Drones on ice: an assessment of the legal implications of the use of unmanned aerial vehicles in scientific research and by the tourist industry in Antarctica

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ABSTRACT. Unmanned aerial vehicles (UAVs), also known as drones, are used in scientific research and a diverse range of other applications across the globe. They are also being used increasingly for scientific research in Antarctica and to a lesser extent by tourists visiting the world's last great frontier tourist destination. Their use in scientific research in Antarctica offers many benefits to science and if used responsibly may be less invasive than other research techniques, offering a rich source of new scientific data. For tourists, UAVs also offer unique aerial photographic perspectives on Antarctica — the ultimate holiday snap shot. Concerns have been raised about the safety of drone use in the harsh and unpredictable Antarctic conditions, as well as possible environmental impacts. This paper considers these issues and the emerging regulatory response to drone use in Antarctica focusing on the *Antarctic Unmanned Aerial Systems (UAS) Operator's Handbook*, which provides guidelines to national Antarctic programmes on the use of UAVs in the Antarctic Treaty area, and the temporary ban on use of drones by tourists imposed by the International Association of Antarctica Tour Operators (IAATO). Both measures arguably constitute a good first response to this emerging issue, although more still needs to be done.

Introduction

Unmanned aerial vehicles (UAVs), also known as drones, are used in a diverse range of applications across the globe. Originally developed as training aids for target practice during World War I, they now take many forms of both ground controlled and pre-programmed autonomous flying systems (Heverly, 2015). Current applications of UAVs include military surveillance and bombing missions, border control and law enforcement (Takahashi, 2013), aerial surveys of industrial construction sites, photography for property sales marketing, live video feeds of breaking news for TV (replacing helicopters), surveying crops, and monitoring the integrity of power lines and pipelines (Perritt & Sprague, 2015).

Drones are also used in scientific research. Mirroring developments in science elsewhere in the world, UAVs are also now increasingly being used for scientific research in Antarctica. To a lesser extent, UAVs are also being taken to Antarctica by tourists visiting the world's last great frontier tourist destination. For the scientific community, UAVs provide lightweight, low cost aircraft platforms that can carry a range of payloads useful for collecting a wide range of scientific data (Anderson & Gaston, 2013). Their use in scientific research in Antarctica offers many benefits to science and, if used responsibly, they may be less invasive than other research techniques offering a rich source of new scientific data. For tourists, UAVs also offer unique aerial photographic perspectives on Antarctica – the ultimate holiday snap shot.

However, at recent Antarctic Treaty Consultative Meetings (ATCMs) and other Antarctic Treaty forums, concerns have been raised by some states about possible environmental impacts and the safety of UAV use in the harsh and unpredictable Antarctic conditions. Germany and Poland were the first to raise concerns about the potential environmental impact of UAV use in Antarctica in a joint working paper submitted at ATCM XXXVII held in Brasilia in 2014 (ATCM, 2014). This working paper raised questions about the potential environmental impact of UAV use in Antarctica observing:

> …hardly [sic] is known about the UAV's possible environmental impacts. In particular, if they are intended to [sic] use near animal colonies disturbance of these animals cannot be excluded. If applied appropriate [sic] sensitive UAVs could be a useful and less invasive method to e.g. measure the size of a bird colony. If applied irresponsible [sic] they could cause additional disturbances e.g. of breeding birds.
>
> In this context it would be important to know if there are so far any experiences with possible environmental impacts of UAVs in polar regions made by Parties or SCAR. If yes, it would be useful to exchange and discuss them. Another relevant question is: Do we need guidelines for the responsible use of UAVs near animal colonies with minimum distances? (ATCM, 2014, p. 2)

Debate sparked by this paper led to the inclusion of a discussion on the implications of UAV use in Antarctica on the ATCM agenda. Furthermore, the International Association of Antarctica Tour Operators (IAATO) recently imposed a temporary ban for the 2015/16 and 2016/2017 seasons on the use of drones by tourists in Antarctica, pending further consideration of their environmental impact, safety and appropriate regulatory responses.

This paper aims to examine the current state of play with respect to UAV use in Antarctica and highlight the extent and nature of UAV use in Antarctica by scientists and tourists. A second aim of this paper is to examine the regulatory response to the use of drones in Antarctica that is currently emerging. The paper begins by explaining the value of drones to scientific research in Antarctica and highlighting a number of scientific research projects where UAVs have been used. It then goes on to examine the potential environmental impacts and safety risks posed by the use of UAVs in Antarctica. The paper then undertakes an interrogation of emerging regulatory responses to UAV use in Antarctica. This includes an examination of this issue within the various Antarctic Treaty forums and in particular the development of the *Antarctic Unmanned Aerial Systems (UAS) Operator's Handbook* (herein, UAS Operator's Handbook), which provides guidelines to national Antarctic programmes on the use of UAVs in the Antarctic Treaty area. The paper then examines how Antarctic Tour operators are responding to requests by tourists to operate drones in Antarctica. While the response of treaty parties and the tourist industry to the emergence of these issues has been quite prompt, further work will be required to put drone use on a sustainable and safe footing into the future. The paper concludes with a consideration of outstanding issues for Antarctic policy makers to address in the future.

The benefits of drones to science

Across many scientific disciplines basic research is driven by the collection and analysis of data. Research involving the collection of data from UAVs is already well-established in many scientific disciplines. For example, UAVs have been used extensively in photogrammetry, remote sensing and mapping (Colomina & Molina, 2014). UAVs also have a broad range of uses in ecological research (Anderson & Gaston, 2013). In ornithology, fixed wing UAVs have been widely used for census works and observations including close up video filming of birds in flight (Vas, Lescroël, Duriez, Boguszewski, & Grémillet, 2015). A key benefit of UAV use in such research is that they allow repeat surveys of colonies of birds with minimal disturbance allowing for monitoring of temporal and spatial variation of breeding pairs (Anderson & Gaston, 2013), although the extent of disturbance of bird populations is still unclear.

Low-altitude flights of UAVs also enable collection of finer spatial resolution data. Where previously access to satellite and airborne sensors on fixed wing aircraft provided similar types of datasets, access to both was prohibitively expensive and inaccessible to many researchers. UAVs offer a cheaper and relatively more accessible alternative (Koh & Wich, 2012).

UAVs are also emerging as a powerful tool in conservation management aiding law enforcement efforts to stem poaching of threatened species in Africa and parts of Asia (Pimm et al., 2015). While the author has not been able to identify any examples where drones have been used for law enforcement in Antarctica or the Southern Ocean, it is foreseeable that the technology could be adapted to law enforcement or monitoring, especially in the context of steps to limit so-called illegal, unreported and unregulated (IUU) fishing in the Southern Ocean. At least one regional fisheries management organisation, the Western and Central Pacific Fisheries Commission, in conjunction with non-governmental organisations, such as the WWF, has already begun exploring the potential utility of drones for fisheries management. This has included a trial flight of an aerosonde UAV in Palau in 2013 (WWF, 2014).

Drones and Antarctic science

A desktop review of published literature (both peer-reviewed scientific literature and 'grey' literature on the internet) for the purposes of this study has confirmed that UAVs are now used by many national research programmes in Antarctica including those of Australia, the USA, the UK, Japan, South Korea, New Zealand, Poland, Norway, Germany, Portugal and Chile. A total of 19 research projects using drones in Antarctica were identified as set out in Table 1. While not intended to be an exhaustive account of UAV research in Antarctica, as some of the examples shown in Table 1 illustrate, UAVs are used in a diverse range of applications across many scientific disciplines. These include a range of research projects involving aerial geomagnetic surveys, meteorological measurement and biological observations (Higashino, Funaki, Hirasawa, Hayashi, & Nagasaki, 2013). Other applications include measurement of sea ice and measurement of the impacts of climate change.

It is also worth noting that on occasion UAVs have also been used to assist with navigation of vessels transporting researchers to and from Antarctica. For example, in December 2015, a UAV launched from the Australian vessel the *Aurora Australis* helped the icebreaker navigate through sea ice on its annual resupply voyage to Casey Station (Griffith, 2016). Launched from the aft deck of the *Aurora Australis* the quadcopter UAV provided real-time imagery of sea ice conditions providing useful additional information to assist with vessel navigation (Australian Antarctic Division, 2015).

The benefits and risks of drone use in Antarctica

As highlighted above, drones are emerging as an integral part of scientific research in Antarctica. In many respects they are just like any other piece of scientific equipment and their use in Antarctica should be embraced for the benefits they bring to science.

In a working paper presented at ATCM XXXVIII in 2015 the Council of Managers of National Antarctic Programs (COMNAP) highlighted that in the Antarctic context the use of drones has two main benefits: safety and logistics or operational (COMNAP, 2015)

In Antarctica's notoriously changeable and extreme weather conditions flying helicopters and fixed wing aircraft in support of scientific research can at times be extremely dangerous. While aircrew flying in these extreme conditions are highly skilled and typically very

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Table 1. Examples of research projects using UAVs in Antarctica.

Year conducted	Researcher affiliation (nationality)	Location in Antarctica	Model of UAV	Research conducted using UAV	Source
2007	British Antarctic Survey (UK) Technical University of Braunschweig (Germany) Mavionics	Weddell Sea	Unknown	Measurement of the physics of sea ice formation.	Sanderson, 2008
2008/2009	Monterey Bay Aquarium Research Institute (USA)	Southern Ocean, east of the Antarctic Peninsula	Model plane-Sig Kadet Senior (2008) and Sig Rascal 110 (2009)	Observations of free drifting icebergs and delivering payloads for scientific research to icebergs. Observations of the margins and interior top surface of iceberg from above, as well as placing GPS tracking tags on top of icebergs to establish reference frame tied to the iceberg itself.	McGill, Reisenbichler, Etchemendy, Dawe, & Hobson, 2011
2009	University of Colorado (USA) AAI (USA)	Terra Nova Bay	Aerosonde UAV	Study interaction of katabatic winds and sea ice formation/Antarctic polynya.	Brears, 2011; Cassano, 2010
2009	Geospatial Research Centre, University of Canterbury (New Zealand)	Scott Base	Unknown	Collection of data on the surface elevation of ice using laser altimeter coupled to a video camera and GPS.	Brears, 2011
2009	Center for Remote Sensing of Ice Sheets, University of Kansas (USA)	McMurdo Station	Meridian UAV	Assessment of capacity Meridian UAV in the field and verify its radar system.	Brears, 2011
2010–2011	National Oceanic and Atmospheric Administration (USA) Viasat (USA) Aerial Imaging Solutions (USA)	Cape Shirreff, Livingston Island, South Shetland Islands	Quadcopter md4-1000-microdrones; APQ-18 quadcopter, Aerial Imaging Solutions; hexacopter APH-22, Aerial Imaging Solutions	Used in estimating abundance, colony area and density of krill-dependent predators in Antarctica. Also used to estimate size of individual leopard seals.	Goebel et al., 2015

Table 1. Continued

Year conducted	Researcher affiliation (nationality)	Location in Antarctica	Model of UAV	Research conducted using UAV	Source
2011	National Institute of Polar Research (Japan) Kyushu University (Japan) Aita University (Japan) Yamagata University (Japan) Tohoku University (Japan) Robista (Japan) RC Service (Japan)	Bransfield Basin, King George Island, Livingstone Island, Deception Island	Purpose built UAV known as the 'Ant-plane'	Aeromagnetic and aerial photographic surveys for use in development of high-resolution magnetic anomaly maps.	Funaki et al., 2014
2011	University of Tasmania (Australia) University of Wollongong (Australia)	Robinson Ridge, Windmill Islands, East Antarctica	MikroKopter OktoKopter	Using aerial photography from UAVs to generate ultra-high-resolution digital surface models of Antarctic moss beds.	Lucieer, Turner, King, & Robinson, 2014
2013	Center for Remote Sensing of Ice Sheets (USA)	Subglacial Lake Whillans, Ross Ice Shelf	Unknown	Remote imaging of ice-bed interface	*sUASNews*, 2014
2013–2014	Center for Remote Sensing of Ice Sheets, University of Kansas (USA)	Subglacial Lake Whillans and the WISSARD drill site	GIX UAS	Radar measurements of ice thickness of fast moving glacier with fine resolution to determine bed topography and basal conditions. Data can be used to improve ice-sheet models and generate accurate estimates of sea level rise in a warming climate.	Leuschen et al., 2014
2014	Kyushu University (Japan) National Institute of Polar Research (Japan)	Livingstone Island, Deception Island, South Shetland Islands	Not specified	Aerial magnetic observations and aerial photography of Livingstone Island and Deception Islands providing basic data on the regression of glaciers due to global warming.	National Institute of Polar Research, 2014
2014	Korea Polar Research Institute (South Korea) Korea Institute of Science and Technology (South Korea)	King Sejong Station, Barton Peninsula	Vision 1000–8 Octocopter	Development of UAV-based aerial photography for potential application in studying distribution and mapping of plants and animals.	Park et al., 2014

Table 1. Continued

Year conducted	Researcher affiliation (nationality)	Location in Antarctica	Model of UAV	Research conducted using UAV	Source
2014	National Institute of Polar Research (Japan) Kyushu University (Japan) Fukuoka University (Japan)	Syowa Station, East Ongul Island, Dronning Maud Land	Phoenix-S1 (balloon assisted UAV)	Collection of stratospheric aerosol samples at an altitude of 22 km and observation of aerosol density at an altitude of 23 km.	National Institute of Polar Research, 2015
2014/2015	Waikato University (New Zealand)	Taylor Valley, Trans-antarctic Mountains	Hawk; Swamp Fox UAV	Mapping of the levels of cyanobacteria in streams and lake edges.	Hyde, 2014
2015	Warsaw University of Technology (Poland) Northern Research Institute Tromsø (Norway)	Henryk Arctowski Station, King George Island, South Shetland Islands		Collect baseline geospatial environmental data on seal and penguin populations, flora distribution and glacier retreats used to monitor climate change effects.	Warsaw University of Technology, 2015
2015	Australian Antarctic Division (Australia)	Southern Ocean to Casey Station	Hovering quadcopter, model unknown	Guidance of Antarctic resupply icebreaker ship *Aurora Australis* in navigation through sea ice on voyage to Casey Station.	Griffith, 2016
2015	Not specified, drone launched from USAP icebreaker *Nathaniel B. Palmer*	En route to the ice shelves of East Antarctica	Spreading Wings S1000	Sea ice research.	Williams et al., 2016
2015	Centre for Natural Resources and Environment, Instituto Superior Tecnico (Portugal) Instituto de Geografia e Ordenamento de Territorio, University of Lisbon (Portugal) Korean Institute of Ocean Science and Technology (South Korea) Polar Institute (Chile)	King George Island, Barton Peninsula	Not specified	High-resolution mapping of periglacial and ecological features to monitor impacts of climate change.	Bandeira, Branco, Viera, & Pin, 2015

experienced, accidents do occur. For example, in 2012, a helicopter operated by the Chinese Antarctic expedition crashed near China's Zhongshan Station injuring one of its pilots (ATCM, 2012). More recently, in December 2013, a helicopter chartered by the Australian Antarctic Division (AAD) impacted with the surface of the Amery Ice Shelf injuring the pilot and two passengers (ATCM, 2015a). Since, unlike fixed wing aircraft or helicopters, drones carry neither pilot nor passengers there is no risk that either will be injured or killed if a drone crashes.

COMNAP has also noted that the use of drones in the Antarctic context has several logistical or operational benefits compared with traditional fixed wing aircraft or helicopters. Drones are now relatively inexpensive both to purchase and in their ongoing operational costs (COMNAP, 2015). Their small size means that they are also easy to transport and deploy, and because they are typically run on rechargeable batteries, as opposed to fossil fuels, there is minimal fuel transportation cost and, hence, they are cheaper to operate and have less of a carbon footprint than traditional aviation (COMNAP, 2015). In addition, while some level of skill is required to fly a drone in Antarctica's extreme conditions, the pilot training required is significantly less than a fixed wing aircraft or helicopter (COMNAP, 2015).

It has also been suggested that drones could have a role to play in fire-fighting, searching for missing persons, in medical emergencies and quick reconnaissance (for example, crevasse detection) (COMNAP, 2015). While these additional safety features of drones have been noted in the context of debates on drones in Antarctica within the forums of the Antarctic Treaty System, to date there appear to be no reported examples of where drones have actually been used for these purposes.

While drones offer many benefits in terms of safety and logistics they also pose risks to safety different to fixed wing aircraft or helicopters. While there are no pilots or passengers on board a UAV, there is always the risk that a UAV might collide with the pilot operating the UAV or other bystanders, such as scientists or tourists, on the ground (COMNAP, 2015). When operated near bases with active runways, skiways or landing pads where fixed wing aircraft and helicopters are operating from there is also the risk of a UAV colliding with such aircraft, with potentially disastrous consequences. In the 'crowded operational space' around bases there is also the risk of injury to bystanders and damage to the built environment of stations, infrastructure and scientific instruments (COMNAP, 2015).

In addition, there is also the potential for radio signals and other electromagnetic signals from bases to interfere with control of UAVs possibly resulting in UAV pilots losing control of the UAV (COMNAP, 2015). COMNAP (2015) has also highlighted a range of other factors that can lead to UAV crashes including pilot error, pilot medical issues, loss of communication with UAVs, loss of line of sight (important for some less sophisticated UAVs that rely on the pilot being able to see the UAV for it to be safely operated), equipment failure, mid-air collision with other aircraft, and weather conditions (COMNAP, 2015).

The potential environmental impact has been another key concern that has been raised in relation to drone use in Antarctica. While this is a key issue there is actually very little data available on the environmental impact of drones on fauna. To date, the limited evidence suggests that the key environmental impact could potentially be on avian fauna, such as penguins, that nest throughout many of the coastal areas of Antarctica. The Scientific Committee on Antarctic Research (SCAR) has noted that 'no peer-reviewed published research [can] be found in the scientific literature … on UAV impacts'. But in the 'absence of published studies on UAV … impacts in Antarctica' SCAR has recommended, *inter alia*, '... members using UAVs in areas with wildlife concentrations [should] support research into UAV impacts, and means to avoid them' (SCAR, 2015, p. 5). Consistent with this recommendation from SCAR, in a working paper submitted to ATCM XXXIX, Germany reported on initial results of research on the interference of UAVs with an Adélie penguin colony on the South Shetland Islands. This paper recommended horizontal and vertical minimum distances for micro-UAVs to Adélie penguin colonies of 100 m and take-off distances of more than 50 m (CEP, 2016a).

Outside Antarctica there have been a few studies on the impact of drones on avian fauna; however, the full picture on environmental impacts is still unclear. One recent study (Vas et al., 2015) tested the impact of drone colour, speed and flight angle responses of semi-captive mallards, wild flamingos and common greenshanks in a wetland area. This study observed that birds were more sensitive to drones approaching vertically and recommended launching drones more than 100 m from birds, but noted different distances may be appropriate on a species by species basis (Vas et al., 2015).

In light of the limited evidence available SCAR has recommended '[i]n the absence of evidence for the Antarctic... [M]embers to consider avoiding UAV launches closer than 100 m to wildlife and to consider avoiding vertical approaches to wildlife with UAVs, until Antarctic-specific information becomes available' (SCAR, 2015, p. 5).

Discussions within the Antarctic Treaty System

The 1959 Antarctic Treaty and the 1991 Protocol on Environmental Protection to the Antarctic Treaty (the 'Madrid Protocol') are the key international treaties relevant to the potential regulation of drone use in Antarctica. Article II of the Antarctic Treaty recognises freedom of scientific research as a key pillar of international governance in Antarctica.

However, the provisions of the Antarctic Treaty recognising freedom of scientific research have to be read in conjunction with the provisions of the Madrid

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Protocol. The Madrid Protocol in particular sets out the elements of the regime of environmental protection in Antarctica. Consistent with the provisions of the Antarctic Treaty Article 3(1) of the Madrid Protocol provides:

> The protection of the Antarctic environment and dependent and associated ecosystems and the intrinsic value of Antarctica, including its wilderness and aesthetic values and its value as an area for the conduct of scientific research, in particular research essential to understanding the global environment, shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area.

Article 3(2) of the Madrid Protocol requires that activities in the Antarctic Treaty area be planned and conducted so as to limit adverse impacts on the Antarctic environment and dependent and associated ecosystems. As such, pursuant to Article 3(2)(b), activities involving drone use in the Antarctic Treaty area must be planned and conducted so as to avoid *inter alia*, detrimental changes in the distribution, abundance or productivity of species or populations of species of fauna and flora; or degradation of, or substantial risk to areas of biological, scientific, historic, aesthetic or wilderness significance. Drone use would need to be 'planned and conducted on the basis of information sufficient to allow prior assessments of, and informed judgements about, their possible impacts on the Antarctic Environment' pursuant to the requirements of Article 3(2)(c) of the Madrid Protocol.

The Madrid Protocol thus requires environmental impact assessments of all activities including scientific research. In addition to the environmental impact assessment regime, Annex V to the Madrid Protocol provides a mechanism for the establishment of protected areas and the regulation of activities in such areas which may be designated as Antarctic Specially Protected Areas (ASPAs) or Antarctic Specially Managed Areas (ASMAs). Activities in both these types of areas are prohibited, restricted or managed in accordance with management plans adopted under the provisions of Annex V of the Madrid Protocol. While currently none of the existing management plans regulate the use of drones within these protected areas in theory management plans could be amended to apply restrictions on drone use in these parts of Antarctica.

It is also worth noting that in 2004 the ATCM adopted the *Guidelines for the operation of aircraft near concentrations of birds in Antarctica (Resolution 2 2004)* (ATCM, 2004), which are also potentially applicable to drones. However, these guidelines largely relate to fixed wing aircraft and helicopters and it is questionable given their terms if they could have meaningful application to drones.

With this background in mind the following discussion briefly examines the consideration of drone use within the Antarctic Treaty System.

Emerging debates within the Antarctic Treaty System

As noted above debate on UAV use in Antarctica was sparked by a working paper submitted by Germany and Poland (ATCM, 2014). The use of drones in Antarctica was first discussed in detail at ATCM XXXVII held in Brazil in 2014 in the context of agenda Item 10 – Safety and Operations in Antarctica and at the meeting of the Committee for Environmental Protection (CEP) (Agenda Item 8b) held immediately before the ATCM. In 2014, the CEP requested reports by SCAR and COMNAP on the utility and risks of UAV operation in Antarctica, as well as papers from IAATO and member states on their experience of UAV use (CEP, 2015). While 2014 marked the first substantive discussions on the issue, more detailed debate did not occur until the ATCM and CEP meetings held in Bulgaria in 2015. At its 2015 meeting, the CEP considered a number of papers on the issue including the requested papers from COMNAP (COMNAP, 2015), SCAR (SCAR, 2015) and IAATO (IAATO, 2015). In addition, information papers on member states' experiences of UAV use in Antarctica were submitted by Poland (ATCM, 2015b), and South Africa (ATCM, 2015c). The USA also presented two information papers on risk-based approaches to safe operations of UAVs in the US Antarctic Program (USAP; ATCM, 2015d) and guidance on UAV use in Antarctica developed for applications to scientific studies on penguins and seals (ATCM, 2015e).

Significantly, a working paper submitted by COMNAP set out a number of key recommendations that have shaped subsequent developments (COMNAP, 2015). In this working paper, COMNAP recommended that national Antarctic programmes develop programme-, equipment- and site-specific guidelines for UAV use based on the COMNAP UAV code of conduct which was being developed. The working paper also recommended that national Antarctic programmes and other operators collect and share data and support research on UAV use. After extensive discussion of these documents CEP's advice to the ATCM merely noted that it 'recognized the benefits of developing guidance on the environmental aspects of UAV use in Antarctica, and agreed that it would consider at CEP XIX initiating work to develop such guidance' (CEP, 2015).

Following on from discussions within CEP there was also considerable discussion on the implications of drone use at ATCM XXXVIII in 2015 both in the context of discussion of the CEP's report to the ATCM, but more significantly as part of the overall discussion of aviation matters in agenda Item 10 on Safety and Operations in Antarctica. In this context the ATCM expressed general support for UAV use in Antarctica and 'acknowledged UAVs as an important tool for the future' (ATCM, 2015f). The ATCM also took note of COMNAP's work on UAVs and in particular noted that it would consider guidelines on UAV use then under development by COMNAP (ATCM, 2015d).

In 2016, the first concrete steps towards a regulatory regime for UAV use in Antarctica were taken. At

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CEP XIX, the CEP considered the initial version of the UAS Operator's Handbook, which had been developed by the COMNAP Unmanned Aerial Systems-Working Group (UAS-WG) and was contained in a working paper submitted by COMNAP to the meeting and the ATCM (COMNAP, 2016). The UAS-WG had been established in August 2015 at the COMNAP Annual General Meeting (AGM) XXVII to focus on UAS-related issues. Its members included representatives from Australia, Germany, the UK, Italy, France, Russia, South Korea, Japan, Poland, China and the USA. In its presentation to the CEP, COMNAP explained that the handbook had been developed as a result of discussions by experts from the 11 national Antarctic programmes who participated in the UAS-WG (CEP, 2016b). The CEP noted that the handbook would be discussed at the ATCM and expressed its support for the handbook (CEP, 2016b). The CEP also recognised the need for more work on the potential environmental impacts of UAV use in Antarctica, and supported the establishment of an intersessional contact group (ICG) to develop further guidance on the environmental aspects of UAV use commencing at CEP XX, when more information on environmental impacts (including a report by SCAR) would be available.

While some CEP members expressed support for a suggestion raised during the meeting to ban the recreational use of UAVs in Antarctica, no such recommendation was adopted. The CEP agreed that recreational uses could be given further consideration during the planned ICG. This oblique reference to recreational uses of UAV was not related to use of UAVs by tourists, but rather as the report of the CEP's meeting suggests it related to 'the utility of carefully managed recreational use of UAVs to station staff, particularly those remaining in Antarctica over winter, would usefully inform future discussions' (CEP, 2016b, p. 91). In essence it has been suggested by the CEP that there may be certain benefits to over winter base morale by allowing scientists to use UAVs for recreational purposes.

At ATCM XXXIX held in Santiago in 2016, COMNAP submitted a working paper on the work of the UAS-WG (COMNAP, 2016) and provided a briefing on the work in developing the UAS Operator's Handbook. The response of the ATCM was merely to thank COMNAP for its working paper and noted 'the usefulness of the UAS Operator's Handbook' and expressed 'overall support for the use of UAVs for scientific purposes and underlined their benefits both for science and other operations in Antarctica' (ATCM, 2016, p. 41). No resolution or other measure was adopted by the ATCM in relation to the UAS Operator's Handbook. Thus it is clear that to date the handbook has no legal effect other than as non-mandatory guidance to national Antarctic programmes.

While it has no legal effect the UAS Operator's Handbook does offer some very clear guidance on how drones can be used sustainably in Antarctica and has been designed to evolve over time as published research on the use and impacts of UAVs in Antarctica becomes available, and as the technology itself evolves (COMNAP, 2016). The following discussion sketches the key elements of this guidance.

The Antarctic UAS Operator's Handbook

The UAS Operator's Handbook is broken into three parts: Part 1 includes some introductory or general background information on why the handbook has been developed; Part 2 contains recommendations to provide guidance to national Antarctic programmes on the use of UAVs in the Antarctic Treaty area; and Part 3 contains appendices of various templates of common forms that might be used and adapted by national Antarctic programmes.

As noted above Part 1 of the handbook sets the scene for why the guidance contained in the handbook is needed and how it should be implemented through a process of risk assessment and mitigation. Thus Part 1 notes:

> The principle objective of aviation regulatory guidelines is to achieve and maintain the highest possible level of safety. Against this background of safe air operations in the Antarctic region, there is also the fundamental consideration in the planning and conduct of all activities in the Antarctic Treaty area as prescribed in the environmental protocol.
>
> In the case of UAS this means ensuring the safety of any other airspace user and of persons, environment, wildlife, infrastructure and equipment on the ground, including areas and equipment of scientific importance. Hazards and risks should be identified and assessed for each specific deployment as for any airborne object, advance notification and communications with other operators in any given region is essential to reduce risk of harm (COMNAP, 2016).

Although the UAS Operator's Handbook has no binding legal effect, it is clear from the reference to the Madrid Protocol that it has been developed with the existing legal regime for environmental protection in mind. Safety concerns also underlie the development of the handbook.

Part 2 contains 12 recommendations to assist with UAV activity in the Antarctic Treaty area. But the handbook explicitly recognises that 'as countries develop their own UAS regulation, national Antarctic programs must act in a manner that does not contradict their national rules and regulations' (COMNAP, 2016).

The following discussion summarises the major points contained in each of these recommendations. Recommendation 1 suggests that national Antarctic programmes should prohibit UAV operations without authorisation from their programme's head of operations, air operations or station manager. Recommendation 2 'strongly recommends' that UAV deployment be primarily for support of science, logistics and operations, and emergency and search and rescue situations. Recommendation 3 then goes on to stress consideration should always be given to the environmental impact of activities as per the requirements of the Madrid Protocol, any ATCM measures and provisions contained in any ASMAs. Recommendation

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4 notes the importance of advanced notification and communication to other Antarctic programmes and bases of UAV use, as well as any existing airspace restrictions. Recommendation 5 then goes on to strongly recommend every national Antarctic programme deploying UAVs to develop their own national operations manuals consistent with international regulations (which may or may not be developed in the future). Recommendation 6 suggests UAVs should carry brightly coloured identification marks including national registration and identification information to identify the pilot and operator in the event of an accident, incident or near miss. Curiously recommendation 7 recommends that national Antarctic programmes take a common approach to safety risk assessment but does not contain any detailed provisions on what such approach should be. Recommendation 8 strongly recommends that UAV flights be notified to other air operations in the area through standard aviation mechanisms, such as communications plans and Notices to Airmen (NOTAMs) where relevant.

In terms of UAV pilot training recommendation 9 states that national Antarctic programmes ensure each pilot has training consistent with appropriate national regulations and applicable requirements of Annex 1 of the Convention on International Civil Aviation dealing with Personnel Licensing.

Recognising that accidents will occur, recommendation 10 states that all UAV operations and all national Antarctic programme operations manuals make provision for the retrieval of waste in event of an accident.

Similarly, recommendation 11 acknowledges that much of this technology will develop and evolve over time and as such recommends that national Antarctic programmes adopt search and avoid capabilities, perception and avoidance systems as they are developed.

Finally, recommendation 12 strongly recommends sharing of operational and certification information and best practice over time.

Part 3 of the handbook contains appendices of various templates and common forms that national Antarctic programmes could use in their UAV operations. These cover issues such as risk assessment and management of environmental impact and safety of human life, communication plans in relation to air operations, NOTAMs, pilot records, flight records, and accident, incident and near miss reporting.

Antarctic Treaty System response-critique

Although the development of the UAS Operator's Handbook is a positive first step in addressing concerns that have been raised in relation to drone use in Antarctica, there are a number of weaknesses in this approach worth noting. First, this document contains recommendations only, which have no binding legal effect. Likewise, it is not clear what the significance is of some recommendations being 'recommended' while others are 'strongly recommended'. Similarly, the handbook only contains recommendations in broad terms on what national Antarctic programme guidelines or regulations should cover, not specific details on how each issue should be addressed.

As such a key weakness of this approach is that it is very much dependent on the content and quality of national regulation by individual Antarctic programmes. In fact many jurisdictions have yet to adequately respond to the regulatory challenges raised by drones within their own mainland territories, let alone develop comprehensive national regulation to apply to their Antarctic operations. Australia is one of the few states that does have detailed regulation of UAVs in place under Sub-part 101.F of the Civil Aviation Safety Regulations 1998. While the AAD is reportedly developing policy guidance on how these regulations will operate in Australia's Antarctic programme, the terms of that policy guidance is not currently publicly available so its adequacy cannot be assessed. Spain has also developed a 'protocol for the operation of aircraft piloted by remote control and automated [sic] (UAV)' (ATCM, 2016). In most other jurisdictions regulation is not as far advanced. Thus while South Africa currently has no specific regulations in place that would apply to drone use in Antarctica, draft regulations are under development (ATCM, 2015c). Similarly New Zealand released a draft policy for comment in 2013, but its status is currently unknown (COMNAP, 2015).

The USA has been developing a regulatory regime for drone use more generally for a number of years, but domestic debate has been long and protracted and it is unclear when a clear regulatory regime will arise for drone use under US law. However, this has not stopped US policy makers from issuing specific guidance on the use of UAVs by USAP personnel. Thus a USAP programmatic notice issued on 15 September 2014 provides:

> Due to the potential operational, environmental and safety hazards posed to Antarctic activities by the operation of Unmanned Aerial Vehicles (UAVs), the use of any UAV, drone, or remotely piloted aircraft in Antarctica by … [USAP] … personnel is prohibited without the specific authorization from the National Science Foundation (NSF). This prohibition includes the operation of commercially available or custom designed 'quad copters', remote controlled camera systems, and any other unmanned airborne systems… A formal policy will be developed in the near future which will outline the process for acceptable use of UAVs for research and/or operational purposes (USAP, 2014).

A related question is whether or not there will be a consistent approach to regulation among all Antarctic programmes that use drones. Given the collaborative nature of Antarctic research there is also potentially an as yet unanswered question as to which state's regulation would apply in research projects involving researchers from several nations. What happens if contradictory national regulations or requirements apply to parties from different nations? Which country's programme guidelines would apply?

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Another unresolved issue is what might happen if drone use by tourists were to interfere with scientific research. The handbook gives no guidance as to how the scientific use of drones might interact with other lawful activities in Antarctica and the Southern Ocean, such as tourism or fishing.

In light of those issues the following discussion examines the separate response that has been developed by the tourist industry in Antarctica.

IAATO moratorium

Regulation of tourist activity in Antarctica relies heavily on the responsible stewardship of tourist operators, principally through guidelines developed by IAATO. IAATO is an international industry organisation comprised of more than 100 companies and organisations from Argentina, Australia, Belgium, Canada, Chile, France, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, the People's Republic of China, Russia, South Africa, Sweden, Switzerland, the UK and the USA engaged in Antarctic tourism (IAATO, 2016b).

In the 2014/2015 tourist season, 68 UAV flights were reported by IAATO members, comprising 44 in coastal regions and 24 in deep field environments including coastal areas fringed by ice shelves (IAATO, 2015). The vast majority of these flights were primarily for professional filming purposes and to a lesser extent for ice reconnaissance or in support of scientific research work (IAATO, 2015). Of these 68 flights, only one major incident was reported when one UAV was lost in a crevasse at Waddington Bay. This UAV was operating from a yacht. In addition, there was one reported case of a tourist operating a UAV without approval that was stopped by the tour operator (IAATO, 2015).

In the 2015/2016 season, IAATO reported a total of 96 UAV flights associated with activities of IAATO members. Of these, 89 flights occurred in coastal regions and seven occurred at non-coastal deep field sites, primarily for commercial filming purposes (IAATO, 2016a). There were no reported incidents involving UAVs during the 2015/2016 season, although there was one reported instance of an unauthorised flight at Neko Harbour (IAATO, 2016a).

To its credit IAATO has recognised that the use of UAVs by tourists in Antarctica does come with potential environmental impacts. Thus IAATO has noted:

> UAVs have the potential to cause more than a minor or transitory impact, particularly in wildlife rich coastal regions of Antarctica such as the Peninsula or Ross Sea areas. Their use could also undermine other visitor's wilderness experience if operated incorrectly or insensitively, and may generate waste if lost (IAATO, 2015, p. 1).

In an information paper submitted at the ATCM in 2015, IAATO reported that for the 2015/2016 season a temporary moratorium on the use of UAVs applying to their members' operations (originally developed for the 2014/2015 season) was re-affirmed with some minor amendment at the IAATO meeting in 2015 (IAATO, 2015). The current version of the IAATO statement on the use of UAVs that applies for the 2016/2017 tourist season provides:

> IAATO accept the general use of UAVs within their members' operations, provided the following criteria have been met:
>
> - For the 2016–17 season, recreational UAV flights are not allowed in coastal areas;
> - UAV flights for scientific or commercial purposes are allowed, if conducted with the permission/authorization from a competent authority;
> - UAV flights are allowed at deep field sites, including coastal areas bound by ice shelves, if conducted with the permission/authorization from a competent authority.
>
> Members who allow UAV flights should have standard operating procedures in place that are specific to their operation.
>
> Prior to conducting the activity, the use of Unmanned Aerial Vehicles (UAVs) must be included in the operator's permit/authorization conditions e.g. Advance Notification, Environmental Impact Assessment (EIA) and Waste Management Permit (WMP), where relevant (IAATO, 2016c, pp. 1–2).

Thus under the terms of the current moratorium recreational UAV flights would not be permitted in coastal areas, although UAV flights for scientific or commercial purposes would be allowed if conducted with permission/authorisation from a competent authority. But as noted above current regulation to the extent it applies to scientific research conducted as part of national Antarctic programmes is at best patchy and under development, while regulation for commercial uses has not been canvassed at all in the current debates. Similarly, UAV flights by tourists would also be allowed at deep field sites, including coastal areas bound by ice shelves, if conducted with permission/authorisation from a competent authority. But here again currently there is no mechanism in place for competent national authorities to grant permission for tourist uses.

More significantly, as noted above under the IAATO statement, UAV flights are allowed at 'deep field sites, including coastal areas bound by ice shelves', if conducted with permission/authorisation from a competent authority. But the IAATO statement does not clearly define what these sites are and where these sites are located. One way that this issue could be addressed would be for these sites to be identified on a map. If IAATO were to publish such a map tour operators would then clearly know where UAVs should or should not be used. This would also help identify any potential conflict with important sites such as roosting sites, locations where active scientific research is being undertaken or other sites where UAV use may raise concerns. As far as the author is aware to date no such maps exist.

Similarly, while the IAATO statement makes clear that prior to conducting the activity the use of UAVs must be included in the tourist operator's permit or authorisation conditions such as those relating to advance notification, environmental impact assessment and its waste management permits, where relevant, it is not clear how these conditions of approval are to be sought.

In addition, a series of points to be considered for operators were suggested by IAATO to its members. These points are as follows:

1. Legal requirements

The tour operator and pilot must be familiar with, and adhere to, Antarctic Treaty and National legal requirements.

2. Flight Operations and Piloting of UAVs

All flights should be pre-approved by an authorized person/ EL.
UAV equipment should be inspected by an authorized person/EL to ensure that it meets the requirements outlined in the authorised operating procedures.
UAVs should be of robust construction with suitable safety features for use in Antarctica. If operated over water it should have a flotation device or alternative mechanism (such as a leash) to allow for recovery if it lands in the water.
UAV pilots should be able to demonstrate proficiency and experience in varied flying conditions.
UAVs should not be operated in the immediate vicinity of a vessel if the vessel's radar is operational.
Every flight should adhere to the individual Members Standard Operating Procedures and a risk assessment carried out in advance for the activity.
Each flight should have a pilot and an observer (except during solo expeditions).
Pre-flight planning should include identifying an alternate landing area away from the launch site should the launch site become unusable. The authorized person/EL should be made aware of the alternate landing site before the flight begins.
A test flight should be undertaken to show the authorized person/EL that the equipment is fit for purpose, and the pilot is proficient in its operation and use in the Antarctic.
Each flight should begin with an airborne test of the UAV and its systems in an area away from people and wildlife. This should include testing the UAV's failsafe systems for auto-return. (It is noted that south of 70 degrees, failsafe systems may be unreliable).
The pilot should maintain visual contact with the UAV at all times.
The observer should maintain a lookout over the area for wildlife, people or other hazards, change in weather conditions and is responsible for monitoring signs of disturbance by wildlife.
The observer is responsible for maintaining VHF radio contact with the other staff (Authorized person/EL/Bridge/Communications team). The pilot should not use a VHF radio while the UAV is airborne.

3. Flight restrictions

Flights should be conducted in fair weather, with a cloud base sufficiently high that visual contact can be maintained with the UAV at all times.
Total flight durations should not exceed 15 minutes, and the pilot must have a way to monitor the flight battery voltage at all times during the flight. (It is noted that in colder conditions flight time will be controlled by battery life).
Flights should not be started in winds exceeding the UAV manufacturers recommended maximum and should be aborted if winds exceed 25 knots.
The maximum altitude should not exceed 300 feet (90 meters) Above Ground Level (AGL) at any time.
The maximum distance away from the pilot should not exceed 100 meters but never beyond visual contact of the observer.

4. Environmental restrictions

UAVs must not be flown over or near to concentrations of wildlife on shore or at sea, or over concentrations of marine mammals and flying birds.
UAVs must not be flown over Antarctic Specially Protected Areas (ASPAs).
UAVs must not be flown over Antarctic Specially Managed Areas (ASMAs) unless the activity is specifically allowed in the ASMA Management Plan.
UAVs must not be flown directly over designated Historic Sites and Monuments (HSMs).
UAVs must not be flown in the vicinity of scientific stations without the permission of the Base Commander.
If any wildlife indicates disturbance, unusual behaviour, or interest in the UAV, the flight should be aborted immediately.
In the event of a crash, every effort should be made to collect all the remains and evidence of the UAV, if safe to do so.

5. Record Keeping

A log of flights must be maintained, including location, length of flight, weather conditions, any crashes or unexpected landings.
UAV flights must be recorded on the PVR (post-visit report).
Additional reporting to the operator's competent authority may be required under permit/authorization conditions (IAATO 2015, pp. 4–6).

These points for consideration are comprehensive and do cover the key issues that have been raised in relation to UAV use in Antarctica, including important issues such as pilot training, safe operation in hazardous conditions and, importantly, significant restrictions on where UAVs can be flown. IAATO therefore appears to have introduced robust recommendations to its members. While the explicit recognition of the need of operators to comply with the provisions of the Antarctic Treaty and the Madrid Protocol is a positive sign, it remains to be seen whether these points for consideration will be adequate into the future and whether or not more robust regulatory responses may be required by state parties to the Antarctic Treaty and the Madrid Protocol. One obvious measure that states could adopt to strengthen this might be for key provisions banning flight over ASPAs, ASMAs and Historic Sites and Monuments (HSMs) to be included in relevant management plans and other instruments regulating activity in such protected areas.

Similarly, it might also be worthwhile for state parties to revisit the provisions of the *Guidelines for the operation of aircraft near concentrations of birds in Antarctica* adopted under Resolution 2 at ATCM XXVI in Cape Town in 2004 (ATCM, 2004). These guidelines contain recommended separation distances and recommended measures to avoid disturbance of wildlife by fixed wing aircraft and helicopters. For example, under the guidelines, penguin, albatross and other bird colonies must not be overflown below 2000 ft. However, with the minimal noise and less disturbance caused by UAVs, overflight at much lower altitudes might be permissible. But given the acknowledged lack of scientific evidence on environmental impacts noted earlier, any such changes to the guidelines will need to await the outcome of the collection of further data on possible environmental impacts of UAV use.

In addition, consideration may also need to be given as to whether further amendment to the guidelines is required to specify when UAVs can be used so as not to disrupt breeding seasons. The flight season of fixed wing aircraft and helicopters is currently restricted and given the current state of scientific knowledge it is an open question as to whether these could be relaxed for some UAVs. Again this awaits further information on the environmental impact of UAVs.

Other outstanding issues

The measures adopted by IAATO are a welcome step. In many respects the IAATO provisions are more comprehensive than those contained in the UAS Operator's Handbook. Many of the IAATO provisions could be integrated into the handbook, provisions on operating in protected areas or those dealing with the weather in which UAVs can or cannot be operated being two obvious examples, although many others might also be worth incorporating. Given that the UAS Operator's Handbook is regarded as a living document that has been designed to change over time, provisions of the IAATO measures could easily be copied and incorporated.

However, some of the IAATO provisions would not be appropriate for scientific research. For example, the requirement that the pilot maintain visual contact with the UAV at all times. While this is desirable for small UAVs it is not practical for some of the larger long-range UAVs used by some national Antarctic programmes such as the British Antarctic Survey. For large drones such as these, regulation would instead need to address minimum requirements for electronic communication or radar contact, for example. This one issue suggests that as regulation evolves it may be that we see the emergence of guidelines appropriate for specific forms of technology. Similarly, as scientific understanding of the environmental impact of UAVs grows it might be that species-specific guidelines for overflight might be appropriate.

In a similar vein the regulatory response to UAVs in Antarctica may have to evolve over time as other international regulatory frameworks are developed. One obvious area that will need to be watched by Antarctic policy makers will be the work of the International Civil Aviation Organisation (ICAO) on drones. The most relevant aviation treaty in this context is the Convention on International Civil Aviation (signed in Chicago on 7 December 1944 and amended by the ICAO Assembly [Doc 7300]; hereinafter referred to as the Chicago Convention). Article 8 of the Chicago Convention provides:

> No aircraft capable of being flown without a pilot shall be flown without a pilot over the territory of a contracting State without special authorization by that State and in accordance with the terms of such authorization.

Given the, at times, ambiguous nature of jurisdiction in Antarctica, it is unclear if drone use in Antarctica constitutes international civil aviation within the remit of ICAO. In the context of the contested nature of claims to territory in Antarctica and the provisions of the Antarctic Treaty dealing with territorial claims what meaning do we give to 'territory' in the Antarctic context? How is special authorisation to be obtained when, as noted above, most countries active in Antarctica are yet to develop regulation of drone use in Antarctica under their national law? For the time being these remain unanswered questions.

In any event ICAO is still struggling with developing an appropriate regulatory response in areas within national jurisdiction where these concepts are not contested. In 2011, ICAO issued a circular on UAS as a 'first snapshot on the subject' (ICAO, 2011, p. iii). Although further work on developing appropriate regulatory frameworks for UAVs is currently being undertaken by ICAO, the first regulatory instruments are not likely to be issued before 2018 (Casey, 2015). Nonetheless, developments outside the Antarctic Treaty System, such as those under the auspices of ICAO, will need to be monitored in coming years for their implications for drone use in the Antarctic context.

Long term, other questions may arise from the increased use of UAVs in Antarctica that we cannot yet anticipate. Crampton (2016) recently argued that UAVs 'constitute socio-technical assemblage of the sky and vertical space' and urges future analysis not only of their technological development and capacities but also of the implications 'their effects and affects' (p. 137). What will be both the long-term effects and affects of UAV use in Antarctica? These are questions we may only ever be able to answer with hindsight. But two initial issues come to mind. First, if UAVs are now to hover in the most remote and isolated place on earth what does this mean for the conceptualisation of Antarctica as a wilderness? This is a question that in turn raises the key question raised by Bastmeijer nearly a decade ago, 'What are wilderness values in the context of the polar regions and when would these be affected?' (Bastmeijer, 2009, p. 73). Can one really have a wilderness if drones buzz overhead?

Alternatively, what might the 'nationalisation' of airspace through separate regulation of UAV use by national Antarctic programmes have on airspace over Antarctica. Will this undermine the 'grand bargain' on the sovereignty question, the freeze on territorial claims set out in Article IV of the Antarctic Treaty? The regulation of drone use in airspace that is currently strictly neither national nor international may, longer term, hold as yet unknown implications for the 'frozen' claims to sovereignty in Antarctica.

Conclusion

As the data set out in this paper has highlighted drones are increasingly becoming an integral part of scientific research in Antarctica, and their emergence is largely to be welcomed. There is also emerging evidence of their use by tourists in Antarctica. Both uses raise issues of their environmental impact as well as safety. These key issues highlight the need for a regulatory response in some form.

The development of the UAS Operator's Handbook and the measures introduced by IAATO are a promising first response. While both of these responses are positive first steps it is clear that they will need to evolve over time. The greatest weakness appears to be the fact that separate responses have emerged for scientific and tourist use of drones, and neither has any binding legal force. While the non-legally binding nature of both responses may not be an issue if they are implemented, in future a more holistic response merging the two responses into one might be appropriate. Each has positive aspects that if combined could provide a more robust response. It is clear that drone use will increase over time and that the regulatory response will need to adjust to increased use, changes in technology and, most significantly, the growing understanding of their environmental impact.

Often the first visceral response to the emergence of any new technology or issue in Antarctica is to call for a moratorium on its use or deployment. As the discussion above has highlighted, given the widespread use of drones in Antarctic scientific research already a moratorium is neither achievable nor desirable. In the case of tourist use, a limited moratorium has been implemented by the tourist industry; however, this is unlikely to hold for long and therefore the emerging regulatory response will need to evolve with growing tourist use. It is clear that drones will increasingly be seen on and above the ice in the Antarctic and the Southern Ocean over coming years and that debates on appropriate regulatory responses to their use will evolve as well.

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