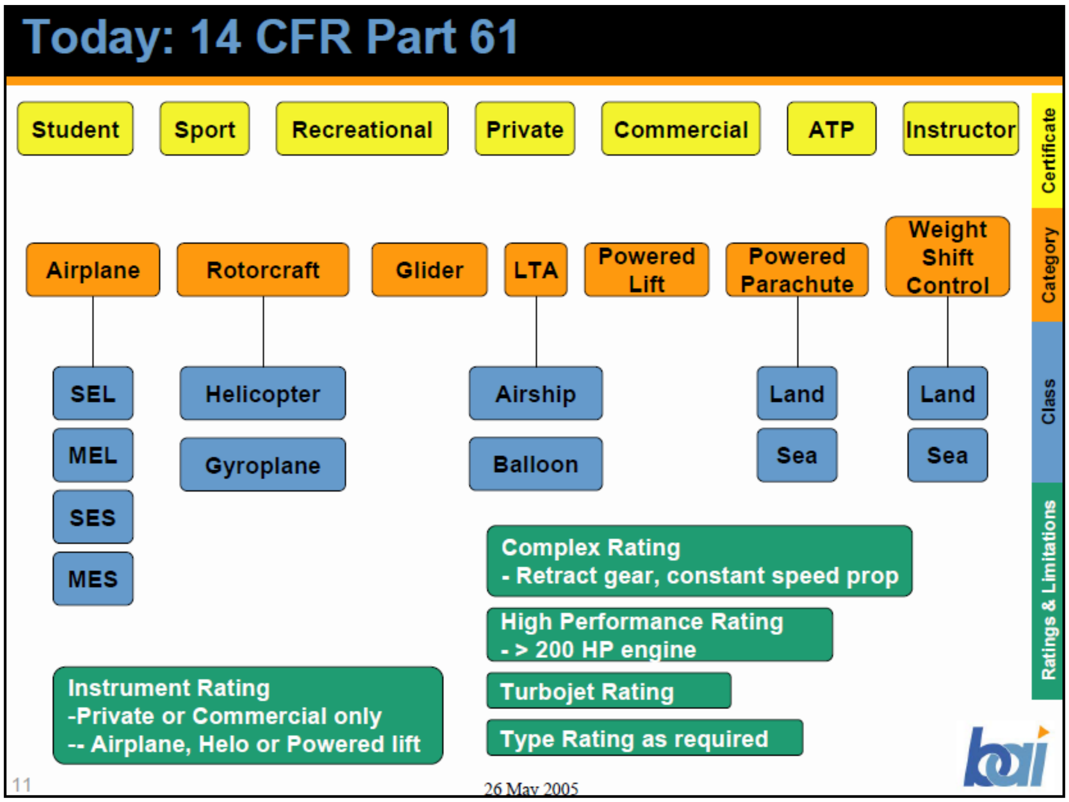

Diagram 3.2: Current Manned Category and Class. ASTM F38

3.5. One current line of thinking[10] is to consider airspace usage as a delineator for UAS classification. For example, if UAS access to Class C and D airspace is required then the Class differs from a VFR-only, Class G UAS. This system is actually in use with manned aircraft which must meet different airworthiness, equipage and training standards for different airspace access. As the airspace system changes with NextGen and Single European Sky (SESAR) implementation and with a move to a

[9] http://www.ainonline.com/?q=aviation-news/aviation-international-news/2011-10-04/small-uas-rule-will-begin-phased-entry-unmanned-aircraft

[10] CJCSI 3255.01 “Joint UAS Minimum Training Standards”, July 2009. p. 4

simplified ‘Terminal’ and ‘Enroute’ airspace division, it would be expected for the UAS classes to conform to new access requirements (e.g. ADS-B equipage etc.).

3.6. One further option for subdivision is the various flight control modes available to UAS. These range from direct radio control (with joystick and limited autopilot) through semi-autonomous (using keyboard and mouse: MQ-1C Gray Eagle) and on to autonomous (using a stored flight profile: RQ-4B Global Hawk). ASTM F38, an American Standards Development Organization (SDO) considers these as Classes within a separate UAS Category[11], however light-weight autopilots and even First Person Viewing (FPV) technologies will rapidly close the gap between the first two. Current draft legislation suggests that fully-autonomous systems in the NAS will likely need some pilot override making them semi-autonomous by definition[12].

3.6.1. At the SUAS-end of the UAS spectrum (e.g. Desert Hawk III, RQ-11B Raven), the platforms and controllers are indistinguishable from model aircraft. Current regulations make the use of these systems for ‘profit, aerial photography or demonstration’ as the delineator between model a/c and UAS. Most CAAs now recognize that UAS flown within visual line-of-sight (VLOS), below 400ft AGL and within Class G airspace as being a distinct class. Some CAAs place weight or kinetic energy restrictions on their model aircraft, but such calculations (based on potential ground impact damage) result in complex operating constraints, and for these systems that will always remain within Visual Line Of Sight (VLOS), this may be overly proscriptive.

3.6.2. At the HALE-end (e.g. RQ-4B Global Hawk, Global Observer), these very large UAS predominantly operate in Class A airspace above 18,000ft AMSL (or equivalent) and have significant redundancy features to ensure safe climb and descent profiles within Restricted Operating Zones (ROZs). They operate exclusively Beyond Line of Sight (BLOS) using satellite Command, Control and Communication (C3). Their size and weight place them in a certification class (i.e. FAR Part 25 / EASA CS 25) equivalent to large business jets (although single-engine UAS are difficult to match to such criteria). Their access to highly regulated and congested airspace makes them the ‘field-leader’ in bringing UAS / NAS integration forward. Their Size, Weight and Power (SWaP) typically allows for manned equipage levels (e.g. IFF, triplex flight controls, ADS-B, etc.). These UAS have operated successfully within NAS as well as internationally[13], but always under strict authority and CAA scrutiny.

3.6.3. The most complex UAS / NAS issue is within the TUAV and MALE areas. Such systems operate throughout the airspace realm (typically 6000 to 25,000ft AMSL) and from small, unprepared sites or regional airfields. They utilize LOS C3 (but typically outside of visual range, up to 70 NM) and the larger systems use BLOS as well. Their SWaP often limits levels of equipage and this may be a good area to provide a split in requirements: smaller UAS having a different class to the more-capable ones. Currently these systems establish ROZs to operate within civilian airspace and they remain separated from manned traffic. Ironically, these UAS probably have the most utility within the field of UAS (see Section 2.0) and their reduced size and cost could make them more prolific. The focus, therefore, should be on solving the issues inherent in integrating this class of UAS into the NAS.

3.7. **Suggested Position.** A Category / Class / Type system mirroring the established manned program would seem the most appropriate for integrating UAS into the current NAS. The designation of ‘UAS’ would then be added as a Class within the Category, and then each system deemed to require specialist training would gain a Type designation. For delineating NAS access requirements,

[11] Jeff Goldfinger, Brief on “Developing Standards for UAS Pilots” for CERI UAV HF Workshop, 2005. Slide 13-16
[12] CASA AC 101-1(0) p. 4
[13] http://www.defensenews.com/story.php?i=7156215

the most important categorization is therefore Class for various UAS types, and a 3-class system is suggested:

3.7.1. The first, Class 1, should be set for any sized UAV utilized solely within Class G airspace, below 400ft.

3.7.2. The second, Class 2, for UAS operating above 400ft within airspace classes C through G. An option for these systems remaining VFR is possible.

3.7.3. Class 3 would be for UAS cleared for all airspace and altitudes.

3.8. The Class 1-3 terminology closely mirrors current FAA UAS (known as Remotely Operated Aircraft – ROAs) categories 1 – 3. It is also similar to the 'USAF Vision' of 3 categories: Cat 1 (low-altitude); Cat 2 (local effects); Cat 3 (theatre-capable). An example of the subsequent divisions is given in Table 3.3 and Diagram 3.4 with the respective Class and certification options shown in Table 9.4.

UAS Class	Airspace	Equipage	Training	Example	Notes
1	G (<400')	Visual LOS	Model Aircraft License	Desert Hawk 3 Raven	
2	C,D,E,(F),G	As Manned, S&A, LL	CPL equivalent Type Rating A/R	Shadow Scan Eagle	S&A – Sense & Avoid LL – Lost link Possibly VFR only
3	All	As Manned, S&A, LL	CPL equivalent IR Type Rating A/R	Predator Global Hawk	IFR

Table 3.3: Suggested UAS Classes

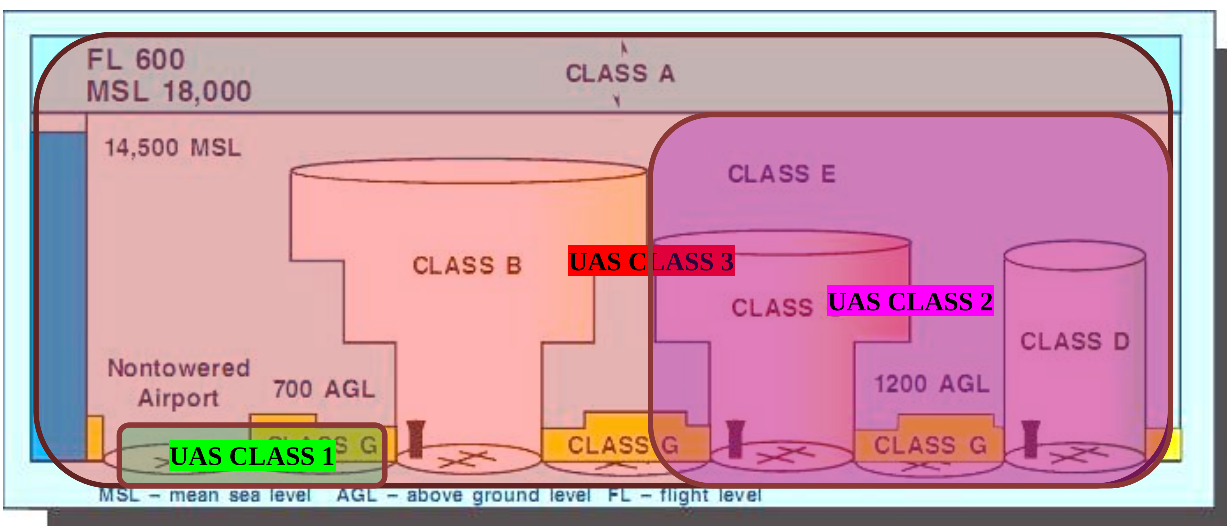

Diagram 3.4: Suggested UAS Classes by Airspace

4.0. UAS STANDARDS

4.1. Although the recent dawn of UAVs has been described as a 'Wright Brothers' moment in aviation, it is important to note that neither the congested airspace nor the regulatory environment existed in 1903. For acceptance into a well-established aviation community, the entire Unmanned Aircraft System needs to 'mature', in a generation, to the extent that manned aviation has in over 100 years.

4.2. Fortunately, the mechanisms to assist are already in place in the form of the Standards Development Organizations (SDOs). These traditionally objective groups of international Subject Matter Experts (SMEs) are tasked to provide 'best advice' to rule-making entities (such as CAAs) and to assist in bringing new technologies and techniques into active and safe civil service. Examples of relevant SDOs are American Society for Testing and Materials (ASTM), Radio Technical Commission for Aeronautics (RCTA), North Atlantic Treaty Organization (NATO) and ICAO.

4.3. Aviation standards are extant and novel systems such as composite airframes, Electronic Flight Bags (EFBs) and Automatic Dependent Surveillance – Broadcast (ADS-B) are all rapidly incorporated into the framework already in place. It should be noted that for Light Sports Aircraft (LSAs) to be brought into the current standards system took only 18 months, with ASTM F37 working in close cooperation with the FAA to ensure a workable and safe set of procedures. That must be the goal of UAV systems, and all parties have made already significant progress in this regard. The major 'go slow' items are the genuinely novel aspects of unmanned aviation, in particular:

4.3.1. **Sense & Avoid**. This almost entirely novel system has significant standardization requirements. These include detection range and field of regard; false alarm rate, operational concepts, etc. (see Section 7.0).

4.3.2. **Autonomous Flight Operations**. Even if the coming generation of UAS requires Human-In-The-Loop (HITL) operation, the degree of autonomy is increasing exponentially (as it is in the manned community[14]) and autonomous flight ops may become commonplace in the longer term. The current systems are not intended for entirely autonomous operations, however in 'Loss of Command Link' scenarios they must be treated as such. Autonomy issues relate directly to software standardization in particular.

4.3.3. **Datalink / C3 Security**. The necessarily 'fly by wireless' character of UAS operations exposes them to several significant security concerns such as jamming, interference, eavesdropping or hijacking. Mitigation strategies, such as encryption, need to be articulated and validated (to include signal delay issues).

4.3.4. **GCS Architecture**. Although many cockpit standards, in the Human-Machine Interface (HMI) sphere, could be 'walked across the aisle' from manned platforms, the majority of fielded UAS possess neither a joystick, nor a throttle or rudder. The GA-ASI Predator family of UAS is almost unique in having retained these controls. This imposes a paradigm-shift on Ground Control Station (GCS) designers, and their guidance must come from the SDOs to ensure UAS certification.

4.4. A list of UAS-specific systems and the current state of their relevant SDO standardization is shown at Table 4.1.

4.5. **Suggested Position**. The current SDOs are well-placed and have made significant inroads into the UAS issues. An emphasis on applying safety metrics to UAS issues is sound, if considered within the caveats of 'remotely piloted', HITL systems which possess integrated, highly-trained aircrew operators. The search for technology-only solutions, although likely a sound strategy given 20 years, will hinder UAS application in the short to medium term. A stepped approach, using manned aviation

[14] D R Haddon, "Aircraft airworthiness certification standards for civil UAVs", The Aeronautical Journal, Feb 2003. P. 82.

standards as a backbone and caveated standards linked to airworthiness elsewhere, is potentially more fruitful.

System	Standard	Body	Note
Airworthiness	STANAG 4671	NATO	
	F2501	ASTM	
	E.Y013-01	EASA	Interim to Part 21 B of EC 1702/2003
Aviation Software	DO 178B	RCTA	
C3 / Datalinks	DO 260B	RCTA	ADS-B - 1090MHz Air Transport
	DO 282B	RCTA	ADS-B - 978MHz General Aviation
	DO 264(X?)	RCTA	Being drafted
	STANAG 4660	NATO	C2 links
	STANAG 7085	NATO	Imaging datalinks
General UAS	DO 304 / 320 / 264	RCTA	
	UAS SARPs	ICAO	Being drafted. Cir 328 AN/190 released in 2011
Sense & Avoid	F2411	ASTM	
	DO 289	RCTA	
	PFP(N*)D(08)0002	NATO	N* - NATO Naval Armaments Group
	DO 264 (Y?)	RCTA	Being drafted
UAV Control Systems	STANAG 4586	NATO	
UAV Aircrew Training	STANAG 4670	NATO	
	ARP 5707	SAE	
	F2635 / F2636	ASTM	
	8219.1-3.6	DCMA	
	CJCSI 3255.01	CJCS J7	BUQ I to IV

Table 4.1: UAS Standards

5.0. CURRENT UAS REGULATIONS

5.1. ICAO, the global aviation regulatory body, generates procedures and recommended practices (SUPPS, PANS and SARPS) that are integrated into national regulations. They have taken a conscious decision to standby and observe / advise national CAAs in their development of UAS rules. The principle of 'conform not create'[15] ties UAS to follow the current ICAO Annexes, especially Annex 2 – Rules of the Air. In this respect, many of the UAS integration technical issues (e.g. Sense & Avoid, No Radio - NORDO, equipage etc.) arise directly from the need to meet ICAO guidelines. It is ICAO's stated intent to publish UAS-specific SARPS in due course, which will lead directly to greater international consensus in UAS regulation. In 2011, ICAO published their UAS Circular, Cir 328 AN/190, to provide an update on their perspective and some guidance for CAAs to continue regulatory activity.

5.2. In a 2004 review of applicability of the current guidance[16], it was assessed that only 30% of manned aviation regulations directly apply to UAS. Another 54% can be adjusted to fit. Equipage and Concepts of Operations (CONOPS) differences emphasize the importance of datalink security, Flight Termination Systems (FTS) and Automatic Recovery Systems (ARS) and drive a requirement for achieving manned-equivalent Sense & Avoid (S&A) capabilities. In addition, over 65% of all fielded

[15] Op. cit. OSD. p.88
[16] JAA UAV Task Force Final Report, 2004. Appendix 4-1 to Enclosure 4

UAS weigh less than 150kg[17]. All of these points have led numerous nations to develop (or adopt) their own UAS-specific CAA guidelines and regulations. Interestingly, most have chosen to approach the issue in similar fashions.

5.3. It is important to note that there is currently no such physical entity as a ‘UAS license’ and each system, as it is deployed nationally in civilian airspace, is subject to a case-by-case review of UAV airworthiness, pilot training, mission sets, frequency management and safety mitigation procedures. Each nation uses slightly different terminology and procedures, and each is governed by its own set of national regulations. A list of example states and their documentation is shown in Table 5.1.

5.4. National UAS regulations attempt to mitigate two safety risks: midair collision (MAC) and a crash involving fatalities on the ground. A commonly accepted principle[18] is to ensure that UAS, in or out of FINAS, have an equivalent level of safety (ELOS) to current manned platforms. To address these issues, more rigorous standards, extra equipment and specialist training is mandated by the national CAAs. Each of these added requirements is addressed separately in this paper, but brief summaries of both risks are given below, as well as a summation of the main regulatory items.

5.5. Midair and near-midair collisions (NMAC) in 2010 accounted for 3.6% of US manned accidents, resulting in 19 fatalities (5 on the ground)[19]. The UAV’s lack of an onboard pilot, who has ‘see and avoid’ collision responsibility in manned aircraft, has pushed most regulations to demand an equivalent ‘sense and avoid’ system (unspecified) be fitted to UAS.

Nation	Certification or License	Applicability	Regulation	Note
Australia	Operating Certificate		CASA Pt 101 AC 101-1(0)	Very modest requirements
Canada	UAS Pilots Permit	< 35kg unless CPL	CAR	Special Flight Ops Certificate
EASA	UAS Operator License	>150kg	E.Y013-01	
ICAO	UAS Operator License	Guidance	Cir 328 AN/190	
JAA/ JARUS	UAS Operator License	Light <150kg	Papers only	
Malaysia	UAV Operations in Malaysia	>20kg and >400ft	AIC 04/2008	Mirror of FAA and CAA regs
UK	CPL(U)	Up to 150kg then to EASA	CAP 722	Standards undefined
	Radio Control Achievement Schemes	Non-commercial	CAP 658 British Model Flying Assn	A – Safe solo B – Display C – Aerobatics
USA	Certificate of Waiver or Authorization(COA)	Public bodies	FAA Order 7610.4	Not Class B airspace
	Special Airworthiness Cert -Experimental	Private bodies	14 CFR 91.319	Not commercial R&D / training only
	Model Aircraft Operating Standards	Non-commercial	AC 91-57	Guidance only
South Africa	UAS Operator License		Interim Policy Civil UAS in SA	Mirror of FAA and CAA regs

Table 5.1: UAS Regulations

[17] Ibid. Annex 1. p. 6 and Appendix 3-1 to Enclosure 3. p. 1
[18] ICAO (2011), Cir 328-AN/190 Appendix. p. 35
[19] Micheal Nas, “Pilots by Proxy”. p. 27

5.6. Just over 2% of 2010 US aircraft mishaps were due to controlled flight into terrain (CFIT) and although these led to no ground fatalities, CFIT and MAC accounted for over 94% of the lethal accidents. Over the same period, 70% of US aircraft mishaps were 'pilot related', including four flying while intoxicated (FUI?) and 2 aircrew incapacitations. Spatial disorientation accounted for 32%, incorrect airspeed 19% and incorrect configuration 7%.

5.7. This leads to an interesting juxtaposition about UAS safety: the lack of a pilot, any passengers (for the foreseeable future) and the low average mass, may reduce the potential fatality rate within the unmanned class of air vehicles, making them inherently safer than manned platforms, by definition.

5.8. A number of national regulators have agreed on a series of 'entry requirements' within the policies listed in Table 5.1. Those that have the widest concurrence include:

5.8.1. Small UAVs flown in Class G airspace, below 400ft AGL, within VLOS (sometimes defined with a range of about 1500ft) are lightly regulated. Outside of control zones and away from towns, the few limitations include training (often with national model aircraft associations[20]) and an airspeed limit. The utility of these Class 1 UAS is significant but their threat minimal, hence the 'firming up' of the legal policies is being prioritized, especially in the US[21] and Europe.

5.8.2. To extend the VLOS concept, the requirement for visual observers or chase planes, even in 'reserved' airspace, is extant in many nations. This is true for most operations not in Class A airspace. It should be emphasized that no UAVs are cleared to currently operate in truly unsegregated airspace, except in Australia (covered below). The majority of regulatory efforts are directed at the Class 2 UAS proposing to undertake BLOS FINAS operations, and the 'holy grail' for their acceptance is a certified (by standards suggested in Section 7.0) Sense & Avoid (S&A) system with the ELOS of manned platforms[22]. As no such system currently exists, the regulations are purely hypothetical, except…

5.8.2.1. The Australian CASA regulations have adopted a more 'manned aircraft' oriented approach. They do not demand S&A, or chase planes / observers, but simply state that:

> *"Unless the controller of the UAV is provided with sufficient visual cues to enable the acquisition and avoidance of other air traffic, UAV flights in controlled airspace will be treated as IFR flights, subject to ATC control."*[23]

CASA demands that UAS utilize an 'Unmanned' callsign (as does the UK), have Instrument Rated crews when flying IFR and have UAVs able to 'glide clear of populous areas': all equivalent to manned regulations. For FINAS, only a NOTAM is required, and not the establishment of a Restricted Operating Zone.

5.8.3. Class 3 UAS are generally abrogated from the requirements for chase planes and observers (difficult at FL600) in most regulations[24], but the level of equipage and airworthiness mirrors that of manned systems with the addition of S&A. Robust C3 architecture is emphasized, but pre-approved Lost Link (LL) procedures are mandated, as well as either an FTS or ARS (more likely given Class 3 SWaP characteristics).

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[20] UK CAA Directorate of Airspace Policy, CAP 722, 2010. Section 2 Chapter 5 Page 3
[21] Op. cit. ainonline
[22] HQ ACC/DR-UAV SMO White Paper, "Sense & Avoid Requirement for ROA", June 2004. p. 4
[23] CASA AC 101-1(0) Para 5.7.1
[24] FAA UAS Interim Operational Guidance 08-01, Para 8.2.13. p. 12

5.9. From a legal perspective, the role of the Pilot in Command (PIC) remains extant as in manned aviation. The PIC retains the legal obligation for safe operation of the air vehicle as well as having a responsibility to meet all training and medical requirements[25]. Unfortunately, as a clear-cut definition of those requirements has not been established, there is a significant issue when legal liability is considered. The high cost of insurance coverage for UAS operations alone may become the limiting force in their expansion.

5.10. As levels of autonomy rise, the same issue of liability becomes more central. 'Pilot error', a contributory factor in over 70% of aviation accidents[26], may give way to 'Programmer error' as a cause for a significant portion of future autonomous UAS mishaps. The rigorous application of software standards (such as DO-178B, see Table 4.1) may help mitigate this potential.

5.11. The position of UAS within the international legal schema adds a further element of complication. Larger or advanced UAVs are restricted in their utilization by both the 1987 Missile Technology Control Regime (MTCR) and the 1988 Intermediate Range Nuclear Forces Treaty (INF). They are on the US Munitions List and therefore restricted by the US International Trade in Arms Regulations (ITAR). Should these treaties be applied to the full extent of their reach, development of the technologies required to advance UAS for FINAS would be effectively banned.

5.12. **Suggested Position.** There are significant legal hurdles to UAV operations in unsegregated airspace, beginning with the wider INF / MTCR / ITAR issues, and continuing with the manned-aviation-based ICAO regulatory framework. Some nations have begun the process of developing active, positive and progressive regulations such as those proposed by the Australian CAA, CASA, which should be studied as potential models for adoption in whole or in part. The language of manned aviation should be used at all junctures, and the expectation of having UAS enter NAS with unrealistic technological assets should be avoided and not codified. Industry will find a solution given realistic guidance and sensible options. Focus, R&D, insurance coverage, and then limited and full FINAS will surely follow when a legal framework is in place.

6.0. UAS AIRWORTHINESS & CERTIFICATION

6.1. For an Original Equipment Manufacturer (OEM) in the aviation field, CAA certification is the primary goal. From flap screws through head-up displays and on to entire airframes, they must all undergo rigorous safety and manufacturing tests to prove that they have attained the required standard established by the SDO, as well as subsequent CAA endorsement. UAS OEMs must endure the same trials, but with the added scrutiny of skeptical CAAs applying unproven standards to manufacturers who may be new to the world of civil aircraft. This is not an easy proposition, but a very necessary one.

6.2. The current manned system to obtain a Certificate of Airworthiness for build-quality and structural integrity is partly based on airframe Kinetic Energy (KE) during emergency scenarios. Chart 6.1 shows one such scenario (Loss of Control) and how increasing KE leads to increased standards, with JAR 25 being the most demanding.

6.3. This KE system, although based on aircraft size and capability (which translates poorly into the UAS sphere), does have the advantages of being well established and based on 'risk to 3rd parties'[27], which is of significant concern to regulators and insurers: it is therefore probably an excellent position to start 'migrating' manned requirements to the UAS community. For example (shown in Chart 6.1),

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[25] FAA Order 8130.34 "Airworthiness Certification of UAS", 2008. A-4
[26] Op. cit. Nall. p. 39
[27] Op. cit. JAA TF. Appendix 3-4 to Enclosure 3. p. 3-5

Global Hawk would rate as a JAR 25 aircraft (equivalent to a Boeing 737), whilst Predator and Hunter UAVs rate as JAR 23 (equivalent to a light corporate jet).

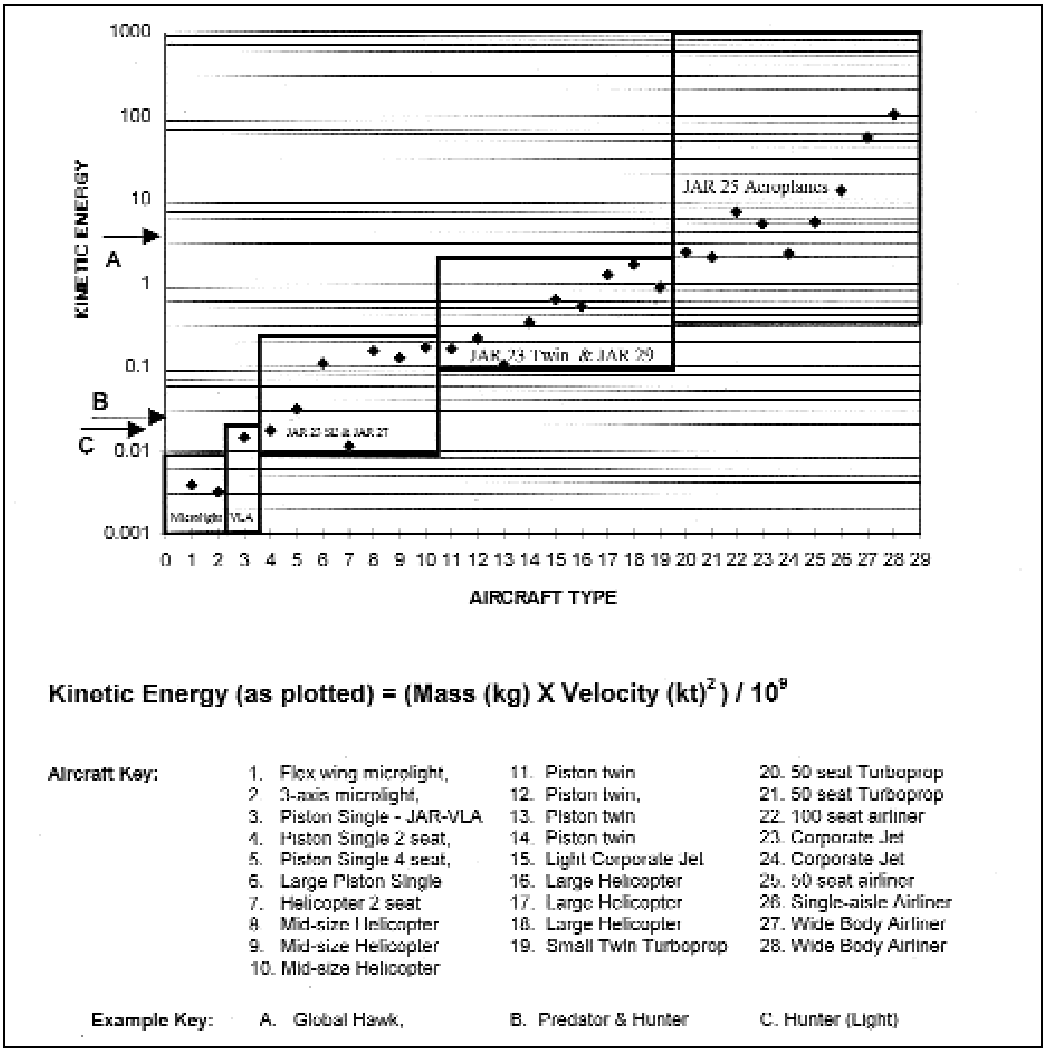

Chart 6.1: Kinetic Energy Plot vs. Airworthiness Requirements (Haddon, 2003).

6.4. With safety as the primary benchmark, numbers are of great importance. In summary of a considerable wealth of studies, manned aviation has the following safety record:

6.4.1. Air Transport Carrier accident rate =10^{-7} per flying hour (1 accident per 10 million hours)[28]

6.4.2. General Aviation rate = 10^{-5} per hour (1 accident per 100,000 hours)[29]

6.4.3. MAC / NMAC rate = 8.57 x 10^{-6} per hour (9 per 1 million hours)[30]

6.4.4. Ground fatalities rate = 5 – 18 x10^{-7} per hour (5 to 18 fatalities per 10 million hours)[31]

[28] Op. cit. Nall. p. 39
[29] Ibid.
[30] Chris Geyer et al, "Avoiding collisions between aircraft", Jan 2008. p. 8
[31] Op. cit. Nall.

6.4.5. Current Lockheed Martin F-16C fighter rate = 120×10^{-5} per hour (120 per 100,000 hours)[32]

6.5. By definition, an EQUIVALENT level of safety (ELOS) for UAS to attain would be in the 10^{-5} to 10^{-7} accident-per-hour range and specific Target Level of Safety (TLOS) rates are often defined in the 1309 section of the Class Certification documents (i.e. 14 CFR / CS 23, 25 etc.). NATO FINAS has set the suggested TLOS at 10^{-6} for UAS[33], and this is the airworthiness rates UAS OEMs should be targeting. However there are complications.

6.6. Because of the added factor of vulnerable C2 links, the immaturity of both S&A technology and evolving Concepts of Operations (CONOPS), and the real fear that one UAS-induced fatality will set the field back several decades, the TLOS levels are being artificially raised from the NATO-suggested 'Extremely Improbable' level of 10^{-6}.

6.7. Current Airworthiness and Certification bodies are suggesting rates as low as 10^{-8} (1 accident in 100 million hours) and some even suggesting 10^{-9} [34]: this is one accident in a billion flying hours. To put this in perspective, if the manned community was held to this standard, all manned flying would cease immediately.

6.8. The current UAS accident rates are approximately:

6.8.1. Predator MQ-1 / MQ-9 rate = 120×10^{-5} per hour (120 per 100,000 hours)[35]

6.8.2. Shadow 200B rate = 150×10^{-5} per hour (150 per 100,000 hours)[36]

6.8.3. Global Hawk RQ-4A/B rate = 100×10^{-5} per hour (100 per 100,000 hours)[37]

6.8.4. A breakdown of these UAS accidents[38] shows a different trend to manned aviation, with between 21 and 47% being due to 'Human Factors' (70% in manned) and between 42 and 65% due to aircraft failures (19% in manned). This reversal is likely due to the immaturity of current UAV designs, and is expected to improve in the aircraft category as manned-equivalent aircraft system certification regulations come into force.

6.8.4.1. The Predator family has a more manned-equivalent accident rate, with 67% due to Human Factors, 13% on landing, and 42% due to aircraft failure. This somewhat more mature system is unique in that it operates with manual joystick inputs and normal take-off and landing techniques.

6.9. The complication of multiple failures is often highlighted as being beyond the capability of current unmanned system's programming. The suggestion is that a pilot is required to assimilate the flight conditions and choose a non-standard course of action, something automation would find difficult to replicate. This is an important area to cover, but the point has to be repeated that a human crewmember is in a position to make all the same piloting and command decisions for the vast majority of the scenarios. An FTS or ARS is available should link be lost. This area is covered further in Section 12.0.

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[32] DOD OSD, "Airspace Integration Plan for Unmanned Aviation", Nov 2004. p. 32
[33] NATO STANAG 4671, "UAV Systems Airworthiness Requirements (USAR)", 2007
[34] INOUI, "UAS in SES", 2005. p. 51
[35] DOD OSD, "Airspace Integration Plan for Unmanned Aviation", Nov 2004. p. 32
[36] Ibid.
[37] Ibid.
[38] K Williams, "A Summary of Unmanned Aircraft Accident/Incident data: HF factors implications", 2004. p. 5

6.10. It is therefore clear that UAS OEMs have a significant burden of proof to show the airworthiness of their aircraft to attain FINAS certification. But as airframes, propulsion, autopilot and other onboard systems improve their Mean Time between Failures (MTBF), and redundancy of these systems increases, another certification issue presents itself.

6.11. ICAO has highlighted the conundrum of having to certify either the entire Unmanned SYSTEM as a whole, or to certify the Unmanned Aircraft, the GCS and other equipment such as Launch / Recovery elements (LREs) and datalinks separately[39]. The difficulty comes when a long-range UAV is 'handed over' from one GCS to another GCS, potentially of different design, origin and even in a different State of Design or Registry.

6.12. With ubiquitous systems coming on line, this issue is further complicated. The US Army's One System GCS (OSGCS) is designed to be able to fly all of their UAV classes, from Raven (our Class 1) through Shadow (our Class 2) and onto the MQ-1C Gray Eagle (potentially Class 3), with only a different software menu selection, and possibly even at the same time.

6.13. Both 'whole system' and 'individual elements' approaches are being proposed in different States (EASA considers the entire UAS approach most appropriate[40]). Smaller OEMs with unique and proprietary equipment could certify the end-to-end UAS, whilst larger operations might wish to certify combinations of UAV / GCS / LRE and datalink. In a similar fashion Cessna 172s, can be certified with original 'round dials' or with modern Garmin G1000 glass cockpit displays.

6.14. It is imperative that the computer software code element be considered. The increase in aviation lines of code has been incredible generation on generation, but far less so than in the automotive industry. For comparison:

6.14.1. F-22A Raptor – 1.7 million lines.

6.14.2. F-35 Lightning II – 5.7 million lines.

6.14.3. Boeing 787 Dreamliner – 6.5 million lines.

6.14.4. S-Class Mercedes Benz – 100 million lines (20 million in navigation / radio alone).

6.15. As software drives more aspects of aviation, its standardization, testing and redundancy is of paramount importance. Aviation software standards already exist, but the coming complexity level will make multiple failure conditions extremely difficult to program for. This gives rise to the 'pilot error vs. programmer error' debate which is entirely relevant.

6.16. This is where the unmanned SYSTEM needs to be considered as a whole: each of the scope UAVs has a qualified human crewmember in direct control of the aircraft in all but emergency Lost Link scenarios. During normal operations, the Pilot in Command (same terminology has been widely accepted) has an equivalent level of influence on the flight path as with any comparable manned aircraft. The software load of most modern aircraft makes true 'manual' flight, without some computer interaction, highly irregular, and the product of multiple emergencies itself. Current UAS all have the advantage of being designed with a Flight Termination or Automatic Recovery System (FTS / ARS) integrated from first principles: this gives a measure of 'get you home' capability that is currently lacking in manned aviation (although 'single pilot incapacitation' systems are now on the market).

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[39] ICAO (2011), Cir 328-AN/190 Ch 6
[40] Op. cit. JAA UAV TF. p. 19-20

6.17. The software code ‘issue’ is one that both manned and unmanned aircraft face equally, but UAS require automatic redundancy features, such as ARS, to mitigate the multiple failure risk.

6.18. As with commercial manned operators, each entire-UAS business proposal will need to meet the same criteria for issuance of a (UAS) Operator Certificate. This includes details on organization, flight operations, pilot and maintenance training programs, the equipment certification plan and the safety management system (SMS) in place. These requirements are very similar to the current ones for Certificate or Waiver of Authorization (COA) or Special Airworthiness Certification[41] for UAS operations within ROZs, and so should not be too onerous on UAS pilots.

6.19. Focusing on the likely requirements to attain the TLOS, propulsive reliability will be a major factor, and the increase in multi-engine UAVs (Mantis, Dominator and Talarion) is a move in the correct direction for Class 2 and 3 systems. Single-engine designs, including the Global Hawk RQ-4B, are limited in their populous area over-flight options. Less than 50% of Europe could be covered at 10^{-5} TLOS, though this rises to 94% at a TLOS of 10^{-6} [42]. Robust onboard Health, Usage and Monitoring Systems (HUMS) will be required and potentially some form of redundant or fault-tolerant control system may be requested. Many of these technologies already exist and have been test flown in anticipation of these requirements.

6.20. Other unique ‘problems’ highlighted include physical security of GCSs (in line with lockable airline cockpits). This is a minor concern though, and solvable with a deadlock or similar. Of course, a ‘wireless’ hijack could not be prevented this way. Another (potentially bridging) solution is the certification of Optionally Piloted Vehicles (OPVs) which can remove the pilot and be flown remotely in reasonably short order. Two mature systems are the K-Max rotary wing OPV and the Skyraider fixed wing pusher aircraft.

6.21. **Suggested Position.** Certification of UAS for FINAS is the end-state goal of UAS OEMs, and this paper is designed to highlight the issues and requirements to that end. There is a need to apply pressure on both OEMs and CAAs to ensure a reasonable compromise in this area. UAS OEMs need to understand the rigorous standards currently in place for manned aviation, and build to those MTBF rates AT A MINIMUM, as well as deciding the ‘best fit’ certification route for their UAS.

6.22. For Airworthiness Certification, the current KE discriminator seems most appropriate, and gives much commonality with manned airframes.

6.23. CAAs need to keep TLOS rates to sensible levels and be prepared to grant FINAS certification with levels of restrictions in place, as well as grant OEMs the option of part or whole-certification of their systems. Lessons should be learnt from the current COAs and FINAS certifications around the globe. As an example, the Dutch took 5 years to grant the Spewer UAS a certificate of airworthiness[43]; this should not be the norm.

7.0. SENSE AND AVOID (S&A)

7.1. A significant milestone is predicted[44] to be the flying of a certified S&A system that fulfills the ICAO (who call it Detect & Avoid) and 14 CFR 91.113 requirement for all pilots to be able to ‘See and Avoid’ other traffic regardless of the flight condition. There are 2 very important areas that are often overlooked, and they are covered below.

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[41] FAA UAS Interim Operational Guidance 08-01, 2008. p. 5-6
[42] R. Weibel, ”Safety Considerations for Operation of Different Classes of UAVs in National Airspace”, 2004. p. 5
[43] Avionics Magazine, “Europe’s Answer: UAVs in Controlled Airspace”, Aug 2003. p. 3
[44] Op. cit. HQ ACC/DR-UAV

7.2. The requirement to meet / exceed the ELOS for MAC / NMAC (8.57×10^{-6}) translates into a MTBF for a fully functioning S&A system of 0.51 failures per 1 million flight hours. This is the current rate that the human S&A system (Mark 1 eyeball) is failing. This translates in the US to 48 NMACs per month[45], and failures in human vision contribute to 0.8% of all accidents. Our belief in the infallibility of aircrew is not borne out by the statistics that only 56% of 'factor' aircraft are spotted by pilots when not 'cued' by air traffic control (ATC). That figure rises to 86% when cueing is received.

7.3. The second point expands on the common vision of an S&A system. Rather than simply spotting conflict aircraft, many of the draft regulations[46] go on to state that the S&A system needs to perform the following functions:

7.3.1. Follow 'Right of Way' regulations with both airborne and GROUND traffic.

7.3.2. Avoid inclement weather and retain cloud / visibility limits for flight plan.

7.3.3. Respond to Aerodrome markings and pyrotechnics.

7.3.4. Respond to visual signals from intercepting aircraft.

7.3.5. Avoid terrain and man-made obstacles by minimum separation distances.

7.3.6. Respond to pyrotechnic, smoke and emergency signals from the ground.

7.3.7. Maintain separation, spacing, sequencing and visual following of traffic as directed by ATC.

7.3.8. Avoid all airborne objects, including para-gliders, balloons etc.

7.3.9. Operate in all lighting conditions, day and night.

7.3.10. Operate in both VFR and IFR conditions.

7.3.11. Respond to both cooperative and non-cooperative aircraft.

7.3.12. Respond to aircraft in distress.

7.4. These extremely arduous requirements are imposed on the least-qualified manned Sports Pilots and are therefore reasonable. However they greatly complicate the solution if an all-technical, fully-autonomous approach is taken. The system then becomes more of a 'Sense and Respond' entity than a simpler 'Sense and Avoid' one. Therefore the solution should be sought by leveraging technical advances in miniaturization and computer vision algorithms, and combining them with aircrew training and CONOPs that allow for a Class 2 / 3 UAS to comply with these requirements. As emphasized here, the integral role of the PIC and crew should not be ignored in meeting these requirements.

7.5. This point should not be understated: the difference between a technical-based Sense & Avoid system and an operator-based Sense & Respond capability is a very important distinction. At all times within normal operations the aircrew controlling the UAV should have the ability to complete all the requirements in Para 7.3. The current widespread military use of UAS in effectively unsegregated and crowded airspace on operations has shown that standard sensor suites already allow crews to complete most of these roles safely. The only real omissions are the important 7.3.8 and 7.3.11 which

[45] Op. cit. Geyer.
[46] ASTM F2411-07

require more situational awareness inputs than are currently widely available (although Para 7.7 describes a current working example). This is where technology is beginning to complete the picture.

7.6. The technical solutions have taken precedence in recent years and months and a combination of EO / IR / Acoustic / LIDAR / Radar sensors[47] (Table 7.1) have all been flown on UAVs or surrogate UAVs to considerable success. Algorithms to allow for 'smart responses', either pilot-directed or autonomous, are all being tested in heterogeneous environments[48]. A Shadow 200 flew with a Small Sense and Avoid System (SSAASy) in February 2011[49] and BAMS, the latest version of the Global Hawk, is to be fitted with a full cooperative and non-cooperative S&A by the end of 2012. The Multi-Intruder Autonomous Alert (MIAA) has successfully flown a combination of EO / Radar and TCAS sensors in the S&A role[50].

7.7. The EuroHawk UAS has just been certified for flight within Germany's controlled airspace, but the 'Safety Case' presented to the DFS (national ATM authority) satisfied the S&A requirement with the use of a 'Sense and Avoid Assistant (SA^3) computer-based tool shown in Figure 7.2. This display integrates all known primary and secondary radar tracks amongst other data to give the EuroHawk crew improved Situational Awareness[51].

Acoustic		**Electro-optical**		**Microwave**	
Active	**Passive**	**Active**	**Passive**	**Active**	**Passive**
Sonar	*Microphone*	*Lidar/Ladar*	*Focal Plane Array*	*Radar*	*Heterodyne*
none	SARA	General Dynamics Robotic Systems	Defense Research Associates	Amphitech	none
		Riegl	Foster Flight	Flight Safety Technologies Inc	
		Fibertek	Geneva Aerospace	Lockheed Martin	
		Velodyne	Northrop Grumman Corp	Multispectral Solutions Inc	
				Sierra Nevada Corp	

Table 7.1: Trialed Sense & Avoid Systems (Anand, 2007).

7.8. Although possibly too detailed for this paper, a brief synopsis of the S&A technical capabilities is given for audience awareness. Numerous tests have been run to determine the range and azimuth requirements (the Region of Interest (ROI) or Field of Regard (FOR)) of a 'manned-equivalent' S&A system.

7.8.1. A combination of NATO and ICAO[52] guidelines result in an FOR of +/- 110^o in the front hemisphere and +/- 15^o vertically, whilst FAA[53] mandates +/- 120^o in azimuth and up to +37 / -25^o in the vertical. Note there is no 360^o requirement although some in-trial radar systems may provide that capability. Figure 7.3 depicts the current standards for an operational S&A system to be fielded.

47 Op. cit. Anand & Geyer
48 Luis Mejias et al, "ARCAA demonstrates Closed-Loop Sense & Avoid using Machine Vision", Unmanned Systems, Dec 2010. p. 40-41
49 http://www.businesswire.com/news/home/20110228005038/en/AAI-Shadow%C2%AE-UAS-Successfully-Demonstrates-Sense-Avoidance
50 AFRL "Latest Sense & Avoid flight testing", Air Vehicle News & Accomplishments, Jul 2008. 08-3516
NextGen

52 Op. cit. HQ ACC/DR-UAV
53 Op. cit. ASTM F2411-07. p. 3

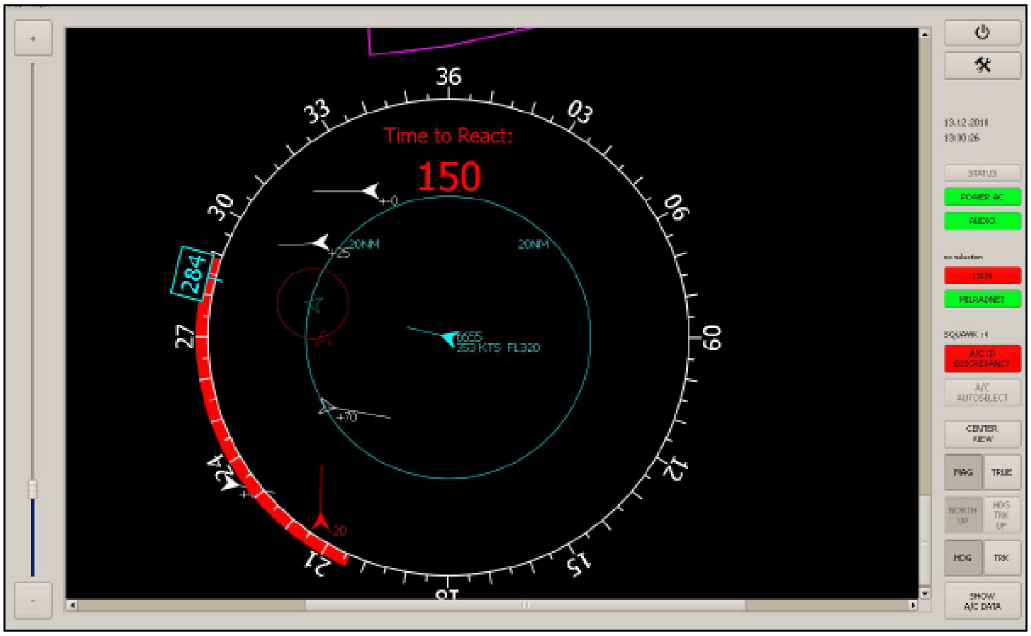

Figure 7.2: EuroHawk's Sense and Avoid Assistance (SA[3]). German Air Force.

7.8.2. Range requirements are based on separation provision ('don't scare others') of 0.5NM horizontally (increased from a mandated 500ft) and 500ft vertically, and then collision avoidance ('don't trade paint') of 500ft horizontally and 350ft vertically. Tests[54] done in a laboratory (using MARCAT, a Mid Air Collision Assessment Tool) and in the field, incorporated over 10 seconds of latency for BLOS comms to the GCS before autonomous action is undertaken to avoid NMAC. A typical example of 500kts closure would require a 23.5 second detection, which translates to a detection range of 3.26NM. Typical cooperative systems, such as the Avidyne TAS 600, can detect traffic up to 21NM out.

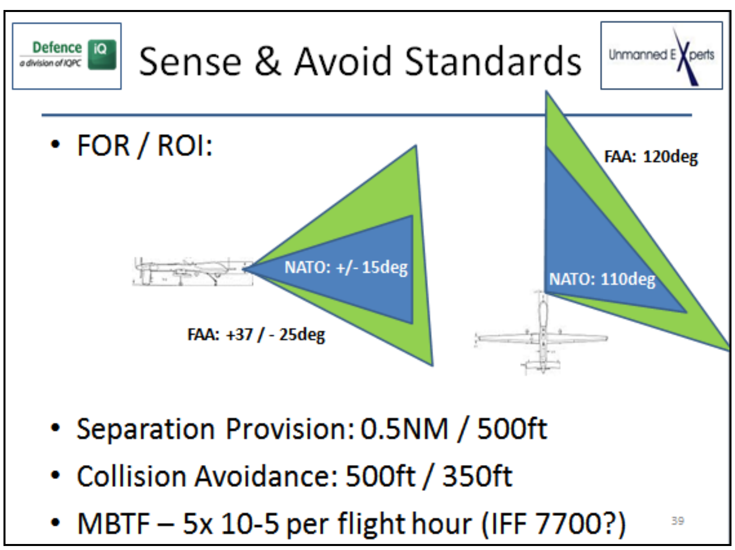

Figure 7.3: Current Sense & Avoid Requirement Standards.

[54] Op. cit. HQ ACC/DR-UAV SMO. p. 12

7.8.3. Finally, to achieve the TLOS, the S&A system must also have a MTBF of 5x 10^{-5} failures per flight hour. Should the S&A systems fail, most CAAs consider the UAV unable to follow the Right of Way regulations and is therefore (by definition) an 'aircraft in distress'. Australia mandates an IFF code of 7700 under these conditions[55].

7.9. For such an important system, the level of redundancy should be significant. It would be expected that any fielded S&A system would be able to perform the following actions:

7.9.1. Alert pilots of 'factor' aircraft in time for avoidance maneuver.

7.9.2. Autonomously perform avoidance maneuver if required (lost link etc.).

7.9.3. Built in Tests (BIT) to provide Health, Usage and Monitoring of System (HUMS).

7.9.4. Alert pilots of any system degradation / failure.

7.9.5. Automatically switch to back-up S&A system if required / commanded.

7.9.6. Perform risk mitigation procedures (such as squawk 7700) if failure and lost link.

7.10. A 'one-size-fits-all' solution is highly unlikely, but 'families' of S&A systems may well ease certification issues. Small UAS have been tested with a Ground-based S&A (GBSAA) radar system that may allow them to 'tunnel' through unsegregated airspace between VLOS of pilots or between ROZs[56]. A combination of active and passive sensors with TCAS or ADS-B will probably provide the simpler S&A requirements of Para 7.3 but pilot interaction, with access to good situational awareness (SA) will likely be required for all the more esoteric items such as reactions to ground pyrotechnics or conducting Search and Rescue (SAR) operations. A three class system of S&A has already been proposed[57] from HITL (Class 1) to Automatic Air and Ground avoidance capable (Class 3).

7.11. TCAS took 13 years to develop and field, and it is now mandatory on all aircraft over 5700kg or carrying over 19 passengers. It is hoped that with ADS-B (Out) becoming commonplace by 2015, and (In) by 2018, NextGen and SESAR air traffic controllers will have sufficient Situational Awareness (SA) to mitigate much of the MAC/NMAC concerns in controlled airspace. However, in the same timeframe, lightweight and modular S&A systems will very probably become available to UAS and GA users alike. Within the next 7 years it is likely that a combined ADS-B (IN) / S&A system will be available to all types and mandatory in some (as with TCAS).

7.12. **Suggested Position.** A 'multi-discipline' approach to UAS 'Sense & Respond' requirements needs to be advocated, with the sensor-heavy technical solutions being confined to S&A alone. HITL interactions and CONOPs should be advanced as solutions to the more esoteric demands. Military UAVs are currently taxiing, taking off, sequencing, responding to ground signals, and maintaining deconfliction from other air assets in extremely complex - and effectively unsegregated - airspace. There are many lessons learned that need to be captured and translated for the civilian FINAS debate, not least how over 2 million hours have been flown by military Class 2 UAVs with only one MAC incident, subsequently blamed on the manned aircraft crew[58]?

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[55] Op. cit. CASA AC-101(0). p.4
[56] Stew Magnuson, "Domestic Unpiloted Aircraft may use 'Tunneling' to fly in National Airspace", Mar 2011
[57] Op. cit. Geyer. p. 8
[58] http://defensetech.org/2011/08/17/midair-collision-between-a-c-130-and-a-uav/

8.0. COMMAND, CONTROL AND COMMUNICATIONS (C3)

8.1. The C3 issues with 'fly by wireless' UAS can be broken into three main areas of concern: protected and secure command frequencies (often referred to as Command Link – CL, or Up Link – UL) and seamless integration into current and near-future Air Traffic Control procedures. A third worry is the lack of available bandwidth for the increasing full motion video (FMV) and data streams being fed back from the UAVs (known as Return Link – RL, or Down Link - DL). It is estimated that by 2015 the US DoD surveillance platforms alone will require an Exabyte (1 billion Gigabytes) of bandwidth.

8.2. To secure frequency bands, within which all UAS could establish CLs and RLs, is a daunting prospect and one that has been tabled for the January 2012 meeting of the World Radio-communication Conference (WRC). Proposals for a 'protected spectrum'[59] have been made and the likelihood is that a section of the RF spectrum will be available in 2012 for OEMs to start designing their UAS CL/RL systems. In the interim, nations have the purview to allocate national frequencies to certain roles, for example the UK CAA has certain aviation and radio-navigation frequencies allocated to them by the UK national frequency management body, Ofcom.

8.3. With a frequency band available, means must be found to secure the CL from interference, tampering or hostile takeover. Encrypted waveforms and data packets are becoming standard in many industrial applications and their migration to the UAS field seems likely. In addition, with the increasing data-flow of ADS-B equipped aircraft, security protocols will undoubtedly become the norm for aviation datalinks, and UAS can benefit from these developments, if not lead their introduction. Discussions of the future NextGen and SESAR airspace management systems often mention a System Wide Information Management (SWIM) concept[60]: it is this data-flow that may suggest novel methods of secure CL and RL for the UAS community.

8.4. Air Traffic Controllers are concerned that a flood of poorly equipped, semi-autonomous, pilot-less aircraft will crowd radar screens with unresponsive, hazardous tracks, converging on congested airspace with no way to control them. The worries are well-founded: both OEMs and UAS Operators need to address them from design to CONOPS, and provide ATC with the 'seamless' integration they have effectively been promised by CAAs. More on this subject is found in Section 12.0.

8.5. UAS must be able to meet all standard air traffic requests such as turn and climb rates. They must have sufficient equipment for navigational accuracy (not solely GPS) as well as the comms fit for the airspace requirements, to include IFF and radio-relay. The requirement to monitor emergency distress frequencies remains extant, but it is well within the SWaP of most Class 2 and 3 UAVs. Several CAAs[61] have regulated that the term 'Unmanned' be added to the callsign in radio communications with ATC which may be a useful discriminator initially, but would seem to poorly serve the UAS community as it matures.

8.6. 'Lost Link' (LL) is a major concern for airspace users and ATC alike. Manned aircraft have well-established lost comms procedures, called NORDO, which involve 'squawking' 7600 on the IFF, either returning to base, or following the filed IFR flight plan. Most current Class 2 UAS already have the capability to fulfill all of those requirements. Some early work has commenced on providing LL UAVs with their own unique emergency IFF code, with 7400 being suggested. Flight Termination Systems (FTS) or Automatic Recovery Systems (ARS) are now standard equipment in this generation of UAS.

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[59] Barnard Microsystems Ltd, "UA communications scenarios". p. 2
[60] Op. cit. INOUI. p.40
[61] Op. cit. CASA AC 101(0). Section 5.13.6. p. 6

8.7. Operators must establish sensible NORDO standards, communicate them to ATC, and then adhere to them, demonstrating that LL UAVs follow predictable flight paths. Although effectively autonomous during a LL scenario, UAVs must either have a full-up S&A system, or act as an aircraft in distress. The ground-based GCS does offer some alternate methods for easing ATC concerns, to include using land-lines / VOIP telephones and large powerful SATCOM radios to contact ATC services, and these additional safety capabilities should be highlighted where applicable.

8.8. Many UAS do not launch or recover from fixed airfields and therefore their climb and descent profiles will not necessarily conform to established airspace structures in a given area. It is important for UAS Operators to establish NOTAM procedures to inform all airspace users of the non-standard activities. When operating from an airfield, but not the runway, then pattern work similar to rotary wing operations should be developed.

8.9. Finally, and to doff a cap to ATC, there is an excellent quote by Jon Cusack as a Terminal Controller in the movie 'Pushing Tin':

"Oh, you really think the pilot is controlling this plane? That would really scare me."

In NextGen, aircraft will use Trajectory Based Operations (TBO) and follow 4 Dimensional Trajectories (4DT) that are potentially uploaded directly to the Flight Management System (FMS) by ATC[62]. In this manner, ATC will actually have direct (albeit pilot-supervised) control of aircraft in their AOR from the ground: this is not unlike GCS control of UAVs. There are some (controversial) suggestions that Air Traffic Controllers will actually be the only C3 agency for portions of UAV transit operations, taking the aircraft from an LRE and handing over to a GCS in the operating area.

8.10. A cautionary tale is worth noting here. Potential conflicts between ATC instructions and TCAS / S&A systems have already resulted in numerous fatal accidents in manned aviation[63]. The coordination of this interface between on and off-board collision avoidance systems will be one of the major areas that UAS ATM CONOPs will need to address. Interestingly, if ATC has 'control' of UAVs transiting their airspace, such incidents may not occur as regularly.

8.11. **Suggested Position.** Ensuring that WRC 2012 allocates spectrum to UAS is paramount to solving the datalink certification concerns. After that, OEMs must work hard on the security of those CLs and adopt cutting-edge data protocols as they are introduced to the NextGen and SESAR airspaces. SDOs and concerned parties must walk in lock-step with CAAs to ensure that UAS are considered at every turn. GCSs must be designed with all back-up systems available and UAS Operators must ensure CONOPs are cleverly constructed, trained to and closely followed.

9.0. CREW TRAINING AND CERTIFICATION

9.1. As stated previously, there is currently no such entity as a 'UAV Pilot's License'. Most of the various CAA regulations reference some sort of Operator's Certificate or License (see Table 5.1), but the mechanism for attaining one is unspecified. In fact the UK CAA's CAP722 even discusses a Commercial Pilot's License (Unmanned) – CPL (U) but, again, without further detail[64].

9.2. ICAO has established guidance that ties the training of UAV pilots to Annex 1 – Personnel Licensing[65]. They have also stated that they will only consider Remotely Pilot Aircraft (RPA – aircraft 'managed on a real-time basis') as opposed to autonomous systems, and have excluded passenger-

[62] FAA's NextGen Implementation Plan. p. 32
[63] BFU, "Ueberlingen Accident Investigation Report", May 2004
[64] Op. cit. CAA
[65] ICAO Cir 328-AN/190 Ch 7

carrying UAVs in the near-term[66] as well as pilots flying multiple UAVs. ICAO also raises the issue of training for the UAV, or the GCS, or both. It is doubtful, however, that any future UAV pilot will be certified without attaining Practical Test Standards (PTS) in both the aircraft (UAV) and cockpit (GCS).

9.3. There are numerous suggestions for UAS crew positions and their respective training. Typically Class 1 UAS will operate with one UAV pilot (UAV-p) at the controls and potentially one UAV commander (UAV-c) supervising the mission. Class 2/3 UAS will often have a dedicated payload operator or sensor operator (SO). These positions have different nomenclature across the CAAs, the most common of which are given below:

9.3.1. Pilot (UAV-p): Pilot, Operator, Air Vehicle Operator (AVO), Pilot At Controls (PAC)

9.3.2. Commander (UAV-c): Mission Commander (MC), Supervisor, Pilot In Command (PIC)

9.3.3. Sensor Operator (SO): Mission Payload Operator (MPO)

9.4. To tie these positions to manned aviation, the CAAs have implemented training requirements that equate UAV-c to Pilot In Command (PIC) or Captain, and UAV-p to Co-pilot or First Officer (FO)[67]. The SO is often unrated in military UAS, which grossly underestimates their worth, but that debate has continued for many years. The PIC / FO analogy is the most useful and will be continued in this paper.

9.5. It seems important to emphasize here that the concept of ‘Pilot in Command’ or PIC has been readily embraced by the UAS community, and there is no indicated intention to abrogate ‘remote pilots’ from any of the PIC’s safety of flight responsibilities. Indeed most current UAS pilots are themselves commercial manned aircrew, and proposed training and certification regulations (highlighted in this Section) will ensure parity of knowledge between the communities.

9.6. Even the complex procedures of ‘handover’ of a UAS between different GCSs is based on, and a mirror of, the ‘you have control / I have control’ system of manned 2-pilot operations, with a PIC designated at all times. Only when the UAV is Lost Link does the issue of ‘who’s flying?’ become extremely pertinent: procedures and CONOPs are already in place with military UAS to answer this, and some expansion is in Section 12.0.

9.7. At one extreme (i.e. Class 3) a crew of ‘airmen’ would be controlling a 12 ton aircraft through highly congested airspace with no ‘special consideration’ by ATC. They will be positioned behind Boeing 787s, sequenced in front of Airbus A380s and commanded to complete complex rerouting and weather avoidance whilst maintaining ‘sense and avoid’ vigilance. They will traverse many FIRs and change IFF, ADS-B and comms settings numerous times. They will contend with system failures, some potentially catastrophic, and they may need to divert to an unplanned airfield and take visual spacing on the local, non-cooperative traffic as they nurse a damaged flight control system to earth. If they make it to their operating area they will be required to perform highly specialized mission profiles before a long return sortie.

9.8. This scenario highlights the enormous commonality between manned and unmanned aviation undertaking FINAS. The UK CAA is correct to utilize the CPL (U) moniker because of these similarities. SDOs and potential UAS pilots should not be lulled into the ‘video game’ mentality that is currently under-resourcing the manpower for military UAV operations. The ground school portion alone of a JAA CPL requires a year of study and 14 exams including Performance, Weight and

[66] ICAO Cir 328-AN/190 Para 2.7
[67] Op. cit. FAA UAS Interim Operational Guidance 08-01, 2008. p. 3

Balance, Operations, Instrument and Visual Navigation, and Communications (detailed later in this Section). The PTS for manned CPL students are considerably more rigorous than the PPL and most complete an Instrument Rating (IR) to fully utilize the privileges of the CPL license.

9.9. Several SDOs, including ASTM, DCMA and NATO, have come to this consensus and are proposing adapting civil training courses and standards to meet the anticipated needs of the future UAV pilot[68]. In essence the training program is identical to ICAO Annex 1 and 14 CFR 61, 63, 65 and 67 with some items removed and some UAS-specific additions. A suggested high-level list of CPL (U) PTS is shown In Table 9.1.

Common CPL / IR Topic		UAS Removed	UAS Added	Notes
1	Preflight Preparations		Datalink Planning GCS Handovers	
2	Preflight Procedures	Cockpit Management	GCS Management Datalink Initiation + Test	
3	Airport Operations		Lost Link on Ground procedures	
4	Pattern Operations	Taxi / Take off if rail launched	Flight Termination System Auto Recovery System Auto Take-off / Land (ATOL)	
5	Performance Mnvrs			Simulator work?
6	Ground Reference			Simulator work?
7	Navigation	Diversion if ARS / FTS	Lost Link procedures	
8	Slow flight / Stalls			If autopilot allows
9	Basic Instruments	UA if autopilot flown	Likely covered in 5. above	Simulator work?
10	Emergency Ops	A/R if ARS / FTS	Lost Link procedures	
11	Night Ops			Often EO/IR
12	Post-flight Procedures			
13	Additional Items		Handover between GCSs Sense and Avoid operations	
14	Instrument Rating ATC Clearances		Lost Link Procedures	
15	Instrument Approaches	Limited Panel A/R		

Table 9.1: Suggested UAS CPL (U) and IR Syllabi

9.10. The IR requirement has been codified in some regulations that demand only MANNED IR and current pilots be allowed to fly UAS on an IFR flight plan[69]. Until a CPL (U) IR exists, this may be the only realistic option.

9.11. This seems an opportune moment to underscore some of the fundamental differences between manned and unmanned flight, and therefore the delta in training requirements for certification:

9.11.1. **Joysticks.** Currently only two Western ‘families’ of Class 2/3 UAS operate with a joystick for ‘manual’ control (GAASI Predator and Selex Galileo Falco). All others rely on a ‘point and click’ mouse input, preprogrammed routes and uploaded normal and emergency actions. The latest edition of the Predator, the MQ-1C Gray Eagle, has now foregone the joystick, and auto take-off and land

[68] Op. cit. Goldfinger
[69] Malaysia AIC 04/2008, “UAV Operations in Malaysian Airspace”, Feb 2008. p. 3

(ATOL) should be retrofitted to that fleet in the very near future. This means that the traditional pilot's desire to 'turn and burn' or 'yank and bank' is replaced by 'scroll and roll'™. More importantly, the UAS training regimen needs to focus more on building Situational Awareness (SA) and mission planning than on hand-eye coordination and reactions.

9.11.2. **Out-the-Window.** The majority of fielded systems have both a slewable payload camera system and a fixed 'pilot view' camera either in the nose or the tail of the airframe. Switching between the two, and using the slew feature to scan for weather, traffic, navigation references, etc. is part of the duty cycle of a UAS crew. It is a slower, more complex process than in manned aircraft and has some positive features (i.e. 360^o field of view with zoom and Day/Night capabilities) and some negative aspects (i.e. not motion-cued, monocular and slow to react). Training to this environment is UAS-specific, and manned flying experience does not necessarily translate well.

9.11.3. **Day or Night flying?** Most Class 2/3 UAS have both EO and IR payload cameras, with the IR being effective for almost 24 hours of the day. With satellite BLOS control, it is not uncommon for the pilot to be 12 hours 'out' from the local time at the UAV's location, and therefore the logging of day or night hours does not have the same connotation. This also applies to the training requirements.

9.11.4. **UAS Crewing.** The traditional UAS is, counter-intuitively, manpower 'heavy' with a typical crew including a UAV-p, a SO and additional crew members such as a UAV-c, Intelligence or Imagery Support and potentially a 'relief' crew. For those systems that separate Launch-Recovery Element (LRE) from Mission Control Element (MCE), the 'LRE crew' is another dimension to the crew structure. Crew Resource Management (CRM) is paramount in effective UAS operations (i.e. requesting the SO to scan left / right for traffic or weather?) and requires thorough training to.

9.11.5. **Simulation vs. Live flying.** There is no such concept as 'Seat of the Pants' UAS flying and therefore a fixed simulator can very accurately portray the 'form, fit, function' of the GCS and the operating environment. Computer software and graphics can provide extremely realistic mission scenarios, weather, failures and interactions with other airspace users, including ATC. There are many advantages of UAS simulation over live flying, especially with the current, very restrictive, airspace options. To that end, there are solid arguments for simulation providing the majority of training and currency requirements[70] to acknowledge this unique aspect of UAS.

9.12. The opposite end of the UAS spectrum (Class 1) sees a small model aircraft hand-launched from a field, clear of any local airfields. The single UAV-p uses a laptop and mouse to place waypoints on a 1:100,000 scale map as a UAV icon follows over the screen. A small window depicts the payload view which the pilot moves using a small joystick. He surveys the fence line of the surrounding farmland at 300ft AGL until his hand-held radio crackles to life and one of his posted visual observers tells him to turn south. He obliges and brings the small plane into auto-land beside him after its 20 minute flight. The footage was reviewed that afternoon and a 5 foot section of worn hedge was later repaired.

9.13. Clearly training requirements differ considerably in this scenario, but there are still aviation topics that require PTS. This stepped approach has been best codified by the US military in the adoption of Basic UAS Qualifications (BUQ) Levels 1 through 4[71] as depicted in Table 9.2. These address the core Knowledge, Skills and Attributes (KSA) of the myriad UAS pilots.

[70] Op. cit. JAA UAV TF, Appendix 4-2 to Enclosure 4. p. 8 & 11
[71] Op. cit. CJCSI

BUQ Level	Airspace	Crew position	Training	UAS Group	Notes
1	VFR E, (F), G <1200ft	Non-pilots MPO / SO	Ground school Msn Prep + Planning Datalinks + Comms Aircraft Ops Emergencies / LL Checklists SUTTO / Pattern Ops Vis Navigation / Fuel plans	1: <20lbs / <1200ft	Desert Hawk Raven
2	VFR D,E,(F),G <18000ft	All	As above + Radio Navigation Weights + Balance Airfield Ops Flight Plans + Clearances ATC procedures	2: <55lbs / <3500ft 3: <1320lbs / <18kft	Shadow Hunter Exceed FAA Sports Pilot
3	VFR B – G <18000ft	All	As above + IFR Planning + Flt Plans IFF / TCAS Basic Instrument Flight Unusual Attitudes Diversion (?)	4: >1320lbs / <18kft	Predator Exceed FAA PPL.
4	IFR ALL <FL 600	All	As above + Global Navigation Procs SAR ATOL Advance Instrument Flying	5: >1320lbs / >18kft IFR	Reaper Global Hawk Exceed FAA PPL + IR

Table 9.2: Basic UAS Qualifications and JUAS UAV Groups

9.14. Current ground school requirements for manned commercial aviation have significant global concurrence (JAA, FAA, etc.) and traditionally consist of 13-14 topics (listed in Figure 9.3) and taken over 650 hours of tuition. Regardless of planned operations, be it local area passenger flying or transatlantic air transport, the course is identical covering items from hypoxia to polar navigation and mass / balance in large passenger aircraft. Many of these topics are far from relevant, but the course is regarded as a 'leveler' such that all CPL and ATPL holders have a common knowledge base.

9.15. It should be assumed that ALL nascent commercial UAS pilots will be required to undertake this level of ground school training, regardless of relevance (i.e. number of air stewards required?) as well as some UAS-specific coursework, suggested below.

9.16. As UAS operations have numerous unique aspects, further ground school training is suggested, perhaps as a separate 'UAS Operational Procedures' block with a high-level topic list including:

9.16.1. Datalinks 101

9.16.2. Lost Link / Auto-Recovery Systems / Flight Termination Systems

9.16.3. Autonomy 101

9.16.4. Sense & Avoid 101

9.16.5. Launch-Recovery Operations

9.16.6. Handover Procedures

9.16.7. UAS-specific Emergency Procedures

9.17. Therefore our Class 1 pilot would undertake a course to include CPL ground school (Figure 9.3), with some UAS additions (listed at 9.16) and then practical training similar to BUQ1 (Table 9.2) to qualify for a UAS Class 1 (Airplane) License. This should be considered a Commercial Certificate to keep Class 1 UAS pilots at the same 'level' of ground school KSA as Class 2/3 UAS and manned commercial pilots. It may seem excessive for Class 1 UAS, but should be considered 'the cost of entry' to NAS for any future UAS pilots.

9.18. Likewise our Class 2/3 UAS aircrew would undertake the CPL (U) ground school outlined above, then the PTS, for their systems (Table 9.1), including an IR as required. This way, all airspace users can be comfortable with the degree of training and certification of UAS pilots operating any Class of UAS within the NAS.

9.19. Table 9.4 lays out the suggested Classification system and how these licenses would apply. Red shows an adoption of a manned program, whilst **Bold Red** shows a UAS-specific category.


Phase 1
- Aircraft General Knowledge
- Instrumentation
- Air Law

Phase 2
- Radio Navigation
- Flight Planning
- Aircraft Performance
- Mass & Balance
- Operational Procedures
- Human Performance

Phase 3
- Principles of Flight
- General Navigation
- Meteorology
- IFR/VFR Communications

Figure 9.3: Commercial Pilot's License Groundschool

Category	Airplane	Rotorcraft	LTA	Pwr Chute	Glider	Pwr Lift	Wt Shift
Class	SEL / SES MEL / MES **UAS-A 1,2,3**	Helicopter Gyroplane **UAS-R 1,2,3**	Airship Balloon **UAS-L 1,2,3**	Land Sea **UAS-P 1,2,3**			
Ratings	Type**(ME)** Instrument **BLOS** **Flt Control**	Type**(ME)** Instrument **BLOS** **Flt Control**	Type Instrument **BLOS** **Flt Control**	Type Instrument **BLOS** **Flt Control**			
Certificate	Student Sport Rec Private CPL **CPL (U)** ATP Instructor	Student Sport Rec Private CPL **CPL (U)** ATP Instructor	Student Sport Rec Private CPL **CPL (U)** ATP Instructor	Student Sport Rec Private CPL **CPL (U)** ATP Instructor			

Table 9.4: Suggested UAS Classification and UAS Pilot Certification

9.20. The table is written to suggest that CPL (U) is the only valid UAS Certificate, although the use of UAVs recreationally could be envisioned (with some difficulty). The main distinction is at the Class level (1 to 3) within the extant manned Categories of Airplane through Powered Chute. UAS Type ratings are a matter of considerable debate, but the manned process of deciding on a case-by-case basis seems valid, and major training burdens such as BLOS and Multi-engine would fit this profile. The Flight Control Mode (joystick / mouse / autonomous) might also be included in the Type rating.

9.21. The Class 1 example highlights another interesting UAS-unique crew position, that of observer. They are currently mandated, either on the ground or in a chase plane for Class 1 and 2 UAS and CAAs have regulated that they have their own training requirements[72] which typically include:

9.21.1. Radio Telephony License.

[72] Op. cit. FAA UAS Interim Operational Guidance 08-01, 2008. p. 9-10 & 16

9.21.2. Training in ICAO Annex 2 – Rules of the Air.

9.21.3. Class 2 medical.

9.22. Some suggested civil regulations would actually reduce the training burden for the Class 1 pilot, if they remained below 400ft, within VLOS and in Day VFR conditions. He would then only need to complete PPL ground school and UAS-specific training[73]. Although the difference is potentially minimal, the importance of becoming a 'Commercial pilot' should not be underestimated in the eyes of other stakeholders, and therefore the stricter entry level should be pursued.

9.23. The Defence Contract Management Agency (DCMA) has suggested that UAV-p qualifications should include a PPL, a current IR, a minimum of 300 hours manned PIC or 200 hours as a UAS MC and 100 hours manned PIC, AS WELL AS a CPL (U). The result is actually very similar to our CPL (U) Class 3 example, but again it seems important to have worked through the same KSA as the manned brethren with which the UAS pilots will 'share' the airspace.

9.24. Manned CPL students are required to have, amongst other specific events, a minimum of 200 hours flight time. Studies are being undertaken, currently unpublished, that suggest UAS pilots might equally benefit from a minimum of 75 hours actual UAS flight time and 150 hours simulation experience. As these numbers are confirmed through research, they should be applied to the PTS listed at Table 9.1.

9.25. Associated issues, which still require addressing, include the areas below. Manned equivalency can often be 'read across' effectively, but there may be some UAS-specific issues that arise:

9.25.1. Instructor qualifications.

9.25.2. Different UAS – GCS combinations (i.e. new models or portable GCS versions).

9.25.3. Different Flight Control characteristics (i.e. mouse vs. joystick vs. preprogrammed routes).

9.25.4. Currency requirements (i.e. they may differ for launches, en route operations, recoveries etc.).

9.26. Finally, medical requirements for UAV-p have always been an area considered able to move away from the rigorous 1st and 2nd Class medical standards for manned CPL issuance. It is certainly true that mobility is not a requirement, neither is long-sighted vision, although corrected short-range and color vision remains important. Heart-health and chronic illnesses may also be acceptable as the ground-based pilot can be rapidly hospitalized and replaced if required. Australian CASA demands that they are solely 'fit to drive', but initial ICAO regulations suggest that there would be a medical minimum standard[74].

9.27. **Suggested Position.** It is paramount that the professionalism of UAS pilots be established from the outset, and thus there is considerable benefit to modestly adapting current CPL training courses to cater to all UAS Class pilots. The ground school courses are practically ready for use and the PTS for all Classes are well developed. Simulation should be the primary method of 'flight' training due to its inherent utility and low cost, but an element of live flying will likely be required to meet these PTS.

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[73] Op. cit. Malaysia. p. 3

[74] Op. cit. ICAO. p. 33

10.0. CONCEPT OF OPERATIONS (CONOPS)

10.1. CONOPs have been referenced throughout this paper and NASA has budgeted $30 million per year to develop acceptable procedures across the spectrum of UAV operations. The production of these documents, which need to be widely briefed and acknowledged, should aim to demonstrate the professionalism of the UAS community, as well as help develop a common ‘air picture’ for all airspace users.

10.2. As a minimum the following topics should be comprehensively addressed:

10.2.1. **Mission Sets.** It is important to understand the civilian roles (Table 2.1) to which UAS are best suited and to write manned-airframe friendly procedures to maximize that utility. At all times however, the parallel goal should be to minimize the impact on the resident community of GA and Air Carrier operators. If airspace stakeholders understand what the phrase “Figure 8 orbit with 3 miles standoff on 135°. On station time 8 hours” means, and why it is being performed, the scope for misunderstanding is significantly reduced.

10.2.2. **ATC Integration.** As NextGen is rapidly being developed, a priority must be to coordinate a set of CONOPs describing how best to interact with ATC. UAS bodies are in a position to discuss each step with airspace authorities. They must be prepared to revise the documents as UAS technology improves, as well as alter their systems to incorporate the new ATC capabilities as they arise. The possibility of an Air Traffic Controller physically moving a UAV should be touted as how ‘ATC-friendly’ this Class of aircraft can be.

10.2.3. **Sense & Avoid.** This is a game-changing technology that will very likely spread to manned aviation as soon as it is proven. With this capability, the UAS community should package robust CONOPs for its effective, and minimally intrusive, employment. These documents should be made available to the manned community when the technology shifts into their realm.

10.2.4. **Sense & Respond**. Beyond S&A, there is a need to complete the ‘Sense and Respond’ requirements listed at Section 7.3. These demand a combination of technology and training, meshed into a very clear set of procedures that can be used to demonstrate certifiable compliance. S&R CONOPs can be used by OEMs to design future systems, incorporating needed technology, but ignoring others. Checklists and Flight Manuals can be designed with the CONOPs as guidance, and all UAS Operators will have a common language, much like how manned aircrew can quote ‘Lost Comms’ procedures verbatim.

10.2.5. **Handover Procedures**. This UAS-unique procedure needs to be fully explained to the aviation community, with an emphasis on their remaining an unbroken chain of PICs, each fulfilling his or her duty of care. In addition, newer OEMs can use this document to ensure novel UAS can fulfill the requirements for said chain.

10.2.6. **Lost Link Procedures.** Although compared to an IFR-flight planned NORDO, there are many more intricacies to a complete LL scenario, including the use of FTS or ARS. These need to be dictated to ensure predictability and robustness in multiple failure situations. The confidence of the manned community rests heavily on the unmanned sphere’s actions in this department.

10.3. With considerable military experience in UAS operations it will be of tremendous benefit to the unmanned fraternity if their tried-and-tested CONOPs are brought across to the civilian side for implementation of these systems. Professionalism is a baseline requirement and therefore UAS Operators should mirror the daily flight activities of the better manned aviation outfits, or the military, to hold the community above reproach.

10.4. **Suggested Position.** Operationally-smart manned and unmanned aircrews need to be tasked to bring these CONOPs from paper-napkin notes to actual flight test, potentially through the NASA program or beyond. The technology-heavy solutions need to be tempered with realistic HITL procedures. Adapting automation to assist the UAV-p in fulfilling PIC duties should be a priority, but the CONOPs will help translate the intent to all stakeholders. At all times, a UAS should be heralded as a trained, professional and tightly-regulated commercial operation.

11.0. UAV EQUIPAGE

11.1. UAV platforms, and their associated GCS, LRE and datalinks, will all require a Minimum Equipment List (MEL) which will vary according to their Certification requirements. The underlying 'manned equivalent' guidance remains primary, and therefore any UAV wishing to enter Class C airspace on an IFR Flight Plan will need to match the Communications, Navigation and Surveillance (CNS) fixtures of similar manned aircraft.

11.2. Australia's CASA[75] has produced the most comprehensive equipage lists, but their suggestions mirror initial thoughts of other SDOs and CAAs. An ADS-B requirement will become regulation for UAS in the coming years, but MITRE designed a PDA-sized[76] system costing less than $1000 that would provide the capability to all classes of UAS. A summary of likely UAS requirements for CNS is given in Table 11.1.

Class	Airspace Flight Rules	Equipment	Notes
UAS 1	G (<400') VFR	Flight Termination System 2-way Comms w/ observers 2-way Comms w/ATC	 If within 5NM of tower
UAS 2	C,D,E,(F),G VFR / IFR	Encoding Altimeter IFF Mode S/C VOR/DME Direct 2-way comms Navigation / anti-collision lights Flight Data + voice recorder Flight Termination System Automatic Recovery System Displays: Attitude / Datalinks Lost Link logic S&A capability Redundancy HUMS / Built In Test equipment	 Possibly direct from GCS Possibly UAV and GCS One or both FTS / ARS Within GCS Both UAV and GCS
UAS 3	All VFR / IFR	As UAS 2: Autonomous S&A capability Increased redundancy	

Table 11.1: Probable UAS Equipage Requirements

11.3. **Suggested Position.** Again, the parallels with manned aviation should be adhered to, and all UAS OEMs wishing to undertake FINAS will need to build to the current standard. It is equally important though, that SDOs and CAAs do not place overly burdensome or prescriptive technical

[75] Op. cit. CASA. p. 7-8
[76] http://www.mitre.org/news/digest/aviation/06_08/av_uat.html

requirements on UAS 'just in case'. The requirement for equivalence should be demonstrated by all sides throughout the Certification process.

12.0. PUBLIC PERCEPTION & ACCEPTANCE

12.1. In a recent UAS Conference filled with UAV pilots, designers and regulators, the following scene played out: the speaker asked "who would be willing to drive in an unmanned car or bus as the technology matured?"… Most of the audience raised their hands[77]. Next he asked "who would fly in an unmanned Airbus?" and not a single hand left the table. A poor start for the goal of FINAS, perhaps?

12.2. Most of the previous arguments have revolved around physical equipment, tangible documents, and discernable training standards, but many commentators argue that the reason UAS will not be flown in the NAS is in the minds of the general populace. Public perception oft holds that 'drones' will barrel into airliners, plummet into schools and, when they become 'self-aware', will plan the destruction of the human race. A nervous public petition their lawmakers, the lawmakers withdraw regulatory support, and the SDO's work sits idle, with no FINAS and the market dollar moving on to pastures new.

12.3. This force should not be underestimated, and is one of the prime motivators for this paper. Public perception can be altered through sympathetic education, realistic promises and sensible compromises. Some of the more common stereotypical arguments, all validly held, are expressed below, with a counter-position postulated for each:

12.3.1. **Artificial Stupidity**. Stereotype: it is true that Artificial Intelligence (AI) is a product of programming, and 'Strong AI', where a true learning algorithm exists, is several years away. The concern lies in what autonomous systems cannot currently do: respond to the unexpected. An old aviators adage states that you start flying training with a full bag of luck and an empty bag of experience; the goal is to end your career with the situation reversed, but the road is littered with 'the unexpected'. Current AI has tremendous difficulties in 'learning from experience', and therefore cannot move items between those two bags.

12.3.1.1. Counterpoint: until Strong AI can be demonstrated, fully autonomous systems should be considered 'dumb'. The scope of the paper is to have remotely-piloted aircraft (UAVs with a pilot connected) gain access to the NAS, and the only consideration for true autonomy is during Lost Link emergencies. When the UAV is LL, our desire is for it to remain predictable, and our systems and CONOPS are designed to ensure this: a 'dumb' LL UAV is predictable and therefore the result required by all stakeholders, especially ATC. When autonomous UAS, with Strong AI, request FINAS then a further position paper will need researching.

12.3.2. **Shared fate.** Stereotype: **t**he concern is that remotely-piloted system aircrews are not physically 'at risk' from mid-air collision, poor weather decisions or badly executed approaches. This will lead them to make poor Risk Assessments and endanger both their passengers (if any) and other airspace users. Another manifestation of this concern is the 'Video Game mentality'.

12.3.2.1. Counterpoint: the logic is powerful and the concern is genuine. Note, however, the limited initial scope precluding unmanned airliners, so the safety of other airspace users is the concern. All UAS aircrews are trained professionals operating in a sufficiently complex Air Traffic System and utilizing multiple leading-edge technologies. These factors should mitigate against lax risk attitudes,

[77] IQPC UAS Training & Simulation Conference, London, April 2010

but not entirely. Strict training, standardization, accountability and repercussions are all further tools that UAS Operators should engage in to reduce this concern.

12.3.2.2. Counter-intuitively, aircrew that are not facing mortal danger may make MORE rational airmanship decisions concerning weather, diversions, emergency situations and even mission timeline concerns. Without being ‘on the line’, UAS aircrew can consult with ground-based professionals and more experienced crews, then have the option to deliberately terminate a flight in a safe location, with no risk to themselves or others.

12.3.3. **Seat of Pants.** Stereotype: without feeling the G-forces and sideslip, hearing the airflow noise or smelling the oil-tinged airflow, the remote pilot has a dramatically reduced SA of the state of their aircraft.

12.3.3.1. Counterpoint: there are many sensory indications that a Cessna 172 pilot can use to maintain all-around awareness of their speed, altitude, vector and engine system performance. This is less so the case for larger aircraft, most of which have very few useful ‘seat of pants’ experiences, and which regularly need to use artificial feedback to the crew. In addition, human factors studies[78] show that aircrew under G-force undergo numerous disorienting and incapacitating changes which affect their ability to understand, or even respond to, their flight state.

12.3.3.2. An UAS crew in a ‘one G, straight and level’ environment receives no sensory feedback, good or bad, and therefore has to rely on their visual sense alone for orientation. Fortunately, vision is the primary human sensory system: with training and good Human-Machine Interface (HMI) design, aircraft orientation can be readily discernable, whilst avoiding disorienting sensory inputs.

12.3.3.3. Unfortunately, and as an aside, the current suite of UAS HMI leaves considerable work to be done in this field. It is currently the prime cause of Human Factor accidents in the Predator family of aircraft[79].

12.3.4. **The Irreplaceable Pilot.** Stereotype: it is a truism that no pilot will admit to having made an error (they are referred to as the ‘Two-winged Master Race’ in the Royal Air Force). It is equally true that historically over 70% of aircraft accidents and incidents have been attributed to ‘Human Factors’[80] which, until recently, was called ‘Pilot Error’. The aviation community, mostly said pilots, tends to not initially welcome systems that infringe on their traditional duties. Glass cockpits, GPS, TCAS, etc. have all been accepted as improvements to the airspace system, but often reluctantly and older aircrew still prefer, for example, a NDB to back-course ILS plate than to program, and follow the Flight Director on a GPS only approach. An unmanned aircraft may be seen to be the ultimate infringement of those duties.

12.3.4.1. Counterpoint: the current UAS are fully piloted, by crews of the same ilk as manned aircraft. Their cockpit is remarkably similar to a Garmin 1000-equipped business aircraft, and they navigate using their equivalent of a FMS. The latest technology is employed, including ATOL, ARS and S&A, all of which will likely migrate to the manned community. The duties of the PIC have not changed, but the tools to ease the tasks have been employed in force. Unmanned aircrews are simply Remote Pilots.

12.3.5. **The Rogue Drone**. Stereotype: ATC has already witnessed several incidents of UAS not responding to controller inputs[81], infringing on busy airspace without any clearance and without any

[78] Jens Flottau, “Training Turnaround”, Aviation Week & Space Technology, March 2011. p. 42
[79] K. Williams, “A Summary of Unmanned Accident / Incident Data: Human Factors Implications”, Dec 2004
[80] Op. cit. Nall
[81] http://www.suasnews.com/2010/09/1086/washington-considered-shooting-down-mq-8b-firescout-that-went-sightseeing/

procedures to recover the situation. This is the ultimate ‘nightmare scenario’ both for controllers, but also for the UAS community.

12.3.5.1. Counterpoint: both recent incidents were experienced by immature operations: the first, a MQ-8B Fire Scout, encountered a software glitch during initial testing. The second, a RQ-9A Predator B was due to inexperienced operator error. These incidents will never be fully nullified by either training or better software standards, but they are not supposed to be. The idea of a TLOS is to find an ‘acceptable’ level of accidents and incidents, and the TLOS that the UAS OEMs are designing towards are now safer than their manned counterparts. After all, how many manned aircraft infringe airspace or runways annually? Yet that level is still considered ‘acceptable’.

12.3.6. **Sully**. Stereotype: on 15 January 2009, Captain Chelsey Sullenberger III ditched the dead-stick US Airways Flight 1549 onto the Hudson River, and saved all 155 people onboard. This remarkable act of aviating skill has been a beacon for aviation safety and training and an inspiration to aircrew since the event. Unfortunately, it has also become a bar by which UAS are now measured in the public eye to gain access to the NAS. “Would a UAS have landed on the Hudson (the human, illogical move) or crashed into downtown Manhattan attempting to return to an airport (the programmed, logical response)?”

12.3.6.1. This is far from a slur on Captain Sullenberger; in fact the point is that his action was considered ‘Above Average’ in aircrew circles. By definition, this means that the majority of other aircrew facing a double-flameout at low level over a Metropolis would have been less successful: attempting a turn-back, stalling in the finals turn, cartwheeling on touchdown or simply gliding to impact in an effort to relight. Ditching was rarely practiced in training (it is now), and few aircrew had the impressive CV and experience level of ‘Sully’. The bar, therefore, should not be set by him.

12.3.6.2. Unfortunately, there is no evidence to suggest that a UAS could do better, but to avoid an ‘apples and oranges’ comparison, there are some important factors to consider. Firstly, the UAV is still crewed by aviators, albeit remotely, who have similar training to their manned brethren. In addition they do not fear for their own lives, and therefore could potentially make more rational decisions. Without the distraction of fixating ‘out of the window’, UAS pilots might be able to see the ‘bigger picture’ of available runways, highways or waterways. Finally, there are no passengers, as we have previously discussed.

12.3.6.3. However, this event will stand as one of the primary reasons for unmanned Airliners being unacceptable for several decades to come. It is important to be realistic, and in today’s media-driven world, if an unmanned Airbus has completed the same flawless ditching in the Hudson, and all had survived, the headlines would still likely read:

“Drone plane, packed with helpless passengers, crashes into river. Doesn’t even apologize!”

That is the current reality, although by approximately 2035 (maybe a good estimation) perception may have begun to change.

12.4. Finally, and more generically, the UAS field needs to help the manned aviation world and the public, to imagine true FINAS, but not fear it. Vignettes and storyboards, the similarities, the advantages, planned mitigation strategies and trickle-down technologies all need to be widely and emphatically briefed at every opportunity. This will help firm up the FINAS CONOPs in the minds of both manned and unmanned aircrews, and ensure that the language developed remains ‘common’. The goal is for the public to understand that UAS are a ‘good thing’ and to welcome the benefit to society that they have the potential to be.

13.0. SUMMARY

13.1. The goal within the UAS community is for their pilots to be able to 'file and fly' as any other General Aviation (GA) aircrew member currently does. A summary of the pieces that need to be in place follows, with a considered position for assisting the effort forward:

13.1.1. **Classification.** A simple airspace-oriented Class system (with a suggested format given here) within the current manned classification table should be pushed to help frame the debate on the more important aspects below.

13.1.2. **Standards.** Already established by SDOs for most UAS-relevant items, these should be rapidly translated into CAA certification paperwork to give OEMs positive guidance. Vitally important is the setting of ELOS and TLOS standards. These should not be made unobtainable by using 'fudge factors', but should mathematically follow current manned safety performance models.

13.1.2. **Regulations.** Already drafted by many CAAs, and with reasonable international accord, the UAS Rules of the Air should reference the agreed Standards and Class system (above). This codification will allow for targeted system certifications to begin, and lessons to be learned.

13.1.3. **Airworthiness.** OEMs must build well-equipped and manned-equivalent certifiable UAS in line with the Regulations. This piece is the furthest from maturity, and OEMs should be prepared to 'overbuild' initially as the regulatory piece is being codified. CAAs should be prepared to transition segregated COAs into FINAS Certifications in the medium term.

13.1.4. **Technological Advances.** The concerns of S&A and C3 security are being addressed rapidly by all interested parties, and their importance cannot be overstated. Securing a CL frequency band is paramount, and encrypting the datalinks must follow shortly thereafter. S&A technologies should focus on exactly that piece of the 'Sense and Respond' spectrum, but CONOPs and other technical solutions need to be produced rapidly to fill the other areas.

13.1.5. **CONOPs.** These procedures, documents, briefs and training packages will demonstrate the professionalism and earnestness of the UAS community. CONOPs need to be produced rapidly, proactively, and in very close coordination with airspace users and controllers. The education element to these discussions (in both directions) is an oft understated necessity and highest-level engagement should be made.

13.1.6. **UAS Crew Certification.** Training packages are sufficiently theoretically advanced, with a plethora or military experience, such that a CPL (U) course should be produced, tested, run and certified in the very near term. There is a risk that this vital piece may slow the entire FINAS mission if not addressed now.

13.1.7. **Public Acceptance.** Education and experience are the best tools to begin turning the significant momentum against UAS in the NAS, to a more favorable course. This potent issue is understated, and as such is likely the most dangerous threat to FINAS progress.

13.2. In conclusion, there are still significant hurdles to UAS FINAS operations, but taken piecemeal, each of these areas is being worked diligently by the right people. The belief that FINAS will occur 'later rather than sooner' may be tempering efforts, but it is likely that all lines of development will reach their conclusions in a very similar timespan (possibly within 5 years). When this confluence of findings occurs, the aviation community needs to be prepared for the paradigm shift that will happen with startling rapidity. You should now have the knowledge to be central to public preparation and remain in an educated position to guide the developing civil UAS community as it matures.

14.0. APPENDICES

14.1. OTHER AGENCIES

14.2. ABBREVIATIONS

14.3. BIBLIOGRAPHY

14.3.1. Recommended Reading

14.3.2. Other Reading

14.1. OTHER AGENCIES

AFRL – Air Force Research Laboratory
AIA – Aerospace Industries Association
AIAA USPC – American Institute of Aerospace and Aeronautics Unmanned Systems Program Ctte
ARCAA – Australian Research Centre for Aerospace Automation
ASD (HD) – Assistant Secretary of Defense (Homeland Defense)
ASTM F38 - American Society for Testing & Materials
ASTRAEA – Autonomous System Technology Related Airborne Evaluation & Assessment
AUVSI – Association for Unmanned Vehicle Systems International
CAA – Civil Aviation Authority (UK)
CAANZ – Civil Aviation Authority of New Zealand
CASA – Civil Aviation and Safety Authority (Australia)
CCUVS – Canadian Centre for Unmanned Vehicle Systems
CRM – Crew Resource Management
DCA Malaysia – Department of Civil Aviation
DLR – Deutche Zentrum fur Luft und Raumflug (German Aerospace Center)
DoD PBFA – Department of Defense Policy Board on Federal Aviation
EUROCAE WG73 – European Organization for Civil Aviation Equipment
FAA – Federal Aviation Administration (USA)
ICAO UAS Study Group – International Civil Aviation Organization
INOUI – Innovative Operational UAS Integration
JAA / Eurocontrol UAV Task Force
JAPCC – Joint Air Power Competency Centre
JARUS – Joint Authorities for Rulemaking on UAS
JAXA – Japan Aerospace Exploration Agency
JIPT – Joint Integrated Product Team
JUAS MRB – Joint UAS Material Review Board
JUAV – Japan UAV Association
MITRE CAASD – Center for Advanced Aviation System Development
NASA ISR – NASA Integrated Systems Research
NATO FINAS – North Atlantic Treaty Organization Flight in Non-segregated Airspace
RTCA SC 203 – Requirements & Technical Concepts for Aviation Special Committee
SA-CAA – South African Civil Aviation Authority
TAAC – Technical Analysis and Application Center
Transport Canada
UAS PFT (OSD) – UAS Planning Task Force (Office of Secretary of Defense)
UAVNET – UAV Thematic Network
UCARE – UAV Concerted Action for Regulations
UNITE – UAS National Industry Team
US Army USAICPD – Unmanned Systems Airspace Integration Concepts Product Directorate
UVS International – Unmanned Vehicle Systems International

14.2. ABBREVIATIONS

4DT – 4 Dimensional Trajectories
ABSAA – Airborne Sense & Avoid
ADS-B – Automatic Dependent Surveillance – Broadcast
AI – Artificial Intelligence
AOR – Area of Responsibility
ARS – Autonomous Recovery System
ATC – Air Traffic Control
ATOL – Automatic Take Off and Landing
BAMS – Broad Area Maritime Surveillance
BIT – Build in Test
BLOS – Beyond Line Of Sight
BUQ – Basic UAS Qualification
C3 – Command, Control and Communications
CAA – Civilian Aviation Authority
CFIT – Controlled Flight into Terrain
CFR – Code of Federal Regulations
CL – Command Link
CNS – Comms, Navigation and Surveillance
COA – Certificate of Waiver or Airworthiness
COTS – Commercial … Space
CPL – Commercial Pilot's License // (U) - Unmanned
DCMA - Defence Contract Management Agency
DL – Down Link
DUO – Designated UAV Operator
EDA – European Defence Agency
EFB – Electronic Flight Bags
ELOS – Equivalent Level of Safety
EO – Electro-optical
EVO – Equivalent Visual Operations
FAA – Federal Aviation Authority (USA)
FAR – Federal Air Regulation
FINAS – Flight in Non-Segregated Airspace
FIR – Flight Information Region
FMS – Flight Management System
FMV – Full Motion Video
FO – First Officer
FOR – Field Of Regard
FPV – First Person Viewing
FTS – Flight Termination System
GA – General Aviation
GBSAA – Ground-based Sense & Avoid
GCS – Ground Control Station
HALE – High Altitude Long Endurance
HITL – Human in the Loop
HUMS – Health, Usage + Monitoring System
IF – Instrument Flying
IFF – Identification Friend or Foe
IFR – Instrument Flight Rules
IR – Infrared
IR – Instrument Rating

ITU – International Telecommunications Union
JAA – Joint Aviation Authority
KSA – Knowledge, Skills & Attributes
LEMV – Long Endurance Multi-mission Vehicle (Airship)
LIDAR – Light Detecting and Ranging
LL – Lost Link
LOS – Line Of Sight
LRE – Launch / Recovery Element
LSA – Light Sports Aircraft
MAC – Mid Air Collision
MALE – Medium Altitude Long Endurance
MARCAT - Mid Air Collision Assessment Tool software
MASPS – Minimum Aviation System Performance Standards
MC – Mission Commander
MCE – Mission Command Element
ME – Multi-Engine
MEL – Minimum Equipment List
MIAA – Multi-Intruder Autonomous Alert
MOPS – Minimum Operational Performance Standards
MTBF – Mean Time between Failures
NAS – National Airspace
NMAC – Near Mid Air Collision
NORDO – No Radio
NOTAM – Notices to Airmen
OEM – Original Equipment Manufacturer
OPVs – Optionally Piloted Vehicles
OSGCS – One System Ground Control Station
PAC – Pilot At Controls
PANS – Procedures for Air Navigation Services
PIC – Pilot in Command
PTS – Practical Test Standards
RF – Radio Frequency
RL – Return Link
RLOS – Radio Line of Sight
ROA – Remotely Operated Aircraft
ROI – Region of Interest
ROZ – Restricted Operating Zone
RPA – Remotely Piloted Aircraft
S&A – Sense and Avoid
SA – Situational Awareness
SAR – Search and Rescue
SARPS – Standard Recommended Practices
SDO – Standards Development Organizations
SESAR – Single European Sky ATM Research Programme
SME –Subject Matter Expert
SMS – Safety Management System
SSAASy – Small Sense & Avoid System
SUAS – Small UAS
SUPPS – Regional Supplementary Procedures
SUTTO – Start Up, Taxi, Take Off
SWaP – Size, Weight and Power
SWIM –System Wide Information Management

TBO – Trajectory Based Operations
TCAS – Traffic Alert and Collision Avoidance System
TLOS – Target Level of Safety
TRACON – Terminal Radar Approach Control
TUAV – Tactical UAV
UA – Unmanned Aircraft
UA – Unusual Attitudes
UAS – Unmanned Aerial System
UAV – Unmanned Aerial Vehicle
UCAV – Unmanned Combat Air Vehicle
UL – Up Link
VFR – Visual Flight Rules
VLOS – Visual Line of Sight
VOIP – Voice over Internet Protocol
VTUAV – Vertical Take-Off UAV
WAAS – Wide Area Augmentation System
WRC- World Radio Communications

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