

## **Pilots by Proxy: Legal Issues Raised by the Development of Unmanned Aerial Vehicles**

**By Michael Nas**

The development of the Unmanned Aerial Vehicle (“UAV”) has been spurred on in recent years by global conflict and is set to revolutionise aviation. The central premise of the UAV is to remove the pilot from the aircraft and to control it externally. This configuration has aerodynamic, tactical, and economic benefits.

The concept is not new; the first unmanned aircraft – the kite – existed long before manned aircraft. There has been a whirlwind of progress since the humble kite, but the idea remains the same – the aircraft harnesses aerodynamic forces for lift, whilst the controller remains on the ground. The modern UAV, however, is ‘tethered’ to the ground by high integrity data links instead of string, and can perform complex flight tasks that make it suitable for an ever growing array of applications.<sup>1</sup>

The rapid pace of development has largely sidelined the myriad of legal issues inherent in unmanned aviation. The most basic problem is in defining the technology and this has created problems that regulators and industry groups must deal with on a daily basis. For UAVs, pilot externality means that a degree of control is often delegated to on-board computer systems and this raises questions about appropriate pilot skill levels and responsibilities, as well as safety. The UAV is essentially a child of war; traditionally having performed reconnaissance and surveillance roles for armed forces. However, technological development has moved the UAV into a more active wartime role, and I will examine the issues raised by the ‘weaponisation’ of UAVs.

Unmanned aircraft are also perfect candidates for civil service duties. Integration into civil airspace is an important movement and serious attention must be given to the legal issues involved if UAVs are ever to share airspace with manned aircraft. Australia has considerable experience with the Aerosonde surveillance UAV,<sup>2</sup> and is on the verge of acquiring the Northrop Grumman *Global Hawk* system – one of the world’s largest and most complex UAVs.<sup>3</sup> However, the rise of the UAV has been a global phenomenon, and thus I will also discuss experiences in Europe, Canada, and the United States. Further, the scope of this essay will encompass legal issues raised in military, civil government, and commercial UAV markets.

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<sup>1</sup> UAV technology has diverse application potential in areas such as mineral exploration, agricultural spraying and monitoring, coastal surveillance, weather research, and media photography and broadcasting. For an overview of UAV market potential see Wong, K, *Survey of Regional Developments: Civil Applications* (Online, University of Sydney, 2001) <  
[http://www.uavm.com/images/KC\\_UAV\\_civil\\_app\\_KC\\_Wong\\_2002.pdf](http://www.uavm.com/images/KC_UAV_civil_app_KC_Wong_2002.pdf)> (30 October 2006)

<sup>2</sup> DeGarmo, M, *Issues Concerning Integration of Unmanned Aerial Vehicles in Civil Airspace* (Virginia : MITRE Corporation, 2004), “1-13” available online <  
[http://www.mitre.org/work/tech\\_papers/tech\\_papers\\_04/04\\_1232/04\\_1232.pdf](http://www.mitre.org/work/tech_papers/tech_papers_04/04_1232/04_1232.pdf)> (30 October 2006)

<sup>3</sup> La Franchi, P, ‘Australia weighs up advantages of sole-source Global Hawk purchase’ (2006) 170:5043 *Flight International* 14

# 1 Defining UAV

## 1.1 Terminology

Many aircraft have adopted the UAV moniker, but the global scene lacks consistent definition. Throughout its development, the UAV has been known by a variety of generic names including “drones”, “pilotless aircraft”, “uninhabited aircraft”,<sup>4</sup> “Remotely Piloted Vehicles” (“RPVs”) and “Remotely Operated Aircraft” (“ROAs”).<sup>5</sup> The task of accurately defining UAV is made difficult because aircraft in this category vary in size from that of a small bird, to the *Pioneer* and *Global Hawk* platforms at 14 and 44ft respectively.<sup>6</sup> The most accurate label to have emerged is “Unmanned Aircraft System(s)” (“UAS”) which reflects the reality that unmanned aircraft exist symbiotically with support systems and therefore aren’t standalone assets.<sup>7</sup> Use of the term UAV has lingered however, and it remains the catchall definition for unmanned aircraft at this point.<sup>8</sup> Therefore, UVS International (an organisation formed with the goal of integrating UAVs into civil airspace)<sup>9</sup> believes that international agreement is needed on what, precisely, a UAV is.<sup>10</sup>

## 1.2 Finding the right words

Despite the difficulties, the task of regulators and innovators worldwide has been to seek definitions that accurately refine the group but are flexible enough to account for the variety of technologies in existence. One of the major definitional difficulties is that UAVs have military, civil, and commercial application. Therefore, definitions created for one sector may be inappropriate for use in another. I will introduce some of the definitions in current circulation, and then analyse the strengths and weaknesses of each.

CASA’s attempt in AC 101-1(0) defines a UAV as –

*...a powered, unmanned aerial vehicle, other than a model aircraft used for sport and recreation, which may be operated autonomously*

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<sup>4</sup> Wheatley, S, *The Time is Right: Developing a UAV Policy for the Canadian Forces*, (Online, paper presented at the 7<sup>th</sup> Annual Graduate Student Symposium, October 2002) < <http://www.cda-cdai.ca/symposia/2004/Wheatley,%20Stephen.pdf> > (30 October 2006), 2

<sup>5</sup> Above, note 4.

<sup>6</sup> Bone, E & Bolkcom, C, *Unmanned Aerial Vehicles: Background and Issues for Congress* (New York : Novinka Books, 2004), 4 available online < <http://www.fas.org/irp/crs/RL31872.pdf> > (30 October 2006), 4.

<sup>7</sup> The term was adopted by the US DoD in 2005: United States. Office of the Secretary of Defense, *Unmanned Aircraft Systems Roadmap 2005 – 2030* (Online, 2005) < [http://www.fas.org/irp/program/collect/uav\\_roadmap2005.pdf](http://www.fas.org/irp/program/collect/uav_roadmap2005.pdf) > (30 October 2006)

<sup>8</sup> See, however, the comments of Nick Sabatini – associate administrator for aviation safety at the FAA – who says that use of the term UAV “will be going away”: Kessner, BC, ‘UAV Sense-and-Avoid Technologies Not Just a Military Concern’ (2005) 227:22 *Defense Daily* 1, paragraph 6

<sup>9</sup> UVS International is based in Paris and includes 242 corporate and institutional members from 34 countries. ICAO, NATO, FAA, and CASA are amongst the members. The organisation was formerly known as EuroUVS, and changed its name in May 2006 reflect its global nature.

<sup>10</sup> Marsh, G, ‘Europe’s Answer: UAVs in Controlled Airspace’ (2003) 27:8 *Avionics Magazine* 18, paragraph 10

*beyond line of sight of the controller but, in all cases, would be subject to remote control by the controller.*

Similarly, but more generally, Canadian regulations posit that UAV means –

*... a power driven aircraft, other than a model aircraft, that is designed to fly without a human operator on board.*<sup>11</sup>

Whilst there is certainly some advantage in simplicity and flexibility in civil regulations, the Canadian and Australian attempts ignore militaristic concerns in that they do not distinguish UAVs from cruise missiles. The need to make such a distinction is important because the two technologies can be similar in function and design, and some cruise missiles are prohibited under international treaty.<sup>12</sup>

By contrast, the US Department of Defence Dictionary definition is more complete. It defines a UAV as –

*A powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or non-lethal payload. Ballistic or semi ballistic vehicles, cruise missiles, and artillery projectiles are not considered Unmanned Aerial Vehicles.*<sup>13</sup>

This is a more comprehensive and informative definition for UAV operators and regulators. However, the definition is deficient from a civil aviation perspective because it neglects to distinguish model aircraft, which typically operate under more lenient regulations. The UK MoD Joint Service definition is substantially similar to that adopted by the DoD, except that it specifically defines a UAV as reusable.<sup>14</sup>

UVS International offers the fairly detailed explanation of a UAV as –

*An aircraft with no on-board human pilot capable of sustained flight by aerodynamic means, and that is re-usable or non-re-usable, remotely controlled, semi-autonomous, autonomous, or has a combination of these capabilities, that has a loitering capability and can carry various types of payloads, making them capable of performing specific tasks within the earth's atmosphere, or beyond, for a duration, which is related to their mission.*<sup>15</sup>

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<sup>11</sup> *Canadian Aviation Regulations* (CAN) reg 101.1

<sup>12</sup> Such as the *Intermediate-Range Nuclear Force Treaty*: see below, paragraph 4.2

<sup>13</sup> United States. Department of Defense, *Dictionary of Military and Associated Terms* (Online, 2001) < [http://www.dtic.mil/doctrine/jel/new\\_pubs/jp1\\_02.pdf](http://www.dtic.mil/doctrine/jel/new_pubs/jp1_02.pdf) > (30 October 2006), 563

<sup>14</sup> Blyenburgh & Co, *Terms & Definitions Applicable to Unmanned Aerial Vehicles (UAV) Systems* (Online : UVS International, 2006) < [http://www.uvs-info.com/pdf/060501\\_Terms&Definition\\_V5.pdf](http://www.uvs-info.com/pdf/060501_Terms&Definition_V5.pdf) > (30 October 2006), 38

<sup>15</sup> Above, note 14

There is a clear intention here to provide a definition that can cater to both military and civil interests, especially in the provision that a UAV may carry various payloads, i.e. – cameras, weather instruments, or munitions etc. Interestingly, UVS International doesn't limit UAV operation to the atmosphere which begs the question of how they are different from spacecraft, which may also be unmanned and autonomous.<sup>16</sup>

The Swedish Military Flight Safety Inspectorate offers perhaps the most progressive definition thus far. A UAV is said to be –

*An unmanned aircraft possible to recover, being part of a UAV system consisting of the unmanned air component (UAV) and those parts of one or more UAV Support Component(s) that are required during flight.*<sup>17</sup>

The beauty of this definition is that it explains a UAV as more than just an aircraft; it is part of a larger system. The Swedish definition is particularly pertinent because of their experience in civil certification.<sup>18</sup> Of course, this definition doesn't distinguish UAVs from model aircraft or missiles. The lack of consistent definition has impeded the development of regulatory standards.

### **1.2.1 Unmanned Aircraft System**

There is a growing trend in the unmanned aviation community towards recognising that the unmanned aircraft is part of a larger system. Indeed, remove the support components and the aircraft becomes little more than a ballistic missile. Therefore, it is impossible to define a UAV without simultaneously defining the whole system.<sup>19</sup> In general terms, "UAS" describes "the entire system that includes aircraft, control stations and data-links."<sup>20</sup> In reality, the system is far more complex, and Yenne notes that a typical UAS includes –

- Multiple aircraft (Eight in the case of the *RQ-2 Pioneer*, or four in the case of the *RQ-1/MQ-1 Predator*)
- Ground control shelters
- A mission planning shelter
- A launch and recovery shelter
- Ground data terminals
- Remote video terminals
- Modular mission payload modules
- Air data relays

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<sup>16</sup> See below, paragraph 1.3.2

<sup>17</sup> Above, note 14, 36

<sup>18</sup> In 2003, the Swedish Civil Aviation Safety Agency and the Military Flight Safety Inspectorate, together with aerospace companies such as Saab, formed a working arrangement to establish a UAS civil certification framework.

<sup>19</sup> As UAV autonomy increases, however, the complexity of and reliance on support systems will decrease, perhaps to the point where a UAV will become a standalone asset and may therefore be defined as such.

<sup>20</sup> Above, note 8.

- Miscellaneous launch, recovery, and ground support equipment.<sup>21</sup>

However, individual systems employ unique methods that make definition of even the basic elements difficult. For example, Siuru provides a description of the ground control centre for the Lockheed *Aquila* UAV which was developed for the US Army in the early 1980s –

*The nerve centre for the Aquila system was the Ground Control Station (GCS). Here the data from the RPV were processed and displayed, and the UAV flight mission equipment controlled. Inside this mobile station there were control and display consoles, TV monitors, a computer, and other sundry gear needed to support the Aquila. The station was hardened against nuclear and conventional attack. Two-way communications with the airborne vehicle was via a trailer-mounted antenna. The entire Aquila system was mobile so it could be moved relatively easily to keep pace with changes on the fluid battlefield.*<sup>22</sup>

Compare this with the ground control station for a “back-packable” UAS system like *BATCAM* –

*The control station consists mainly of a portable laptop computer, a small power generator, and a simple antenna. The laptop computer is used for all mission functions, including mission planning, vehicle control while in flight, and data collection and display.*<sup>23</sup>

UVS International has highlighted the need for international agreement on precisely what a UAV control station is,<sup>24</sup> however the other UAS elements also require definitional refinement. These difficulties must be addressed in order to develop standards and allow for proper regulation.

### 1.2.2 UAV or UAS?

Having considered the issues above, the question arises as to which definition is correct. In my opinion, the best approach is to use “UAV” only when referring specifically to the aircraft component, and to use “UAS” in all other instances. The definition of UAV should then be formulated so that reference is made to the fact that the aircraft exists only as part of a system, as in the Swedish definition.<sup>25</sup> Taking the better parts of the above definitions, I suggest that a UAV is:

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<sup>21</sup> Yenne, B, *Attack of the Drones: A History of Unmanned Aerial Combat* (St Paul : Zenith Press, 2004), 67

<sup>22</sup> Siuru, B, *Planes Without Pilots: Advances in Unmanned Flight* (Blue Ridge Summit : TAB/AERO Books, 1991), 22, 23

<sup>23</sup> Drew, J et al, *Unmanned Aerial Vehicle End-to-End Support Considerations* (Santa Monica : RAND Corporation, 2005), 95

<sup>24</sup> Above, note 10

<sup>25</sup> See above, paragraph 1.2

*The aircraft component of a system that includes the support equipment necessary for the aircraft component to fly without a human operator on board. The aircraft component –*

- *Must be powered and not a model aircraft;*
- *Must be re-usable;*
- *Must use aerodynamic forces to achieve flight and operate within Earth's atmosphere;*
- *May be autonomous, semi-autonomous, piloted remotely or a mixture of those capabilities; and*
- *May carry lethal or non-lethal payloads.*

I believe it is necessary to distinguish UAVs until the legal mechanisms are established to deal with crossover technologies. Thus my definition expressly excludes model aircraft, and includes the requirement for the aircraft to be re-usable to distinguish from missile technology. Furthermore, the requirements for aerodynamic flight and operation within the atmosphere distinguish UAVs from spacecraft.<sup>26</sup> The final requirement recognises that UAVs have both civil and military applications and may carry corresponding payloads.

With a minor modification, UVS International provides a workable, complementary definition of UAS as –

*The UAV or UAVs (aircraft component(s)) and the required flight control and operating system which includes the control station(s), communication links, data terminal(s), launch and recovery systems, ground support equipment and air traffic control interface.<sup>27</sup>*

While these definitions are useful for general purposes, the continued fusion of UAS and related technologies may ultimately defy a singular definition.

### **1.3 Distinguishing UAS**

The modern UAS is a hybrid technology that has not developed in isolation. Advancement has depended on many scientific areas including computers and software, airframe design, and weapons guidance systems. It is unsurprising then, that UAS employ technologies derived from other areas, and vice versa. Interestingly, Yenne notes that the camera used in the 57-gram AeroVironment *Black Widow* micro-UAV (“MAV”) was “a precursor to those now found in cell phones.”<sup>28</sup> The symbiotic technological spread means that several previously distinct scientific endeavours have merged. This poses

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<sup>26</sup> Note, however, the potential for an unmanned aerospaceplane to force a re-evaluation of the intra-atmospheric flight requirement. An aerospaceplane is one that can take off and land like an aircraft but is also capable of low-earth orbit such as NASA's X-30 project or Burt Rutan's SpaceShipOne. For a discussion of the aerospace plane, see below, paragraph 1.3.2

<sup>27</sup> Above, note 14, 37

<sup>28</sup> Above, note 21, 79

the definitional problem of constantly having to distinguish UAS from cruise missiles, model aircraft, and unmanned spacecraft.<sup>29</sup>

### 1.3.1 Model Aircraft

The line between model aircraft and UAS is becoming ever more blurred. In some cases, the only difference between the two is one of application, for instance, a small model aircraft normally used for sport can be outfitted with camera for aerial photography. La Franchi notes that there is a “flying jet-powered model Airbus A380 airliner in the USA that is larger than a single-seat light aircraft.”<sup>30</sup> Unsurprisingly, the FAA is “worried about where a model stops being a model.”<sup>31</sup>

An example of crossover technology is the tilt-rotor Boeing/Bell *Eagle-Eye*, planned for US Coast Guard missions.<sup>32</sup> The *Eagle-Eye* prototype (called *Pointer*) was 11 feet across the wings and 13 feet from nose to tail and was powered by a 100 horsepower turbine engine.<sup>33</sup> These specifications would make for a mean model aircraft; however, Siuru notes that the control system “consisted of ‘off-the-shelf’ RC equipment familiar to any radio-controlled model aircraft enthusiast.”<sup>34</sup> Furthermore, he says that commercial RC equipment is now of a standard that can “be used in serious UAV development programs.”<sup>35</sup> That was in 1991. Conversely, model aircraft are beginning to use advanced UAV technologies,<sup>36</sup> as with the GPS-guided “TAM5” model aircraft that made the 38-hour voyage from Canada to Ireland in 2003.<sup>37</sup>

The regulatory problem is in finding the dividing line. Regulators must find a way to allow flexibility for model aircraft activities and yet ensure that UAVs operate safely. Several approaches are being used to tackle the issue. ICAO sets an upper weight limit for model aircraft at 25kg which may serve as delineation.<sup>38</sup> However, DeGarmo validly points out that –

*Several sophisticated transoceanic and fully autonomous UAVs today are under this weight limit (e.g., the Aerosonde MK 3 and Boeing’s ScanEagle). Can they therefore be classified as model aircraft?*<sup>39</sup>

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<sup>29</sup> I intend to deal separately with the legal implications of the similarities between UAVs and cruise missiles as discussion is more appropriate to armed UAVs: see below, paragraph 4.2

<sup>30</sup> La Franchi, P, ‘FAA studies three-category UAV classification system’ (2006) 169:5040 *Flight International* 5, paragraph 6

<sup>31</sup> Above, note 30

<sup>32</sup> The Deepwater acquisition plan will see ship-launched UAVs - including 45 Eagle-Eye UAVs and high altitude UAVs - enter service with the US Coast Guard by 2012: Doyle, J, ‘CG wants UAVs to close gap in maritime air patrol hours’ (2006) 219:9 *Aerospace Daily & Defense Report* 3

<sup>33</sup> Above, note 22, 35

<sup>34</sup> Above, note 22, 35

<sup>35</sup> Above, note 22, 35

<sup>36</sup> Above, note 2, “2-39”, “2-40”

<sup>37</sup> Above, note 2, “2-40” n 65

<sup>38</sup> Above, note 2, “2-40”

<sup>39</sup> Above, note 2, “2-40”

It is very possible that they can, and given the difficulties of differentiating between the technologies, perhaps they should. CASA takes a stance of this kind, defining a model aircraft as –

*...any unmanned aircraft other than a balloon or kite, which is flown for sport or recreational purposes, weighing not more than 150kg including fuel and equipment installed in or attached to the aircraft at the commencement of its flight.*<sup>40</sup>

While there are many UAVs weighing less than 150kg that would therefore be defined as a model, when flown for a non-recreational purpose the aircraft “is covered by the term ‘Unmanned Aerial Vehicle’ (UAV) and is subject to the rules applicable to UAVs.”<sup>41</sup> CASA further states under CASR 101-235 that “there is no practicable distinction between a small UAV and a model aircraft except that of use – model aircraft are flown only for the sport of flying them.”<sup>42</sup> The effect of this is to render any unmanned aircraft under 150 kg a UAV when operated for profit, aerial photography, or demonstration.<sup>43</sup> This will be so regardless of the complexity of the UAV in question.<sup>44</sup>

The UK’s CAP 658 has adopted a similar approach, however, the situation is less clear in the US where the only guidance on model aircraft is in AC 91-57, drawn up in 1981. The document does not define model aircraft; however the FAA is currently developing a new classification and certification scheme to accommodate UAVs. Under this scheme, model aircraft and small UAVs will be classified under a “lightly restricted” category.<sup>45</sup> Though it is expected that the new scheme will classify aircraft by weight,<sup>46</sup> the specifics of the approach await to be seen. The release of the scheme is imminent.

### 1.3.2 Spacecraft

The similarities between UAS and unmanned spacecraft are often overlooked. Siuru comments that “space probes such as *Magellan* and *Galileo*... fit the generic term”,<sup>47</sup> and an inspection of the above definitions confirms this.<sup>48</sup> Space probes, like UAVs, are powered, unmanned, use autonomy, carry various payloads, and may be recoverable (but are generally expendable). The only real difference is that a space probe doesn’t use aerodynamic forces - because there is no air in space - and therefore doesn’t “fly”. However, the UVS International definition displays a clear intention to include UAVs

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<sup>40</sup> Civil Aviation Safety Authority, *Advisory Circular 101-3(0) – Unmanned Aircraft and Rockets: Model Aircraft* (Online, 2002) < <http://www.casa.gov.au/rules/1998cast/101/101c03.pdf> > (30 October 2006), paragraph 5.1

<sup>41</sup> Above, note 40, paragraph 5.2

<sup>42</sup> *Civil Aviation Safety Regulations 1988* (Cth) reg 101-235

<sup>43</sup> Egan, K et al, *Unmanned Aerial Vehicle Research at Monash University* (Online : Monash University, 2006) < <http://www.ds.eng.monash.edu.au/techrep/reports/2006/MECSE-15-2006.pdf> > (30 October 2006), 2

<sup>44</sup> Above, note 43

<sup>45</sup> Above, note 30, paragraph 4

<sup>46</sup> *UAV MarketSpace* (undated) < <http://www.uavm.com/> > (30 October 2006), paragraph 29

<sup>47</sup> Above, note 22, 2

<sup>48</sup> See above, paragraph 1.2

operating extra-atmospherically.<sup>49</sup> Because they are unmanned, UAVs can reach extremely high altitudes, for instance, the solar-powered *Helios* UAV “set an unofficial world-record altitude of 96,863 feet” in 2001. While not quite ‘on the verge’ of space (generally defined as 100km or 328,000 feet), UAV technology clearly has the potential to breach the space frontier. The USAF’s *FALCON* programme plans to develop an unmanned aerospaceplane able to take-off on Earth, fly aerodynamically, leave the atmosphere, and return again.<sup>50</sup> Such a craft blurs the line between UAS and spacecraft and presents the problem of conflict between space law and international air law.<sup>51</sup> Those laws would need to be made compatible, and hence we may eventually need to consider an international, codified aerospace law.<sup>52</sup>

## 2 Control issues

### 2.1 Control types

The central tenet of the unmanned aircraft system is that the operator is removed from the cockpit; therefore, control of the aircraft must take place by other means. There are three forms of control that an operator may exert over the aircraft -

- Ground-control or remote piloting;
- Semi-autonomous; and
- Autonomous.<sup>53</sup>

Lazarski explains that command and control procedures –

*are defined by the dependence of the machine on ground control – not by the technological aspects of how the ground controller communicates with and controls the machine.*<sup>54</sup>

The three forms of control therefore exist as part of a spectrum, with most modern UAS employing some degree of autonomy. For present purposes, I

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<sup>49</sup> See above, paragraph 1.2

<sup>50</sup> *Defense Tech: Unmanned is Better* (26 July 2005) <  
<http://www.defensetech.org/archives/001704.html>> (30 October 2006), paragraph 3

<sup>51</sup> Space law is a body comprised of a number of international treaties and conventions drawn up in the late 1960’s, whereas international air law is based on a different set of principles rooted in the Chicago Convention and the Warsaw System. An aerospaceplane would potentially be subject to both air and space law (since it travels in both), and therefore before such aircraft can operate, the interaction and compatibility between the two sets of laws must be examined. For a brief discussion of the legal implications of aerospaceplanes see Diederiks-Verschoor, I, *An Introduction to Space Law 2<sup>nd</sup> Edition* (The Hague : Kluwer Law International, 1999), 87 – 88

<sup>52</sup> There are arguments for and against the development of a singular aerospace law, see Diederiks-Verschoor, I, *An Introduction to Space Law 2<sup>nd</sup> Edition* (The Hague : Kluwer Law International, 1999), 3 – 10.

<sup>53</sup> Lazarski, A, ‘Legal Implications of the Unmanned Combat Aerial Vehicle’ (2002) 16:2 *Aerospace Power Journal* 79

<sup>54</sup> Above, note 53

accept the UK Defence Standards definition that autonomous flight is “flight independent of real time UAV-pilot control input”.<sup>55</sup>

### 2.1.1 Ground control

Ground-controlled UAVs, also called Remotely Piloted Vehicles (“RPVs”), require constant input from the operator.<sup>56</sup> In essence, RPVs are “sophisticated radio-controlled aircraft that use the same basic techniques that are familiar to the R/C hobbyist”.<sup>57</sup> There are very few modern UAVs that are purely remotely piloted. Perhaps the best examples of true RPVs come from the early days of unmanned aviation, in the form of the “Denny drones” which flew under complete radio control,<sup>58</sup> and the Ryan *Firebee* which could be “controlled from either the ground or a manned aircraft.”<sup>59</sup> In the 1980’s and early 1990’s, systems such as *Pointer* and *Sky Owl* began employing both remote control techniques and programmable guidance systems (a basic form of autonomy).<sup>60</sup> Thus the trend in unmanned aviation circles has been towards more autonomous systems.

### 2.1.2 Semi-autonomous

The use of guidance systems is now commonplace and semi-autonomous flight can be defined as requiring “ground input during critical portions of the flight such as take-off, landing, weapons employment, and some evasive manoeuvres.”<sup>61</sup> The USAF’s *RQ-1/MQ-1 Predator* is an example of one such system. The *Predator* operator must assume full control of the aircraft during pre-flight, take-off, landing, and when operating near base, but once airborne an autopilot function can be engaged and the aircraft will follow a set of pre-programmed waypoints.<sup>62</sup> The operator is responsible for the UAV throughout the operation,<sup>63</sup> however, and can assume control at any time.<sup>64</sup>

### 2.1.3 Fully autonomous

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<sup>55</sup> Great Britain. Ministry of Defence, *Defense Standard 00-970 Part 9: Design and Airworthiness Requirements for Service Aircraft – UAV Systems* (Online, 2006) < <http://www.dstan.mod.uk/data/00/970/09000400.pdf> > (30 October 2006), paragraph 1.3

<sup>56</sup> Above, note 53

<sup>57</sup> Above, note 22, 1

<sup>58</sup> Above, note 21, 17. The “Denny drones” were built by the Radioplane Company founded in 1935 by B-movie actor, Reginald Denny. The drones were first used by the Artillery Corps for target practice, but were later used by the Air Corps where they became the first aircraft to be designated with the letter “Q” for drone aircraft. The DoD still uses this designation today.

<sup>59</sup> Above, note 22, 12. The original *Firebee* – the *Model 124 Firebee I* – first flew in 1951 as a target drone. Over 6500 were built, and *Firebees* have been used by all the American Armed Forces. During the Vietnam War, the *Firebee* became the first unmanned aircraft to carry and use weapons: Wilson, J, ‘UAVs and the Human Factor’ (2002) 40:7 *Aerospace America* 54 also available online < <http://www.aiaa.org/aerospace/Article.cfm?issuetocid=233&ArchiveIssueID=28> > (30 October 2006), paragraph 3

<sup>60</sup> Above, note 21, 38, 41

<sup>61</sup> Above, note 53

<sup>62</sup> Above, note 23, 84

<sup>63</sup> Above, note 23, 83

<sup>64</sup> Above, note 23, 86

Fully autonomous capability lies at the other end of the spectrum. In theory, autonomous flight requires no human input in order to carry out an objective following the decision to take-off.<sup>65</sup> An autonomous UAV is able to –

*...monitor and assess its health, status and configuration; and command and control assets onboard the vehicle within its programmed limitations.*<sup>66</sup>

Developments in software have been rapid and several systems are already capable of performing autonomously. The *Global Hawk*, for instance, “has a sophisticated autopilot, allowing it to “fly itself” on programmed flight paths without [human] interference for almost all the mission.”<sup>67</sup> The guidance capabilities of the *Global Hawk* were proven on 23 April 2001 when the aircraft flew non-stop for 22 hours from California to South Australia<sup>68</sup> “without an operator... doing anything more than monitoring its systems”.<sup>69</sup> Unlike *Predator*, *Global Hawk*’s capabilities aren’t limited to flight navigation; it can also take-off and land without human assistance.<sup>70</sup> Thus, under autonomous control, the reality is that the on-board computer is in control – not a human being.

## **2.2 Autonomy issues**

The public perception of autonomous technology is unsurprisingly wary.<sup>71</sup> However, the public is already familiar with several autonomous aviation technologies. For example, commercial airliners commonly employ autopilot navigation that is very similar to UAV autopilot systems – both were originally based on the Sperry gyrostabilizer<sup>72</sup> and now operate thanks to software, GPS, and other aides. Probably lesser known is the fact that F-117 manned stealth bombers can “complete an entire mission, from wheels-up to wheels-down, with no intervention by the pilot except consent to weapons release.”<sup>73</sup> Of course, in both cases a human pilot is on-board to take physical control when needed. Therefore, until automated systems have proven themselves reliable, the legal question remains as to the degree of flight control UAV computers should be permitted. This is primarily a question of ensuring the safety of populated air and ground assets.

### **2.2.1 Human factors and the safety of autonomous flight**

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<sup>65</sup> Above, note 53

<sup>66</sup> Above, note 2, “2-49”

<sup>67</sup> Above, note 23, 64

<sup>68</sup> Above, note 21, 76 and also Blackman, S, ‘Attack of the Drones’ 6:6 *Flight Safety Australia* 56

<sup>69</sup> Above, note 21, 74

<sup>70</sup> Above, note 21, 74

<sup>71</sup> This is especially so when autonomous, unmanned aircraft are weaponised. For a discussion of the legality of autonomous system employment in armed UAVs, see below, paragraphs 4.1.1 and 4.1.2

<sup>72</sup> Above, note 22, 7

<sup>73</sup> Sweetman, B, ‘Pilotless Fighters: Has Their Time Come?’ *Jane’s International Defense Review* 1 June 1997 quoted in Glade, D, *Unmanned Aerial Vehicles: Implications for Military Operations* (Online : Air War College, 2000) < <http://www.au.af.mil/au/awc/awcgate/cst/csatl16.pdf> > (30 October 2006), 6

The critical difference between manned and unmanned flight is the physical experience of the operator.<sup>74</sup> Conventional aircraft “use direct human presence to directly perceive events and conditions around the vehicle”, whereas “remotely operated vehicles keep the human presence at a distance.”<sup>75</sup> In some cases this distance may be half the globe.<sup>76</sup> Situational awareness is imperative for safe flight and is defined as –

*...a perception of the elements in the environment within a volume of space and time, the comprehension of their meaning, and the projection of status in the near future.*<sup>77</sup>

The remote location of the pilot therefore produces “sensory isolation”<sup>78</sup> and often acts as a “barrier” to situational awareness due to –

- Loss of sensory cues,<sup>79</sup> including vehicle vibration and sound,<sup>80</sup>
- The inability to properly scan the visual environment and ascertain the attitude of the UAV,<sup>81</sup> and
- Control and communication delays.<sup>82</sup>

Awareness is further diminished where control is highly automated. In such conditions the pilot “must make decisions with significantly less information about the vehicle than an on-board pilot.”<sup>83</sup> Automated control may therefore inhibit the operator’s ability to respond quickly, which is imperative for safe flight, especially in busy civil airspace.

However, automation can also be desirable. Human operators have poor long-term attention spans<sup>84</sup> and some UAVs undertake long endurance missions (*Global Hawk* can stay aloft for up to 40 hours),<sup>85</sup> which increases the risk of pilot error. Furthermore, external control necessitates an array of sensors to act as surrogate eyes. The on-board computer may be able to

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<sup>74</sup> Glade, D, *Unmanned Aerial Vehicles: Implications for Military Operations* (Online : Air War College, 2000) < <http://www.au.af.mil/au/awc/awcgate/cst/csatl6.pdf> > (30 October 2006), 4

<sup>75</sup> Above, note 74

<sup>76</sup> Above, note 21, 74

<sup>77</sup> Endsley, M, *Design and evaluation for situation awareness enhancement*, (Online : paper presented to the Human Factors Society 32<sup>nd</sup> Annual Meeting, 1988) quoted in Manning, S et al, *The Role of Human Causal Factors in US Army Unmanned Aerial Vehicle Accidents* (Online : US Army Aeromedical Research Laboratory, 2004) < <http://www.usaarl.army.mil/TechReports/2004-11.PDF> > (30 October 2006), 8

<sup>78</sup> McCarley, J & Wickens C, *Human Factors Implications in the National Airspace* (Online : University of Illinois, 2005) < <http://www.humanfactors.uiuc.edu/Reports&PapersPDFs/TechReport/05-05.pdf> > (30 October 2006), 9

<sup>79</sup> Above, note 78, 2

<sup>80</sup> Above, note 74, 4

<sup>81</sup> Above, note 78, 2

<sup>82</sup> Above, note 78, 2

<sup>83</sup> Above, note 74, 4

<sup>84</sup> Manning, S et al, *The Role of Human Causal Factors in US Army Unmanned Aerial Vehicle Accidents* (Online : US Army Aeromedical Research Laboratory, 2004) <

<http://www.usaarl.army.mil/TechReports/2004-11.PDF> > (30 October 2006), 6, 7

<sup>85</sup> Above, note 21, 74

access sensor data and make required changes quicker than a pilot.<sup>86</sup> Indeed, data-link delays may be up to several seconds,<sup>87</sup> which means pilots are slower to notice a problem, effect a change, and see the result.<sup>88</sup> In this regard, the UAV may be 'more aware' of its own environment. Therefore, automation may potentially be superior to human response –

*... the primary benefit of autonomy is that less human monitoring and control is needed. This capability promises to offer greater safety (i.e., intelligent reconfigurable control, prognostic [system] health management and automatic air collision avoidance)...*<sup>89</sup>

RPVs are manually controlled by stick-and-rudder whereas autonomous systems may use computer based “point-and-click” control.<sup>90</sup> With this in mind, it seems that full manual control imposes “the highest and most continuous level of cognitive workload on UAV operations.”<sup>91</sup> There are two options available to overcome the inherent problems of control: invest in technologies that convey better awareness of the UAV's environment to the operator, or invest in better automation software and leave the flying to the on-board computer. Both avenues are being investigated.<sup>92</sup> However, in my opinion, advanced automated systems may eventually be safer and better suited to unique UAS requirements than traditional flight control. The USAF is heading down this path, and so as UAVs become more autonomous the role of the pilot will become increasingly supervisory.<sup>93</sup>

## 2.2.2 Autonomy in civil airspace

The use of autonomous systems in civil airspace is a perplexing issue, and one that relates primarily to safety. In 2001, Lazarski wrote that “the FAA requires that all UAVs operating outside of special restricted areas have certified pilots at the controls and that the UAVs be under semi-autonomous to full ground control.”<sup>94</sup> Similarly, Eurocontrol (an organisation promoting ATC unification across Europe)<sup>95</sup> has proposed that military UAVs must remain

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<sup>86</sup> Above, note 2, “2-16”. See DeGarmo at pages “2-16”, “2-6”, and “2-7” for a discussion of technologies in development at the US Air Force Research Lab that place more flight responsibility on UAV computers.

<sup>87</sup> Above, note 78, 11

<sup>88</sup> Above, note 84, 8 and above, note 78, 7

<sup>89</sup> Above, note, 2, “2-49”

<sup>90</sup> Above, note 78, 2

<sup>91</sup> Above, note 78, 2

<sup>92</sup> See for instance above, note 78, at page 8 where McCarley and Wickens describe the use of “augmented reality” and “synthetic vision” systems to virtually situate the pilot within the UAVs environment. The authors also discuss at page 9 the use of tactile sensory feedback to increase situational awareness. See also, though, DeGarmo's explanation of the Automated Collision Avoidance System (above, note 2, page “2-7”) which detects an imminent collision with other aircraft and temporarily assumes full control of the UAV and makes the adjustments required to avoid it. This technology can be used in both manned and unmanned aircraft.

<sup>93</sup> Wilson, J, ‘UAVs and the Human Factor’ (2002) 40:7 *Aerospace America* 54 also available online < <http://www.aiaa.org/aerospace/Article.cfm?issuetocid=233&ArchiveIssueID=28> > (30 October 2006), para 10

<sup>94</sup> Above, note 53, 79

<sup>95</sup> Eurocontrol represents both civil and military concerns, has 37 Member States, and oversees all aspects of air navigation in Europe, including traffic management and traffic controller training.

under manual control when flying in civil airspace, with “fully autonomous flight reserved for safety mode in the event of data-link loss.”<sup>96</sup> CASA’s approach specifically allows for autonomous operations provided that UAV performance and ATC communications are monitored and that the crew is capable of taking control of the UAV at any time.<sup>97</sup> CASA’s flexibility on this issue parallels the trend towards higher-level autonomy and the Advisory Circular even *requires* autonomous capability in the event of link loss.<sup>98</sup>

## 2.3 Control loss

The biggest UAS safety concern is the potential for control loss, especially over populous areas. The data-links used to control UAVs are vulnerable to jamming and interference,<sup>99</sup> and the possibility of “e-hijacking” a UAV<sup>100</sup> raises questions about how to adequately regulate the technology.

### 2.3.1 Link issues

Unmanned aircraft are inherently dependant on control links – their “tethers”<sup>101</sup> – in order for safe operation. Such is the degree of reliance that interference may cause the aircraft to “go dumb and crash.”<sup>102</sup> UAS controllers cannot take physical control of the aircraft, thus regulations must ensure that unmanned flight is undertaken responsibly. Many lessons regarding the use of remote systems have been learned in Iraq. Here, the vulnerability of UAS control links was especially obvious due to the “proliferation” of electronic and wireless devices.<sup>103</sup> In the overcrowded theatre “everything from radios to improvised explosive device (IED) jammers” caused what was being termed “electronic fratricide”.<sup>104</sup> The “unintended consequences” of the abundance of devices included disastrous effects on UAS in the area.<sup>105</sup> Lt Gen Walter Buchanan said that –

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<sup>96</sup> La Franchi, P, ‘Eurocontrol: UAVs still need pilots’ (2006) 169:5039 *Flight International* 9

<sup>97</sup> Civil Aviation Safety Authority, *Advisory Circular 101-0(0) – Unmanned Aircraft and Rockets: UAV operations, design specification, maintenance and training of human resources* (Online, 2002) < <http://www.casa.gov.au/rules/1998casr/101/101c01.pdf> > (30 October 2006), paragraph 5.2.2

<sup>98</sup> Above, note 97, paragraph 5.10 and see below, paragraph 2.3.2, for a discussion of automated recovery.

<sup>99</sup> United States. United States Air Force, *The US Air Force Remotely Piloted Aircraft and Unmanned Aerial Vehicle Strategic Vision* (Online, 2005) < <http://www.af.mil/shared/media/document/AFD-060322-009.pdf> > (30 October 2006), 17

<sup>100</sup> See above, note 2, “2-20” where DeGarmo comments that UAV data links may be susceptible to malevolent usurpation of control. Modern encryption techniques may be used to combat this but are generally expensive and require high bandwidth. Interestingly, following the terrorist attacks on September 11, usurpation of control has been suggested as an anti-hijacking measure for use in airliners whereby control is handed over to ATC or a pilot in another aircraft (see below, note 204 at paragraph 31). Such technology is already available: see for instance US Patent 6845302.

<sup>101</sup> Above, note 1, “2-20”

<sup>102</sup> Scott, W, ‘UAVs/UCAVs Finally Join Air Combat Teams’ (2002) 157:2 *Aviation Week & Space Technology* 54

<sup>103</sup> Fein, G, ‘Abundance of Devices in Iraq Causing ‘Electronic Fratricide’ General Says’ *C4I News* (Potomac) 10 November 2005, 1

<sup>104</sup> Above, note 103, paragraph 1

<sup>105</sup> Above, note 103, paragraph 10

*Because of all these systems, I can fly a Predator out to a point where power can reduce down to 50 percent. Beyond that, I will lose the link. That range around the Balad (in northern Iraq) and Baghdad areas, because of all this electronic fratricide, is about 35 miles... At the same time in Afghanistan where I have an electronic-free environment, its about 120 miles.*<sup>106</sup>

Electronic fratricide is exacerbated in a military theatre, but one can imagine that similar effects might occur in a future civil airspace with a sky full of UAVs.<sup>107</sup> Furthermore, manned aircraft in Iraq experienced a lot of noise and interference on radio channels,<sup>108</sup> which is something to consider when using UAVs in civil airspace shared with manned aircraft.

### **2.3.2 Automated recovery**

Since physical pilot control is not possible, the UAV must have “numerous fail-safes” in place in case of link loss.<sup>109</sup> The most desirable failsafe is for the UAV to execute an automated recovery. The USAF Strategic Vision suggests that -

*In the event that command and control links have been completely severed between an unmanned system and the command centre, the RPA or UAV should be pre-programmed either to attempt for some fixed period of time to re-establish communications, to execute a fully automated egress from the battlespace, or to independently complete the mission.*<sup>110</sup>

A similar procedure is applicable to civil UAVs. Under their new UAS regulations, the FAA will require information “about what the aircraft is programmed to do and when it is programmed to do it” in the event of link loss. This information must be communicated to ATC facilities before the flight to ensure airspace deconfliction.<sup>111</sup> CASA similarly stipulates the requirement for automated ‘abort procedures’,<sup>112</sup> but also requires data showing the UAV’s “performance under termination conditions.”<sup>113</sup>

Of course, things don’t always go to plan. A US Customs *Predator B* UAV being used for border patrol duties “performed poorly” under termination

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<sup>106</sup> Above, note 103, paragraph 10

<sup>107</sup> One of the issues that UAS will have to deal with in civil airspace is the availability of space on the communications frequency spectrum. Lt Gen Buchanan reported encountering “spectral congestion” in Iraq (see below, note 222, paragraph 11), and DeGarmo observes that civil frequencies in the US are already overcrowded (see above, note 2, page “2-31”)

<sup>108</sup> Above, note 103, paragraph 8

<sup>109</sup> Anonymous, ‘Integrating UAVs Into Our Airspace Is a Multi-Faceted Challenge’ (2006) 164:16 *Aviation Week & Space Technology* 62

<sup>110</sup> United States. US Air Force, *The US Air Force Remotely Piloted Aircraft and Unmanned Aerial Vehicle Strategic Vision* (Online, 2005) < <http://www.af.mil/shared/media/document/AFD-060322-009.pdf> > (30 October 2006), 17

<sup>111</sup> Above, note 109

<sup>112</sup> Above, note 97, paragraph 5.10.1

<sup>113</sup> Above, note 112

conditions when it crashed on 25 April 2006. After noticing a malfunction, the pilot terminated the link with the UAV by shutting down the control station so that it would “enter its autonomous lost-link procedure.”<sup>114</sup> Under this procedure, the *Predator* was supposed to –

1. Fly autonomously via Emergency Mission waypoints to a safe loiter area. (The National Transportation Safety Board reported that the loiter area was at 15,000 feet.)<sup>115</sup>
2. Change transponder codes.
3. Eventually land in a predetermined area.<sup>116</sup>

Instead, the UAV continued to lose altitude until it crashed near Arizona. Thus, Barrie observes that “reliability, coupled with robust, incident-adjustable system architecture, will be essential if regulatory bodies are to be persuaded that large UAVs can operate safely in civil airspace.”<sup>117</sup> The *Predator B* incident is a set-back in the push towards civil airspace integration.

## 2.4 Piloting issues

The “human factor” in UAV control is often sidelined; largely the result of the increasing autonomy of on-board computers. At present there is no global consensus on UAV piloting requirements.<sup>118</sup> Different UAVs and applications call for unique operator requirements, making consensus difficult.<sup>119</sup> Further, the actual experience of operating a UAV varies and can be similar to:

- (a) flying a model aircraft (as with *Raven*);
- (b) sitting in a grounded ‘cockpit’ and controlling the aircraft with stick-and-rudder like traditional aircraft (as with *Predator*);
- (c) sitting in front of a computer and occasionally clicking a mouse (as with *Global Hawk*).

Thus, the flexibility and diversity offered by UAS is also the root of regulatory difficulties. DeGarmo states aptly that –

*Its fair to assume that a large UAV operating out of a major airport would likely require a pilot with extensive certification criteria similar to a commercially licensed, instrument rated pilot of a manned aircraft. However, a pilot wishing to operate a slow, electric-drive, 6lbs. UAV to photograph wildlife, may require minimal or no licensing.*<sup>120</sup>

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<sup>114</sup> Warwick, G, ‘Customs Predator crash caused by operator error’ (2006) 169:5039 *Flight International* 24

<sup>115</sup> Above, note 114, paragraph 4

<sup>116</sup> Anonymous, ‘FAA Cancels Border TFR After Predator UAV Crashes’ *Aviation Daily* (Potomac) 1 May 2006, paragraph 7

<sup>117</sup> Barrie, D, ‘Beyond Control’ (2004) 161:5 *Aviation Week & Space Technology* 57, paragraph 20

<sup>118</sup> Above, note 2, “2-15”

<sup>119</sup> Above, note 2, “2-16”

<sup>120</sup> Above, note 2, “2-52”

It is therefore apparent that developing a standard for UAV operation “is complicated by the diversity in size, autonomy level, and potential uses of UAVs.”<sup>121</sup>

#### 2.4.1 Piloting requirements

In the absence of an international directive, UAV piloting regulations have developed in an *ad hoc* and inconsistent manner. The inconsistency is especially evident within the US Armed Forces, partially because different systems are used. USAF UAVs are operated by IFR-qualified officers “pulled directly from fighters, bombers, and transport aircraft.”<sup>122</sup> Flight officers controlling *Predator*, for instance, may be pilots, navigators or air battle managers.<sup>123</sup> The latter two must also have civil certifications.<sup>124</sup> Navy and Marine UAVs are operated by enlisted personnel with private pilot licenses.<sup>125</sup> Finally, the Army imposes no aviation rating requirements.<sup>126</sup>

Approximately 32% of UAV accidents involve human error,<sup>127</sup> highlighting the need for operational standards. However, after reviewing 221 UAV accidents between 1994 and 2003, Tvaryanas concluded that the figure could be as high as 60%.<sup>128</sup> The accident rates due to operator error vary across the forces and tell an interesting story. Whilst the Air Force’s piloting requirements are the most stringent, 79% of Air Force UAS accidents are caused by human error as opposed to 62% in the Navy and Marines and 39% in the Army.<sup>129</sup> While surprising, the results may be explained by the fact that the Army uses relatively simple UAVs (like *Pointer*) that are usually operated within line-of-sight. The Navy and Marines operate medium-sized UAVs like *Pioneer*, and the Air Force operates the largest and most complex systems of all (*Dark Star* and *Global Hawk*). Endurance may also be a factor: *Pointer* has an endurance of 2 hours, while *Global Hawk* often stays airborne for 24 hours.<sup>130</sup> The risks are therefore increased by pilot fatigue and the need for ground station, or pilot change-overs. Complications with a pilot console change-over led to the Customs *Predator B* crash of 25 April this year.<sup>131</sup>

Large UAVs operating in civil airspace will most likely require IFR-rated pilots with commercial pilots licensing.<sup>132</sup> CASA agrees and has stipulated that –

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<sup>121</sup> Above, note 2, “2-51”

<sup>122</sup> Above, note 93, paragraph 8, and see also above, note 2, “2-15” and “2-15”

<sup>123</sup> Cotton, E, ‘Pilotless Flight’ (2005) 59:8 *National Guard* 20, paragraph 41

<sup>124</sup> Above, note 123

<sup>125</sup> Above, note 2, “2-15”

<sup>126</sup> Above, note 2, “2-15” and above, note 123, paragraph 11.

<sup>127</sup> Croft, J, ‘Unmanned Aircraft and the Maintenance Man’ (2006) 12:4 *Overhaul and Maintenance* 28, paragraph 4

<sup>128</sup> Cahlink, G, ‘Shortcuts, Rush to Field are Key Factors in UAV Accidents, Report Claims’ *Defense Daily* (Potomac) 5 July 2005, paragraph 1

<sup>129</sup> Above, note 128, paragraph 5

<sup>130</sup> Above, note 23, 55. *Global Hawk* has demonstrated an endurance capability exceeding 40 hours, see above, note 21, 74

<sup>131</sup> Magnuson, S, ‘Role of Unmanned Aircraft Questioned’ (2006) 91:632 *National Defense* 42, paragraph 5.

<sup>132</sup> Above, note 2, “2-52”

*...the supervising UAV controller should have completed the ground training applicable to the issue of an instrument rating in order to operate UAVs in controlled airspace.*<sup>133</sup>

Further examination of the skills and training needed to safely operate unmanned aircraft is necessary.

## 2.4.2 Training

Training UAV pilots presents unique problems. Some have suggested that UAV pilots should be trained and certified in a similar fashion to traditional pilots, and “pass tests to prove adequate knowledge and proficiency relative to the type of operation they intend to fly.”<sup>134</sup> But just what knowledge is adequate for a UAV operator? DeGarmo suggests that UAV operators should have knowledge of:

- Aerodynamic principles;
- General flight rules;
- Flight critical systems;
- Navigation;
- Communications;
- Meteorology; and
- Emergency procedures.<sup>135</sup>

The debate rages as to the usefulness of experience piloting manned aircraft in UAV pilot training, and this can be seen in the differing flight requirements adopted amongst the US Armed Forces. The experience of operating a UAV, as noted above, is vastly different to piloting a manned aircraft. It is possible, therefore, that prior experience with manned aircraft may impede UAV pilot performance, rather than improve it. This led McCarley and Wickens to conclude that –

*...simulator experience is likely to constitute a greater portion of training for pilots of unmanned vehicles than for pilots of manned aircraft.*<sup>136</sup>

Controlling a UAV is similar to flying by instrumentation only;<sup>137</sup> therefore the physical experience of simulation is very close to that of actual UAV flight. It is therefore hours on the ground, rather than hours in the air that is crucial from a training perspective.<sup>138</sup> However, flight experience may be advantageous for systems that employ traditional stick-and-rudder control (*like Predator*) and yet inappropriate for automated systems like *Global Hawk*.<sup>139</sup>

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<sup>133</sup> Above, note 97, paragraph 5.15.6

<sup>134</sup> Above, note 2, paragraph “2-52”

<sup>135</sup> Above, note 2, paragraph “2-52” and above, note 97, paragraph 11.4.1

<sup>136</sup> Above, note 78, 13

<sup>137</sup> Above, note 123, paragraph 33

<sup>138</sup> Above, note 2, “2-53”

<sup>139</sup> Above, note 78, 13,14

There are currently no centralised UAV pilot training programmes in the US or elsewhere,<sup>140</sup> and yet the unique qualities of unmanned aviation seem to require a catered system. However, pilot certification and training should reflect the fact that there is no “one-size-fits-all” solution.<sup>141</sup> Therefore, my suggestion is that training takes place in 3 tiers –

1. **Common Flight Training** – under which prospective UAV pilots are educated in DeGarmo’s suggested knowledge set.
2. **Specific Flight Training** – composed of two parts –
  - A – Simulator training appropriate to the type of UAV to be operated.
  - B – Flight training appropriate to the type of control employed in the UAV system to be operated. For example, if the UAV is a *Predator*, flight training should take place in a small aircraft that has similar dimensions and controls. However, if the UAV is a small UAV like *Raven*, training on an RC model of similar specification may be more appropriate for flight training.
3. **Testing** – under which trainees are tested on both knowledge and skill proficiency by way of written assessment as well as by actual use of the UAV they are to fly.

Under this system, previous flight experience may negate the need for Common Flight Training, and part B of Specific Flight Training, but only where the experience is compatible with the type of UAS to be operated. Flight experience wouldn’t, however, negate the need for simulator training or testing. After completion of the course, the pilot would be certified to operate UAS of the type trained for, in a similar fashion to current manned flight licensing.

### 2.4.3 Pilots, operators, or controllers?

Within the broader aviation community there is a distinct aversion to unmanned technology, known as “silk scarf syndrome”.<sup>142</sup> The USAF assigns pilots to the *Predator* and *Global Hawk* squadrons as part of a “three year career-broadening tour”,<sup>143</sup> however, amongst pilots and maintenance personnel UAV assignments are viewed as a “dead-end duty”.<sup>144</sup> Siuru explains that this culture exists in part because –

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<sup>140</sup> *UAV MarketSpace: UAV FAA Pilot Certification – and Human Factors Research* (undated) < <http://www.uavm.com/uavregulatory/pilotcertificationandhumanfactors.html> > (30 October 2006), paragraph 1. See, however, CASA’s training regulations in *Civil Aviation Safety Regulations 1998* (Cth) Division 101.F.3

<sup>141</sup> Above, note 2, “2-53”

<sup>142</sup> Above, note 6, 1

<sup>143</sup> Above, note 99, 19

<sup>144</sup> Above, note 23, 41

*...many decision-makers in the military arena have been pilots who felt more comfortable flying from the cockpit. After all, money spent on UAVs meant less funding for manned aircraft, which are a lot more fun to fly.*<sup>145</sup>

The culture has led to a hot debate about whether those at the UAS controls should be called “pilots”, or “simply operators or controllers.”<sup>146</sup> In response, Allyn Aldrich commented sagely in Aviation Week that modern manned aircraft already employ pilot-assistive technologies. Aldrich says –

*Turn off the electronics in an F-16 and see how long it stays in the air. Present-day pilots are really computer operators. Pilots are valuable but their bases of operations are changing.*<sup>147</sup>

The debate is relevant because modern aviation systems have evolved around the idea of a human pilot in the cockpit, who accepts responsibility for the safety of the aircraft. If UAV flyers are not considered pilots, the question is whether they have the same or perhaps diminished responsibilities.

Under Australian law, the pilot in command is responsible for –

- (a) *the start, continuation, diversion and end of a flight by the aircraft; and*
- (b) *the operation and safety of the aircraft during flight time.*<sup>148</sup>

This responsibility is imposed, in part, because the pilot is on board and physically able to control the aircraft at all times. Nevertheless, despite pilot externality, the USAF Strategic Vision states that –

*In all cases, the RPA or UAV operator is considered the pilot in command (whether rated, unrated, enlisted, or civilian) and is responsible for the aircraft.*<sup>149</sup>

CASA imparts similar duties on the *Supervising UAV Controller* who is “the designated person within the controlling UAV control station tasked with overall responsibility for operation and safety of the UAV in flight.”<sup>150</sup> Therefore, the distinction between pilots, operators, and controllers is of little consequence in practice. Further questions arise, however, regarding the translation of controller responsibility to legal liability, given the uniqueness of unmanned flight.

### **3 Liability**

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<sup>145</sup> Above, note 22, 3

<sup>146</sup> De Meo, L Jr, ‘UAV Operators Are Not Pilots’ (2006) 164:20 *Aviation Week & Space Technology* (Correspondence) 6, paragraph 2

<sup>147</sup> Aldrich, A, ‘UAV Alternatives Not So Cheap’ (2006) 164:26 *Aviation Week & Space Technology* (Correspondence) 6, paragraph 2

<sup>148</sup> *Civil Aviation Regulations 1988* (Cth) reg 224(2)

<sup>149</sup> Above, note 99, 19

<sup>150</sup> Above, note 97, Appendix 1

The combination of manual and computer-assisted piloting essential for modern UAS operation presents the difficulty of apportioning liability in the case of mishap. Where the UAS is in autonomous mode, it may seem appropriate to blame the manufacturer for an accident. The rise of automation in all forms of aviation means the causal link between the pilot's act and the effect has "become so remote or obscured as to raise doubt about the liability aspects involved."<sup>151</sup>

Flight in civil airspace, especially by airliners, is a different proposition in the electronic age. A wealth of devices including GPS and automatic landing systems have reduced pilot burden,<sup>152</sup> and this means the aircraft is not under direct pilot control for long periods. However, Diederiks-Verschoor warns against regarding automated technologies as a "panacea" and says that a pilot's "personal assessment and... timely intervention remains paramount for a proper discharging of his duties."<sup>153</sup> The lesson to be learned from a UAS perspective is that the rise of technology has not diminished the pilot's legal responsibility.

The liability assumed by UAV operating bodies and manufacturers is even less clear. In the US, where there is currently no regulatory infrastructure for UAV certification, it is possible that if a UAV caused ground damage or fatalities –

*...the operator and manufacturer could be sued without being able to claim that their crews, aircraft and procedures met FAA certification standards as some measure of legal protection.*<sup>154</sup>

CASA states that UAV flight approval doesn't abrogate the rights and remedies of people affected by damage or injury caused by the UAV.<sup>155</sup> However, where the cause of an accident is due to defective software, should the aircraft manufacturer be held liable? There is a distinct trend towards strict or absolute liability, and this has "brought with it a substantially increased risk for the manufacturer: it has become vital for him to make sure that his product leaves the factory in perfect condition in terms of safety and reliability."<sup>156</sup> It seems reasonable that despite the increased criticality of automation systems in UAS, manufacturers may be liable on occasion. The trend towards strict liability in commercial aviation, however, has gathered strength over time as traditional aircraft have proven increasingly reliable.<sup>157</sup> It may be too early to impose strict liability on UAV manufacturers and operators involved with fledgling technology.

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<sup>151</sup> Diederiks-Verschoor, I, *An Introduction to Air Law 7<sup>th</sup> Revised Edition* (The Hague : Kluwer Law International, 2001), 137

<sup>152</sup> Above, note 151, 138

<sup>153</sup> Above, note 151, 138, 139

<sup>154</sup> Newcome, L, 'FAA-Type Regulations Will Allow UAVs to Grow' (2001) 155:6 *Aviation Week & Space Technology* 70, paragraph 11

<sup>155</sup> Above, note 87, paragraph 12.7

<sup>156</sup> Above, note 151, 141

<sup>157</sup> Above, note 151, 115

## 4 Armed UAVs

Perhaps the most perplexing – and exciting – UAV development has been the movement towards an active battle role. On 4 November 2002, a CIA *Predator* in the skies over Yemen armed with a Hellfire anti-armour missile, fired on and killed Al Qaeda operatives.<sup>158</sup> Some praised the kill as a “triumph of technology” but others were concerned with the morality and legality of the act.<sup>159</sup> The weaponised *Predator* was the first of a new breed of weapons-enabled UAV – the Unmanned Combat Aerial Vehicle (“UCAV”). The UCAV is the next generation of warplane: the US has stated that “by 2010 one-third of all deep-strike aircraft should be unmanned”,<sup>160</sup> the UK foresees similar capability by 2020,<sup>161</sup> and Australia has also shown interest.<sup>162</sup> The deployment of UCAVs means that pilots are not at risk, but there are a plethora of ancillary legal issues to consider.

### 4.1 Laws of Armed Conflict

The pilot’s absence from the cockpit is a serious issue for UCAVs. The Laws of Armed Conflict (“The Laws of War”) are a set of principles, derived from international treaties – such as the Geneva and Hague Conventions – that regulate the conduct of hostilities between nations.<sup>163</sup> Rules of Engagement (“ROE”) are “directives governing the use of force that commanders issue for specific operations”, and they form the instructions to be followed by combatants in the field.<sup>164</sup> The principles of the Laws of War supply the “legal boundary” for the creation of ROE.<sup>165</sup> Lazarski notes that the details of unmanned combat are not yet settled and specific ROE need to be formulated for UCAVs.<sup>166</sup> Before the use of UCAVs becomes widespread several further issues must also be addressed.

#### 4.1.1 Target discrimination

The principle of discrimination states that forces must distinguish between military combatants and civilian non-combatants.<sup>167</sup> Military forces must not attack civilians.<sup>168</sup> Therefore, before a UCAV can legally attack, the target must be positively identified. Given that there are no human eyes on-board a UCAV the question arises as to how target identification should occur. This is a question of the degree of autonomy that the UCAV has over battle

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<sup>158</sup> Above, note 21, 90

<sup>159</sup> Calhoun, L, ‘The Strange Case of Summary Execution by Predator Drone’ (2003) 15:2 *Peace Review* 209

<sup>160</sup> Kreisher, O, ‘The Right Number’ (2006) 49:7 *Sea Power* 16, paragraph 1

<sup>161</sup> Barrie, D, ‘Unmanned Surrogate’ (2006) 164:20 *Aviation Week & Space Technology* 51, paragraph 12

<sup>162</sup> Above, note 2, “1-13”

<sup>163</sup> Anonymous, ‘Basic Principles of the Law of War’ (2002) 86:10 *Marine Corps Gazette* 36

<sup>164</sup> Anonymous, ‘The Relationship Between Rules of Engagement and the Law of War’ (2002) 86:6 *Marine Corps Gazette* 48

<sup>165</sup> Above, note 164

<sup>166</sup> Above, note 53, 81

<sup>167</sup> Above, note 163, 37

<sup>168</sup> Above, note 53, 80

operations. Under the semi-autonomous model, a human is kept “in the loop” to verify the target and authorise weapons release via data and control links. Weaponised *Predators* currently employ this model,<sup>169</sup> which Klein believes will also ensure traditional accountability measures.<sup>170</sup>

Targeting technology is advancing at a rapid pace. In Australia, the Sentient UAV Vision System is being developed to provide sophisticated ground target tracking capability.<sup>171</sup> The DoD, too, foresees a new generation of “smarter sensors” and states that –

*Multi- and hyperspectral cameras, and foliage-penetrating radars, will provide better (better than human) target discrimination.*<sup>172</sup>

The prospect of UCAVs selecting their own targets is a worrying one, but the trend towards automation means that such development is likely –

*As more UAVs gain laser designators, the need for automatic target recognition will become even greater. UAV sensors do not have a human operator’s “sense” of what might be unusual or out of place. Going back for a second look (or even doing a double-take over your shoulder) is not possible unless automated discrimination spots a target on the first pass.*<sup>173</sup>

While militaries may view the transition as necessary, little consideration has been given to the legality of delegating target selection to computers. For such delegation to be legal, the discriminative capability of UAV computers must be proven reliable and accurate. With current technology, it seems appropriate to require human oversight of target selection.<sup>174</sup>

#### **4.1.2 Decision to fire**

The decision to release ordnance is a separate part of the command and control structure. In modern aviation, the decision to fire a weapon is a complex one involving the assessment of targeting information and employment of the rules of engagement in a “rapidly changing environment”.<sup>175</sup> There is considerable debate about whether UAV computers can or should make that decision. Therefore, the general governmental

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<sup>169</sup> Above, note 23, 86

<sup>170</sup> Klein, J, ‘The Problematic Nexus: Where Unmanned Combat Air Vehicles and the Law of Armed Conflict Meet’ (Online : Air University, 2003) < <http://www.airpower.maxwell.af.mil/airchronicles/cc/klein.html> > (30 October 2006), paragraph 25. Klein notes at page 6 that under conventional chain-of-command, the air crew are responsible for targeting and engaging the enemy and are held accountable for mistakes in this regard. Where the mistake is due to a completely autonomous system, accountability is less clear: see above, paragraphs 2.5.3 and 3 for related discussion.

<sup>171</sup> Anonymous, ‘Australian project aims for clearer UAV vision’ (2006) 169:5042 *Flight International* 26

<sup>172</sup> Rockwell, D, ‘Sensing the future of UAVs’ (2003) 41:9 *Aerospace America* 26, available online < <http://www.aiaa.org/aerospace/Article.cfm?issuetocid=402> > (30 October 2006), paragraph 26

<sup>173</sup> Above, note 172, paragraph 25

<sup>174</sup> Above, note 170, 7

<sup>175</sup> Above, note 53, 81

consensus is that a human decision-maker should be kept in the loop in order to take responsibility for weapons release.<sup>176</sup>

However, in the early 90's aircraft manufacturers were already developing autonomous UAVs that could carry out all combat flight aspects without human intervention. One such example was the Martin-Marietta *Autonomous Air Vehicle* (AAV).<sup>177</sup> Through artificial intelligence, it was planned that the AAV would be able to "think" and would therefore be capable of making reasoned weapons release decisions –

*The AAV's Geometric Arithmetic Parallel Processor (GAPP) computer allows the system to not only "see" the target, but, most importantly, determine that it is the right target. The GAPP uses a parallel-processing neural network computer that mimics the functioning of the human brain to handle the volume and complexity of computations needed to "understand" what the sensors are viewing. When the proper target is identified, the AAV would launch its weapons and then stay around to assess the damage.*

Unfortunately, the AAV never went into production. Developments in artificial intelligence have not yielded the 'sentience' envisioned early-on. Though Siuru stated in 1991 that "the technology is now ready",<sup>178</sup> Scott observed a decade later that UAV computers were still unable to "untangle complicated shoot/no-shoot decisions on the spot."<sup>179</sup> The upcoming US X-45 and X-47 UCAVs will retain pilot oversight for weapons release,<sup>180</sup> however, development of fully autonomous UCAVs has not halted.<sup>181</sup> Future UCAVs may operate self-sufficiently because of the enormous amount of communications bandwidth necessary to keep a human in the loop -

*That's where we are going with very smart computers that correlate imagery and recognise targets. There are few communications other than to tell other aircraft or ground stations where it is and what it is doing.*<sup>182</sup>

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<sup>176</sup> Above, note 161, paragraph 12 and above, note 93, paragraph 11. See above, note 170 for general discussion.

<sup>177</sup> Above, note 22, 42

<sup>178</sup> Above, note 22, 5

<sup>179</sup> Above, note 102, paragraph 5

<sup>180</sup> The new generation of UCAVs are the first to be purpose-built for combat and will include internal weapons bay (above, note 21, 107, 113). Two UCAVs are currently in development in the US: the Boeing X-45 for the Air Force, and the carrier-operated Northrop Grumman X-47, for the Navy. According to Yenne (above, note 21, 109) DARPA has stated that while the new UCAVs will be highly autonomous, the pilot will "remain in the decision process".

<sup>181</sup> The 2005 UAV Roadmap states that DoD plans to equip UAVs with a computer capacity equivalent to human capability before 2030; see above, note 7, 71. Lewis notes that a projection for fully autonomous capability by this time agrees with artificial intelligence research: see Lewis, M, 'UCAV: The Next Generation Air Superiority Fighter?' (Online : Air University, 2002) < <http://www.au.af.mil/au/awc/awcgate/saas/lewis.pdf> > (30 October 2006), 69

<sup>182</sup> Fulghum, D, 'Decades are Needed to Perfect Unmanned War Planes' (1998) 149:5 *Aviation Week & Space Technology* 70, paragraph 5

There is a growing international belief that technology allows for precision warfare and that collateral damage is criminal.<sup>183</sup> Therefore, UCAVs must be proven to deliver weapons accurately before autonomous UCAVs are unleashed in the field. From a moral perspective, proponents must show that “a robot airplane would use the same caution that a human being would use when deciding to employ ordnance.”<sup>184</sup>

## 4.2 Intermediate-Range Nuclear Forces Treaty 1988

Unmanned aircraft share a common ancestry with smart weapons and missiles.<sup>185</sup> While technological evolution has obscured the family resemblance, the similarities in function between cruise missiles and UCAVs are readily apparent: both are unmanned platforms designed to deliver munitions using a degree of autonomy. The UCAV is therefore “stuck in the no-man’s-land between aircraft and cruise missile” and is difficult to categorise.<sup>186</sup> Due to their ability to carry conventional, nuclear, or chemical weapons,<sup>187</sup> UCAVs may violate the *Intermediate-Range Nuclear Forces Treaty* (“INF”). The INF is a treaty between the US and Russia that bans ground-launched cruise missiles with ranges between 500 and 5,500 kilometers.<sup>188</sup> The treaty defines a cruise missile as –

*...an unmanned, self-propelled weapon delivery vehicle that sustains flight through the use of aerodynamic lift over most of its flight path.*<sup>189</sup>

A strict reading of the definition would see UCAVs fall under this description. According to DoD Directive 2060.1, all UCAV initiatives must be evaluated for compliance,<sup>190</sup> and in 2000 a Compliance Review Group determined that armed *Predators* and the USAF X-45 complied with the INF.<sup>191</sup> Though the reasoning is not publicly available,<sup>192</sup> Gormley and Speier suggest that a UCAV may be distinguished because the technology –

- Is designed and intended to be re-usable;
- Takes-off from a runway as opposed to being “launched”;
- Cannot be said to have a “point of impact” – a term used in the treaty to calculate range; and

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<sup>183</sup> Above, note 53, 80

<sup>184</sup> Above, note 53, 81

<sup>185</sup> Above, note 22, 2

<sup>186</sup> Siegel, J, ‘Identity Crisis: Why one man’s UAV is another man’s cruise missile’ (2005) 61:5 *Bulletin of the Atomic Scientists* 33 available online <

[http://www.thebulletin.org/article.php?art\\_ofn=so05siegel](http://www.thebulletin.org/article.php?art_ofn=so05siegel) > (30 October 2006), paragraph 3

<sup>187</sup> Gormley, D & Speier, R, ‘Controlling Unmanned Air Vehicles: New Challenges’ (2003) 10:2 *The Nonproliferation Review* 66, 67

<sup>188</sup> Above, note 187, 72

<sup>189</sup> Clark, R, ‘Uninhabited Combat Aerial Vehicles: Airpower by the People, For the People, But Not with the People’ (Online : Air University, 2000) <

[http://aupress.au.af.mil/CADRE\\_Papers/PDF\\_Bin/clark.pdf](http://aupress.au.af.mil/CADRE_Papers/PDF_Bin/clark.pdf) > (30 October 2006), 61

<sup>190</sup> Above, note 187, 72

<sup>191</sup> Above, note 186, paragraph 2

<sup>192</sup> Above, note 187, 72

- Didn't exist and wasn't contemplated at the time the treaty was created.<sup>193</sup>

These distinctions are somewhat artificial, and it could be argued that the INF technically prohibits UCAVs. Alternatively, they may be “entirely new systems” that require specific mention in the INF if they are to be controlled.<sup>194</sup>

### 4.3 The Missile Technology Control Regime 1987

The *Missile Technology Control Regime* (“MTCR”) is an international non-proliferation agreement that controls the transfer of items that could be used to build weapons delivery systems.<sup>195</sup> Parties to the agreement include NATO, Europe, Australia and New Zealand.

The ease with which a simple UAS could be outfitted to carry weapons is a worrying prospect.<sup>196</sup> For example, New Zealander Bruce Simpson operates a website detailing his attempts to build a cruise missile using “off-the-shelf-components” for less than \$5000.<sup>197</sup> The UAV ethos of achieving more with less may in fact be “inviting loopholes” in the MTCR.<sup>198</sup> DeGarmo observes that aerospace companies can “sell flight management systems specifically designed to turn small manned aircraft (including kit-built ones) into autonomously guided missiles”.<sup>199</sup> Though amendments to the MTCR have attempted to close such loopholes,<sup>200</sup> the potential for malevolent use of simple civilian technologies is a frightening reality that is yet to be properly addressed.

## 5 Integration into civil airspace

There is a worldwide push to integrate UAS into civil airspace, but this cannot occur until UAVs are shown to be reliable. For this to happen, two requirements must be met. Firstly, the UAS must prove it is airworthy and doesn't pose a safety hazard to people on the ground. Secondly, the UAS must prove its “controllability”: showing that it can safely share airspace with other aircraft.<sup>201</sup> UAS will not operate “in empty skies”,<sup>202</sup> they must be able to take-off, climb, cruise, descend, and land safely, as well as “deal with Air Traffic Controllers, steer clear of bad weather and avoid other aircraft, both on

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<sup>193</sup> Above, note 187, 72, 73

<sup>194</sup> Above, note 187, 73

<sup>195</sup> Above, note 187, 74, 75

<sup>196</sup> Above, note 186, paragraph 5

<sup>197</sup> Prior to the project's termination by the New Zealand Government, Bruce had completed four phases of development including procurement of control elements, airframe design and construction, and flight control system design. Bruce imported the control elements from the US without difficulty. See *A DIY Cruise Missile* (9 May 2006) < <http://www.interestingprojects.com/cruisemissile/> > (30 October 2006)

<sup>198</sup> Above, note 2, “2-24”

<sup>199</sup> Above, note 2, “2-24”

<sup>200</sup> Above, note 186, paragraph 5

<sup>201</sup> Above, note 4, 13

<sup>202</sup> Above, note 2, “1-1”

the ground and in the air.”<sup>203</sup> Development costs must simultaneously be kept in check.<sup>204</sup> There are several legal aspects of this movement worthy of examination.

## 5.1 Safety standards

### 5.1.1 Airworthiness

Airworthiness criteria for unmanned aircraft must be established to ensure the safety of other aircraft and grounded populations. The International Council of Aircraft Owner and Pilot Associations (“IAOPA”), a group representing 470,000 aircraft owners and pilots in 64 countries, has asked ICAO “to set strict standards for unmanned aerial vehicles before their use in the civilian sector becomes more widespread.”<sup>205</sup> But what standards are appropriate?

System reliability is “the greatest factor slowing UAV certification in civil airspace”,<sup>206</sup> and the statistics tell a fairly damning story. While crash data is usually concealed, accident rates are thought to be approximately 100 times that of manned aircraft, though this is steadily decreasing.<sup>207</sup> Additional data can be gathered from experience with UAS operations during war-time because “a busy military base is not that different from a large airport.”<sup>208</sup> The USAF has lost half of its *Predator* fleet due to crashes and enemy fire since 1992, though “most of the crashes occurred during testing.”<sup>209</sup> Further, the UK reports that 23 of 89 *Phoenix* UAVs were lost or damaged beyond repair during Operation Iraqi Freedom.<sup>210</sup> Whilst there is evidence to suggest a substantially higher accident rate, it may be ‘unfair’ to take the statistics at face value because over the years, so called “UAVs” have been “developed as experimental or expendable vehicles” (such as decoys and target drones).<sup>211</sup> An Israeli study that took account of 80,000 flight hours concluded that 75% of UAV accidents were due in part to component failures. Newcome notes that manufacturers often use “non-aviation quality components to achieve cost savings” and that “airworthiness standards are needed to rectify this.”<sup>212</sup>

IAOPA’s demands echo the general consensus that UAS should comply with an equivalent level of safety to manned aircraft.<sup>213</sup> CASA has applied this

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<sup>203</sup> Anonymous, ‘There’s nobody in the cockpit – Help! Pilotless planes’ (2002) 365:8304 *The Economist* 90, paragraph 10

<sup>204</sup> Anonymous, ‘Air Force Releases UAV Strategic Vision’ *US Federal News Service* 24 March 2006, paragraph 10

<sup>205</sup> Doyle, J, ‘GA Group Worried About Increasing UAV Use’ (2006) 364:61 *Aviation Daily* 3, paragraphs 1, 2

<sup>206</sup> Above, note 4, 13

<sup>207</sup> Above, note 2, “2-1”, “2-2”

<sup>208</sup> Above, note 203, paragraph 12

<sup>209</sup> Above, note 84, 5

<sup>210</sup> Dickerson, L, ‘Wanted: UAVs’ (2006) 164:3 *Aviation Week & Space Technology* 111, paragraph 16

<sup>211</sup> Above, note 2, “2-11”

<sup>212</sup> Above, note 154, paragraph 8

<sup>213</sup> Doyle, J, ‘Predator Down’ (2006) 164:18 *Aviation Week & Space Technology* 35, paragraph 10 and above, note 4, 13

standard,<sup>214</sup> though the standard itself is ill-defined. For conventional aircraft, mid-air collisions and ground collisions account for approximately 3.6% and 2.2% of aviation-related fatalities in the US.<sup>215</sup> Newcome suggests that approximating these figures would be an appropriate “working definition” for an equivalent level of safety.<sup>216</sup> However, 94% of fatalities are caused by aircraft flying passengers into the ground – an accident presently impossible with UAS.<sup>217</sup> Given the many differences between conventional and unmanned aircraft, including the fact that the pilot is not at risk, it is questionable “whether UAV systems can or should be held to the same safety standards as manned aircraft.”<sup>218</sup> I agree with DeGarmo that the appropriate standard is a question of “acceptable risk”: a balance between recognition of the unique qualities of unmanned flight and adequate public safety. In finding that balance, it should be kept in mind that while UAV accident rates are high, the resultant damage is relatively low.<sup>219</sup> An Army study of 56 UAV accidents found that only 5% of accidents caused damage of more than \$1m US, and only 4% caused an injury. Further, 544 drones crashed over densely-populated South-East Asia during the Vietnam conflict, but there were no resulting human losses.<sup>220</sup> This is a statistic that manned aircraft couldn’t emulate.

### 5.1.2 Avoidance

A pilots ability to “see-and-avoid” other aircraft in shared airspace is an important part of civil aviation. It appears logical to require a similar capability of unmanned flight.<sup>221</sup> The need for avoidance standards is evidenced by Iraq experiences, during which there have been “some incidents with UAVs at lower altitudes hitting helicopters” as well as “near misses at high altitude between UAVs and AC-130s and fighter jets.”<sup>222</sup> Similar results can be expected if current UAS are integrated into civil airspace, and indeed this has been the case in Israel where UAVs “entered areas used by civil aircraft and came uncontrollably near to passenger aircraft.”<sup>223</sup> The legal difficulty is again in defining the standard itself: What is human see-and-avoid capability?

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<sup>214</sup> Above, note 97, paragraph 8.3.1

<sup>215</sup> Above, note 154, paragraph 5

<sup>216</sup> Above, note 154, paragraph 5. Note though, the Swedish Aviation Safety Authority considers that UAVs must not kill more than 1 person in 50 years during peace time, and further that, the risk assumed by a person on the ground is about 100 times lower than road traffic risks: see Sweden. Swedish Aviation Safety Authority, *Flying with unmanned aircraft (UAVs) in airspace involving civil aviation activity* (Online, 2003) <[http://www.luftfartsstyrelsen.se/upload/In\\_english/Aviation%20Safety%20Authority/UAV.pdf](http://www.luftfartsstyrelsen.se/upload/In_english/Aviation%20Safety%20Authority/UAV.pdf)> (30 October 2006), paragraph 2

<sup>217</sup> Above, note 154, paragraph 4. However, as pilotless flight becomes more reliable, some unmanned aircraft may begin to transport passengers. See above, note 203, for a discussion of this possibility.

<sup>218</sup> Above, note 2, “2-1”

<sup>219</sup> Above, note 2, “2-2”

<sup>220</sup> Above, note 2, “2-19”

<sup>221</sup> Fulghum, D, ‘New Vision’ (2006) 164:14 *Aviation Week & Space Technology* 30, paragraph 12

<sup>222</sup> Fein, G, ‘Air Space Deconfliction Remains an Issue for UAV use, General Says’ *Defense Daily* (Potomac) 27 October 2005, 1, paragraphs 4, 7

<sup>223</sup> Egozi, A, ‘Israeli pilots demand stricter UAV regulations’ (2006) 170:5044 *Flight International* 20, paragraph 2

*Not all pilots have the same visual acuity or depth perception, they do not spend equal time looking out the window, nor do they follow consistent scanning techniques.*<sup>224</sup>

Nevertheless, civil regulators have traditionally relied on human “see-and-avoid” abilities as a “last chance” means of avoiding collisions.<sup>225</sup> Indeed, strict duties are imposed on pilots to maintain vigilance in this regard.<sup>226</sup> In June 2005, the DoD adopted the ASTM F2411 standard which is the first “common yardstick” for assessing the quality of sense-and-avoid systems.<sup>227</sup> From a civil perspective, however, industry hasn’t yet offered FAA any solutions that satisfy see-and-avoid requirements.<sup>228</sup>

Research undertaken during development of the ASTM standard revealed that human capability is actually insufficient in some circumstances,<sup>229</sup> and others have suggested that “pilots are poor at identifying potential collisions”.<sup>230</sup> Therefore, there is little cogency in basing UAS requirements on human standards.<sup>231</sup> Some UAS sensor suites apparently surpass human standards. The Swedish *Sperwer*, for instance, is equipped with a nose-mounted colour video camera, as well as infra-red and black-and-white 360 degree mission cameras that can be used for situational awareness.<sup>232</sup> CASA has no specific stipulations, except that large UAVs may need a “collision avoidance system” or “forward looking camera”.<sup>233</sup>

### 5.1.3 ATC interfacing

Ensuring that UAV flights are safe requires regulation of control and communication procedures. CASA advises that the UAV (via control station) should be able to interface and comply with “existing ATC communications equipment and procedures” to such a degree of transparency that the ATC personnel wouldn’t realise that the pilot wasn’t on-board.<sup>234</sup> The *Global Hawk* system employs such a method –

*A radio on board the aircraft links it to the nearest control tower, and a separate satellite link relays speech to and from the aircraft’s operators*

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<sup>224</sup> Above, note 2, “2-4”

<sup>225</sup> Anonymous, ‘Pentagon Adopts Commercial Standards for UAV Sense-and-Avoid Systems’ *Defense Daily* (Potomac) 23 June 2005, 1, paragraph 5

<sup>226</sup> *Civil Aviation Regulations 1988* (Cth) reg 163A

<sup>227</sup> Above, note 225, paragraph 7. The term “sense-and-avoid” is often used in a UAV context because a variety of sensor packages are used to allow the pilot to understand the UAV’s environment.

<sup>228</sup> Doyle, J, ‘CG wants UAVs to close gap in maritime air patrol hours’ (2006) 219:9 *Aerospace Daily & Defense Report* 3, paragraph 10

<sup>229</sup> Above, note 225, paragraph 8

<sup>230</sup> Above, note 2, “2-4”

<sup>231</sup> Above, note 2, “2-4”

<sup>232</sup> Above, note 10, paragraph 35. The USAF is looking to outfit the *Predator* with an advanced sense-and-avoid capability using 3 cameras, each covering an arc of 95 degrees forward of the UAV. See La Franchi, P, ‘Predator to gain interim sense and avoid capability’ (2006) 169:5041 *Flight International* 18

<sup>233</sup> Above, note 97, paragraph 5.7

<sup>234</sup> Above, note 97, paragraph 5.15.4

*on the ground, who thus appear to be inside the plane, even though they may be on the other side of the world.*<sup>235</sup>

Canada's ALIX programme also used an *Altair* UAV to the same effect, proving that the standard is achievable.<sup>236</sup> CASA also suggests the carriage of an SSR transponder.<sup>237</sup> However, ATC interfaces are expensive and their required use will have severe cost implications for smaller UAVs. In order to operate safely in civil airspace, though, it is essential that UAVs be able to follow ATC instructions.

## 5.2 Regulatory framework

It is generally accepted that UAS should “conform to existing procedures and regulations”,<sup>238</sup> that is, UAS should conform to regulations set-out for manned aircraft. In the US, however, no regulatory framework currently exists to allow certificated UAVs to “file and fly” like manned aircraft, and this in turn is impeding the civil UAV market.<sup>239</sup> The FAA deals with UAV flight requests on a “case by case basis”<sup>240</sup> via the Certificate of Authorization (“COA”), and the Experimental Airworthiness Certificate (“EAC”).<sup>241</sup> Restricted flight zones are also used to deal specifically with UAS, for example, the FAA created a 300-mile-long zone along the Arizona/New Mexico border for the ill-fated Customs *Predator B* to use.<sup>242</sup>

COAs are issued to government operators such as NASA, with the objective of ensuring that the UAV operates over unpopulated areas, with an equivalent level of safety to manned aircraft.<sup>243</sup> EACs are similar to COAs, except that certificates are issued directly to private companies, allowing UAV use for company purposes such as “experimental flight testing, marketing demonstrations and crew training.”<sup>244</sup> Both certificates impose operational restrictions such as the need for good weather, chase planes, and ground observers.<sup>245</sup> In November 2005, the FAA issued the first EAC to the General Atomics *Altair*.<sup>246</sup> A total of 50 COAs were issued between 2004 and 2005, but already 55 COAs have been issued in 2006. It is clear that the current US framework is not capable of supporting a high number of requests – flight plans must be lodged months in advance to ensure airspace deconfliction.<sup>247</sup> This is a far cry from the “file and fly” procedures that industry seeks.

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<sup>235</sup> Above, note 203, paragraph 11

<sup>236</sup> Above, note 4, 13

<sup>237</sup> Above, note 97, paragraph 5.7.2

<sup>238</sup> Above, note 10, paragraph 20

<sup>239</sup> Anonymous, ‘Pathfinder explores national route to UAV approval’ (2006) 169:5037 *Flight International* 32, paragraph 2

<sup>240</sup> Above, note 117, paragraph 8

<sup>241</sup> Above, note 92

<sup>242</sup> Anonymous, ‘FAA Cancels Southwest TFR After Government UAV Crash’ (2006) 82:18 *Aviation Week's Airports* 198

<sup>243</sup> Above, note 109, paragraph 8

<sup>244</sup> Anonymous, ‘Altair Receives FAA's First Commercial UAS Airworthiness Certificate’ *Defense Daily* (Potomac) 3 October 2005, 1, paragraph 8

<sup>245</sup> Above, note 244, paragraph 7 and above, note 109, paragraph 5

<sup>246</sup> Above, note 244

<sup>247</sup> Above, note 2, “1-5”

For these reasons, the US is considering a “three-category classification and certification system”.<sup>248</sup> Under this system, UAVs classified as “standard” would be able to file-and-fly, however, the FAA believes that “few systems are likely to achieve “standard” classification in the near term”.<sup>249</sup> CASA’s system is similarly prospective in nature, recognising that, in most cases, their requirements-

*Will render commercial operations non-viable, however, as costs reduce and miniaturization continues, builders of UAVs may soon be able to develop cost effective solutions to current constraints.*<sup>250</sup>

The difficulty in establishing a system that allows UAVs to operate in the same manner as manned aircraft lies in the fact that certification must take account of every element “related to the manufacturing, maintenance, and operation” of the UAS.<sup>251</sup> The Royal Netherlands Army experienced this difficulty first-hand in certifying their *Sperwer* UAV – a process that took 5 years to complete.<sup>252</sup> However, UVS International believes that “individual initiatives are of dubious value in the absence of an internationally accepted roadmap”, given the nature of modern aviation and the trans-national endurance capabilities of platforms like *Global Hawk*.<sup>253</sup>

## 6 Summary

For an essentially simple concept, unmanned aviation presents a wealth of legal and technical challenges to those who seek to employ this form of flight. Many of these issues remain to be settled, and even defining “UAV” is problematic. Having reviewed several answers being offered around the globe, I concluded that the proper definition is one that incorporates reference to all the components necessary to allow a UAV to fly. Further, a proper definition must distinguish UAS from the related technologies found in model aircraft, spacecraft, and missiles.

One of the more vexing problems for UAS, at least for the public, is the use of autonomous control systems. Such systems must prove their reliability before widespread use, but I believe that autonomous systems have the potential to improve safety for both manned and unmanned aviation. Of course, the progression towards more UAV autonomy means a corresponding decline in pilot workload. While this movement may unsettle aviation culture, it is a movement that is also evident in manned aviation, and at present it has not disturbed traditional responsibilities and liabilities. Whether this statement is still true in 10 years, however, remains to be seen.

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<sup>248</sup> Above, note 30

<sup>249</sup> Above, note 30, paragraph 3

<sup>250</sup> Above, note 97, paragraph 4.1. CASA has set the pace, however, being the first nation to enact airworthiness and operational requirements for civil use UAVs: see *Civil Aviation Safety Regulations 1998* (Cth)

<sup>251</sup> Above, note 2, “2-50” and above, note 97, paragraph 7.1

<sup>252</sup> Above, note 10, paragraph 31

<sup>253</sup> Above, note 10, paragraph 9

Safety fears are amplified when autonomous systems are used in combat UAVs. The thought of allowing computers to select and engage targets is frightening and presents conflicts of moral and legal character. Again, continued development and improvement may legally enable such applications of autonomy, but I imagine the moral conflicts will remain for some time. Furthermore, the legality of the UCAV concept is questionable in light of the *Intermediate-Range Nuclear Forces Treaty*. These concerns are compounded by the fact that simple, civilian use UAS components can easily be used to create weapons systems – an issue that the *Missile Technology Control Regime* apparently doesn't adequately answer. There is serious uncertainty surrounding the military application of UAS, and this must be addressed swiftly and thoroughly.

The integration of UAS into a mature civil aviation system involves difficulties in establishing standards for airworthiness, sense-and-avoid capability, and pilot certification. Modern regulatory systems are based on our experiences with manned aviation, and while it is tempting to base UAS standards on these experiences, human standards are not always appropriate. Unmanned aviation is unique and the problems require unique solutions. Civil aviation regulations must find a solution that caters for UAS peculiarities, enforces high levels of safety, and yet allows unmanned aviation to develop. CASA has taken a step in the right direction by preparing for an aircraft that is yet to prove itself but has the potential to transform the aviation industry to a degree unseen since the evolution of the jet engine.

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