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Critical Literature Review
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The Evolution Unmanned Aerial Vehicles (UAV), Emerging Policy Challenges and Future UAV Use in Antarctica

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Abstract: In 2015, the availability and use of UAV's around the world has increased sharply, along with their capabilities and range. This reviews their evolution, users and uses, specific Antarctic considerations and the emerging policy and guidelines regarding their future use in Antarctica.

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Introduction

In recent years, off the shelf remotely controlled Unmanned Aerial Vehicles (UAV's) have become sophisticated, readily available, and have significant range and capabilities. Resulting rapid growth in their popularity and deployment is causing privacy and airspace security issues around the developed world. In Antarctica the increasing level of use is no different, but with additional complications due to the valued pristine state of the continent, historic values, wildlife values and overlapping geopolitical stances.

In response to discussions at the 38th Antarctic Treaty Committee of Managers (ATCM) meeting in 2015, National Antarctic Programs (NAP's) and other operators (such as the International Association of Antarctic Tour Operators (IAATO), have been asked for input regarding the use of UAV in Antarctica. Along with the Arctic Science Remotely Piloted Aircraft Systems (RPAS) Operators Handbook[1], input is being considered in the process of drafting the guidelines that are being drawn up to present to the 39th ATCM meeting in 2016.

In the meantime, the IAATO, has stopped clients from using UAV's for non-commercial activities in the Antarctic region for the 2015/16 tour season[2].

As the first set of formal guidelines are still being developed and have due to be presented to the 39th ATCM meeting, it is not possible to comment on them directly. In the meantime the United States Antarctic Program (USAP) has adopted the in Chapter 4 of Ops Policy Master Draft (2014) is available and is the temporary stand in policy for US operating airspace in Antarctica - essentially requiring Antarctic UAV operators to comply with Federal Aviation Administration (FAA) requirements within US National Air Space (which in practice includes all of NZ's Ross Dependency).

The benefits of UAV use in Antarctica are relatively simple to understand. Today's UAV's are cheap, very capable, very portable and can be deployed in the field for research with a fraction of the risk to human life and financial cost compared to traditional methods and quality data can be gathered rapidly.

Fully understanding the current situation and the 'sudden' need for regulation is not quite so simple. This paper reviews the issues and the complexity and points to the main cause of the today's regulatory haste.

Starting with a review of the historical development of UAV's, I will then summarise and comment on the UAV types and UAV operators (as outlined by the temporary policy) .

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[1] *ARCTIC SCIENCE REMOTELY PILOTED AIRCRAFT SYSTEMS (RPAS) OPERATOR'S HANDBOOK*
(Arctic Monitoring and Assessment Programme (AMAP) Unmanned Aircraft Systems Expert Group)

[2] see IP 88 *IAATO Policies on Unmanned Aerial Vehicles (UAV)*

Finally, I will review and comment on specific issues of UAV's in the Antarctic context, and likely challenges that Antarctic UAV policy may have to contend with in the future.

For the purpose of this paper, military UAV's and operations are not considered.

The History of UAV's

UAV's are not a recent invention, they have been around for over 115 years.

Before the turn of the 19th century, Nicola Tesla[3] publicly demonstrated an unmanned boat that was controlled by radio signal in Madison Square Gardens, New York. He was awarded a US patent covering them in 1898. For decades after this, radio controlled aircraft, cars, boats, submarines have mostly been used by hobbyist and less frequently for research and commercial purposes. Typically these vehicles received radio signals from the transmitter that controlled the direction and speed of the vehicles. For aircraft, fixed wing styled models were the norm and they tended to be scaled down versions of full size aircraft. The enthusiastic and well funded were able to venture into rotary winged craft (helicopters). While electric power is currently predominantly used, historically, virtually internal combustion engines as batteries propelled all and electric motors of the day were neither light enough nor powerful enough for the task at hand.

XSENS CryoWing fixed-wing UAV used by Northern Research Institute in Norway (NORUT) (Source : www.xsens.com)

Advances in technology have meant that the old design limitations have been left behind. As batteries have become lighter and capable of storing and delivering higher loads, electric motors have also become lighter and more powerful. Today, flight times of 30 minutes on a fully charged battery is common. Technology has allowed the basic platform of the "scaled" helicopter to be substantially enhanced by the addition of horizontally rotating blades mounted on the end of arms in a 4, 6, or 8 blade format whose stable flight is substantially computer assisted and GPS linked.

[3] "Nikola Tesla - Engineer, Inventor - Biography.com." 2011. 13 Dec. 2015 <http://www.biography.com/people/nikola-tesla-9504443>

Traditional Helicopter UAV format carrying camera equipment (Source: rcrumble.com_big-rc-helicopter)

Off the shelf DJI Phantom 3 UAV and controller showing Ipad Mini being used to display flight information and live video feed from UAV. (Source DJI.com)

They can have a top speed of over 100kph and are capable of a Vertical Take Off and Landing (VTOL). They can hover at a set altitude in reasonably windy conditions . Using the onboard cameras they can record Ultra High Definition photos and video footage. Radio signals can now be sent between 2 km- 6km range. Given their size and lightweight, very capable multi-rotor UAV's can be carried in a backpack, launched from almost anywhere and flown beyond the sight of the operator by novices who have very little training.

As a generalisation, multi-rotor UAV's tend to get used for closer proximity wildlife work and filming, and wide ranging environmental work is the domain of fixed wing UAV's.

As an indication of the speed that UAV's have evolved, in a 2008 Postgraduate Certificate in Antarctic Studies report (Brears 2010)[4], Brears made no mention of UAV's being used in Antarctica, only fixed wing airplane style aircraft. In the last 7 years, UAV's have gone from an infrequently used science tool, to having severely (albeit temporary) restricting policies placed over their use while the governing community figures out the best way to manage UAV use in Antarctica.

Users

The 2014 AOM policy definitions (Appendix C) glosses over what is the crux of the UAV situation.

The policy breaks down UAV size and capability into 3 Types:

1. 55lbs or less, and capable of less than 70 knots (Approx 130kph) and must only be used for Line of Sight (LOS) flights
2. 22-330 lbs and capable of less than 200 knots (370kph)
3. above 330lbs and 200 knots.

Type 1 and 2 are referred to "sUAV"s (Small UAV's) with Type 1 sometime called "micro UAV's.
Most multi-rotor UAV's are Type 1, with fixed wing UAV's appearing in all categories.
Type 2 and 3 are most often fixed wing aircraft.
For all intensive purposes, most commercially available off the shelf UAV's fall into category 1. Due to their cost and performance, Category 2 and 3 UAV's tend to be flown by well-trained operators (and not relevant to this discussion).

Users are categorised as :

1. Radio Control Pilot (RC Pilot)
2. Pilot - Operator
3. Remote Pilot.

All 3 categories require operators to have current FAA Second Class Medical certificates,

The RC Pilot is identified as likely to be the hobbyist operator of an off the shelf Type 1 sUAV (limited to LOS flight). The Initial Training specified in the UAS Pilot Matrix (Appendix B) includes completion of an Agency (FAA) developed and approved course OR to have completed FAA Private Pilot written exam.

The issue arises in micro UAV's are freely available from retail or Internet stores. The result is the vast majority of micro UAV's are sold to unqualified hobbyist operators. While many hobbyists may be just as skilled and capable as researchers and commercial operators, the range of their abilities can vary hugely and, yet this is the group that

[4] "Using *unmanned aerial vehicles* in Antarctica", Robert *Brears*, 2010.

contains the operators who may launch their first UAV flight in Antarctica. They have non-scientific motives and desires that are widely varied as they attempt to have a close encounter with wilderness (and for some, the closer the better), whether in person or vicariously via a UAV mounted camera.

In the Antarctic context, this is the category that tourist or non-professional/researcher members of a National Antarctic Program (NAP) fall into and this is a key area that needs to be written into policy without creating too much restriction and administration upon genuine scientific operators. It is also this group that the much outreach occurs and is important to consider the public awareness the hobbyist can generate regarding Antarctica.

Specific Antarctic Considerations

1. Wildlife approaches

In Antarctica, UAV's for environmental data gathering using fixed wing platform offers little interference with wildlife, but the need for operators to communicate with other air operators always exists.

Multi-rotor UAV's manoeuvrability allows them to be used for wildlife monitoring. However; there is concern with the disturbance to the natural habitat of the wildlife. This has become an issue. Feedback to COMNAP from NAP's and other researchers tends to vary regarding appropriate minimum distances to avoid wildlife disturbance. However; it is noted (Ellenburg, 2009) that variation in responses vary between species and even by location with-in species exists. So to make rules that will suit all will be difficult.

Globally, there is very little in the way of scientific conclusions regarding wildlife disturbance or responses from the effects of UAV's, . What has been done is based on visual observations. Observations in Information Papers such as the likes of Poland's IP77 "seeing no signs of fright, panic or nest abandonment at UAV approach". These may be an accurate one-off or short-term **observations,** but it is pointed out that behaviour observations do not reflect physiological responses, (Coetzz & Chown, 2015[5], Goebel et al. 2015[6], Vas et al. 2015[7]), nor can it reflect long term accumulated impacts such as described in Ellenburg (2009).

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[5] Bernard W. T. Coetzee* and Steven L. Chown, "A meta-analysis of human disturbance impacts on Antarctic wildlife", Article first published online: 28 APR 2015
DOI: 10.1111/brv.12184

[6] Goebel, M.E., Perryman, W.L., Hinke, J.T., Krause, D.J., Hann, N.A., Gardner, S. and LeRoi, D.J. 2015. "A small unmanned aerial system for estimating abundance and size of Antarctic predators". Polar Biol. DOI 10.1007/S00300-014-1625-4

[7] Elisabeth Vas, Amélie Lescroël, Olivier Duriez, Guillaume Boguszewski, David Grémillet, "Approaching birds with drones: first experiments and ethical guidelines" Published 4 February 2015.DOI: 10.1098/rsbl.2014.0754

It is the physiological and cumulative impacts upon wildlife in Antarctica that is of concern as the long term cumulative impact UAV disturbance has not yet been established of and unfortunately also very difficult and timely to determine.

Vas went on to observe that not only the approach distance is important, but that the approach angle of a UAV has an impact, as vertical type approaches seemed to trigger responses similar to that of an approaching predator. Vas' study involved flamingos and greenshanks in a wetland area and found that 80% of 204 flights "we could approach unaffected birds to within 4 m" (which is exceedingly close and very different to the authors observations during recreational flights) yet a launch distance of 100m be used, but applying these findings to Antarctic species may not be appropriate. The paper acknowledges that further physiological based work for other species, UAV's, population sizes and breeding cycle.

In WP 27 "Wildlife Approach Distances In Antarctica" the Scientific Committee on Antarctic Research (SCAR) recognises that the issue of approach distances (for both foot based approaches and UAV) be urgently reviewed, based upon evidence based research (i.e. physiological indicators) rather than visual behavioural indicators and that a case by case approach be taken.

There is not yet general consensus on the topic of appropriate approach distances. In IP 83, "Guidance on unmanned aerial system (UAS) use in Antarctica developed for applications to scientific studies on penguins and seals" the US contribution comments that approach distances of 30-60m for penguins and 23m for seal has been used, this closer proximity is unlikely to be required for scientific research. In many instances, depending on the data being collected, the degree of sensor (camera) resolution is sufficient that accurate data can often be achieved from distances well beyond distances reported to initiate disturbance behaviour.

Aside the need to determine appropriate approach distances, the requirement for regulation becomes more of a need of management of people's desire to get close to wildlife in order to obtain the wilderness experience. This phenomenon is not limited to tourists, but to people in general, and so applies to all scientific and support staff, backing up the need for SCAR's recommendation for a review of appropriate approach distances - although commercial personal would be expected to be more aware and concerned of disturbance issues.

2. Overlapping legislation and the Presence of UAV's in Airspace

Currently, UAV's do not have on board collision detection/avoidance mechanisms. Due to the possible financial cost and risk to human life, this heightened risk of collision (as remote as it may be in practical terms) is a concern to air space controllers around the world. Internationally, controlled air traffic terminals have “No UAV flight” zones around them. In Antarctica, air traffic is an essential part of life, so the importance of the integrated communication regarding UAV operations and aircraft operations is essential and it needs to be consistent across the continent, regardless of use (tourism, scientific, hobbyist etc), and regulation regarding this is required.

Due to the unique nature of the governance of Antarctica, there are instances where more than one country can consider it has jurisdiction over the activities that occur on the same location. This occurrence highlights the need for the establishment for generally accepted guidelines, and in the case of conflicting policies, the most restrictive is likely to prevail.

The close proximity of the US McMurdo Base and New Zealand Scott Base sets up an interesting dynamic. Due US/NZ reliance on each other for logistical support in Antarctica, and the US essentially controlling the airspace, NZ science programs are needing to ask the US Department of Defence for permission to launch a UAV within McMurdo airspace (which covers most of the Antarctic science the NZ NAP is undertaking). The US approach to UAV’s is currently much more restrictive than the NZ approach, and, NZ scientists have no guarantees of gaining permission to operate a UAV after lengthy and complicated applications process.
Although this situation is likely to correct itself as guidelines, legislation and procedures are established, it is a good illustration of the issues that arise from the open commons governance of Antarctica.

3. Non- recovery of UAV in Event of a Crash.
Any flying vehicle is susceptible to crashing, and the issues of waste and contamination arise when a UAV crashes (or is lost) and is not recovered - violating the Antarctic Conservation Act. Crashes can occur at even close proximity (i.e. into a crevasse or into the sea), was well as if the UAV is out of sight of the operator. While operator training reduces the likelihood of a crash occurring, the risk will always remain (such with the loss of a UAV into crevasse in Waddington Bay by a professional filming crew[8].

While UAV’s can be mounted with tracking mechanisms to aid recovery and off the shelf UAV’s have automatic “return to home” settings if communications are lost, how legislation will fully handle a non-recovered crash is not clear – especially as attempting to recover a UAV from a crevasse may often cause exposure of human life. Currently, under the Antarctic Conservation Act, non-recovery requires a report to be filed and punitive actions may result.[9]

This is one aspect that will be up to policy makers to determine.

4. UAV Prohibited/Restricted Zones.

[8] IAATO, IP88 May 2015
[9] UAS Ops Policy, 2014.

There are some areas that are not near air traffic terminals that are inappropriate for UAV's to be in. For example, sensitive electromagnetic atmospheric experiments, (e.g. Observation Hill), or other sensitive or highly valued areas that are typically covered by an Antarctic Specially Protected Area (ASPA) such as the historic huts. These areas need to be identified and managed appropriately on a case-by-case basis.

Future Challenges

As technological advances are made, UAV (of all sizes) capabilities will continue to increase, and they will become more affordable. An example can be seen in the emerging range battery powered electric engines with on board solar charging technology. A 48-hour long flight by the 13kg SoLong UAV in 2005 (http://www.tu.no/migration_catalog/2005/07/24/solong-info/binary/SoLong%20info) was achieved and this range has increased since then and multi day flights are no longer news.

Today's computer assisted control of UAV's is only a step away from more "artificially intelligently" function units. When commercially available, long ranging self-determining "artificial intelligent" UAV's will give rise to the need to review regulation and operator licensing. The ability for UAV's to assist humans in the Antarctic environment will only extend over time and it will not be the last time that regulation and policy has to play catch up.

Charged with the preservation and protection values of the Antarctic environment, the Antarctic governing community have good cause to be concerned. Given the unpredictability of technological advances, longer range (and flight times) and "artificial intelligence" are just 2 advancements that any current management policies will need to be continually and quickly modified in order to keep up to date.

Conclusion

UAV's will continue to develop in capabilities, and people will find more and more applications for them, guidelines and regulations regarding their use in Antarctica will always tend to be reactionary in nature. As there is little scientific evidence regarding the physiological impacts of disturbance UAV's cause to wildlife, regulation will need to err on the side of caution in order to avoid inappropriate negative impacts upon Antarctic population

While the (untrained, unlicensed) general public can purchase very capable units relatively cheaply from retail shops, yet in many situations (as in Antarctica) require recognised training in order to fly them to their capacity, UAV's (and micro UAV's in particular) will require significant management from the Antarctic governing and management community.

UAV’s have much to offer Antarctica in the way of fast, low impact data collection and educational or outreach video/photography (amongst other things), and it will continue to be a balancing act to establish a stable regulation/guideline format that will allow maximum benefit to be achieved from UAV use and yet not be overly restrictive and cumbersome.