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# Enabling Science use of Unmanned Aircraft Systems for Arctic Environmental Monitoring

W. Crowe, K.D. Davis, A. la Cour-Harbo, T. Vihma, S. Lesenkov, R. Eppi, E.C. Weatherhead, P. Liu, M. Raustein, M. Abrahamsson, K-S. Johansen, D. Marshall, R. Storvold, B. Mulac

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The Arctic Monitoring and Assessment Programme (AMAP) was established in June 1991 by the eight Arctic countries (Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden and the United States) to implement parts of the Arctic Environmental Protection Strategy (AEPS). AMAP is now one of six working groups of the Arctic Council, members of which include the eight Arctic countries, the six Arctic Council Permanent Participants (indigenous peoples' organizations), together with observing countries and organizations.

AMAP's objective is to provide 'reliable and sufficient information on the status of, and threats to, the Arctic environment, and to provide scientific advice on actions to be taken in order to support Arctic governments in their efforts to take remedial and preventive actions to reduce adverse effects of contaminants and climate change'.

AMAP produces, at regular intervals, assessment reports that address a range of Arctic pollution and climate change issues, including effects on health of Arctic human populations. These are presented to Arctic Council Ministers in 'State of the Arctic Environment' reports that form a basis for necessary steps to be taken to protect the Arctic and its inhabitants.

AMAP technical reports are intended to communicate the results of scientific work that contributes to the AMAP assessment process. This report has been subject to a formal and comprehensive peer review process. The results and any views expressed in this series are the responsibility of those scientists and experts engaged in the preparation of the reports and have not been approved by either the AMAP working group or the Arctic Council.

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The AMAP Secretariat is located in Oslo, Norway. For further information regarding AMAP or ordering of reports, please contact the AMAP Secretariat (Gaustadalléen 21, N-0349 Oslo, Norway) or visit the AMAP website at www.amap.no.

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# Executive Summary


The Arctic is a critically important environment with a strong influence on global climate and is a significant source of oceanic primary production. Scientists, researchers and governments have monitored the Arctic environment for decades by the use of aircraft, satellites and *in situ* measurements at the surface. However, collecting the necessary data for proper analysis of the changes and conditions in the Arctic has been extremely difficult, presenting technological, environmental and human challenges that call for innovative approaches to address and overcome the many barriers that the region presents. Foremost being remoteness, severe weather, and lack of infrastructure to support science missions. A potential solution to many of those problems is the use of remotely piloted aircraft (RPA), also known as unmanned aircraft systems, or 'UAS'. The use of UAS for environmental research in the Arctic began in 1999 with research conducted by the University of Colorado and funded by the National Science Foundation to deploy small, low altitude, long endurance UAS from Barrow, Alaska. The number of science missions in the Arctic that have used UAS has gradually increased over the ensuing eleven years. In 2010/11, Arctic UAS missions were performed in the United States, Norway, Greenland, Iceland, Canada, and Russia by at least five different operators of scientific UAS.

AMAP first addressed the issue of using unmanned aircraft to examine the significant data gaps present in Arctic studies, as well as their potential for helping fill these gaps, in spring 2008 at a meeting of concerned Arctic scientists in Stockholm. While the group strongly recommended the benefits of UAS, it acknowledged that the technology is not without challenges, and that understanding these challenges is necessary to realize their potential as an environmental monitoring tool. One of the most significant challenges is gaining access to airspace in order to fly the science missions.

The AMAP UAS Expert Group was assembled specifically to study the research needs in the Arctic and to explore the opportunities for conducting a significant portion of that research using UAS. Management and control of the Arctic airspace is conducted by eight different nations pursuant to Supplemental Agreements to the Convention on International Civil Aviation, under the jurisdiction of the International Civil Aviation Organization (ICAO). Each member State that provides air traffic services in their respective areas of influence in the Arctic is permitted to apply their own domestic civil aviation regulations in international airspace, to the extent that their regulations do not conflict with the Convention and its annexes and supplements. For researchers seeking access to the Arctic Flight Information Regions (FIRs), the task of determining what the rules for that access may be is a daunting one, since the rules may and do change as an aircraft passes from one FIR into the next. Because the research being conducted has a global reach and is for the benefit of all mankind, the impetus for a harmonized approach to gaining access to the Arctic for non-commercial and non-military reasons is great.

AMAP's intent is to apprise participating member States and the research community of the emerging ICAO perspective on the integration of UAS into non-segregated international airspace, domestic airspace and at aerodromes, to consider the fundamental differences from manned aviation that such integration will involve, and to encourage States to help with the development of ICAO UAS policy as well as their own UAS regulations by providing information on their experiences associated with these aircraft. To facilitate ongoing discussions of UAS integration and use in the Arctic, AMAP has compiled a summary of the aviation regulations of the eight member States as they may pertain to UAS operations; has proposed an outline set of Best Practices for the safe conduct of those operations, as well as a guideline for presenting a Safety Case to the Civil Aviation Authorities (CAAs) of the respective States to support permissions to operate in the Arctic; has described the technical and scientific capabilities of UAS; and, has outlined and proposed a strategy for UAS proponents and CAAs for the safe integration of UAS into the Arctic airspace.

The report concludes with three recommendations on future activities and projected deliverables for AMAP and the UAS Expert Group. The recommendations address policy considerations at the international level, cross-border agreements and collaborative airspace management strategies, as well as the development of the tools that will enable member States, their civil aviation authorities and potential users of the Arctic airspace to implement these policy and operational recommendations.

# 1. Introduction

The Arctic is a critically important environment with a strong influence on global climate and is a significant source of oceanic primary production. The effect of climate change is exaggerated in the Arctic and, as a result, the Arctic is undergoing very rapid change. Sea ice thickness and coverage are diminishing faster than projected just a few years ago and ecosystems are under severe stress. Because of the very rapid changes, scientists are scrambling to increase their understanding of the many climatic processes and mechanisms taking place within the Arctic. Unfortunately, monitoring the Arctic is extremely difficult, both from satellites and from ground-based stations. Manned flights across the Arctic supply some critical data, but are limited by weather conditions and are often not able to fly safely below the cloud layers, which can be as low as a few hundred feet for much of the year. There are many satellites in polar orbits that provide excellent coverage of the Arctic, but many of the instruments carried are unable to 'see' through the clouds that are present across the Arctic for much of the year. Owing to their long endurance, low altitude flight, and the lack of people on board, unmanned aircraft systems (UAS) offer new solutions to taking measurements across the vast Arctic that cannot easily and safely be made in any other manner (see Figure 1.1 for how UAS could complement the existing earth observation systems and Figure 1.2 for how UAS could

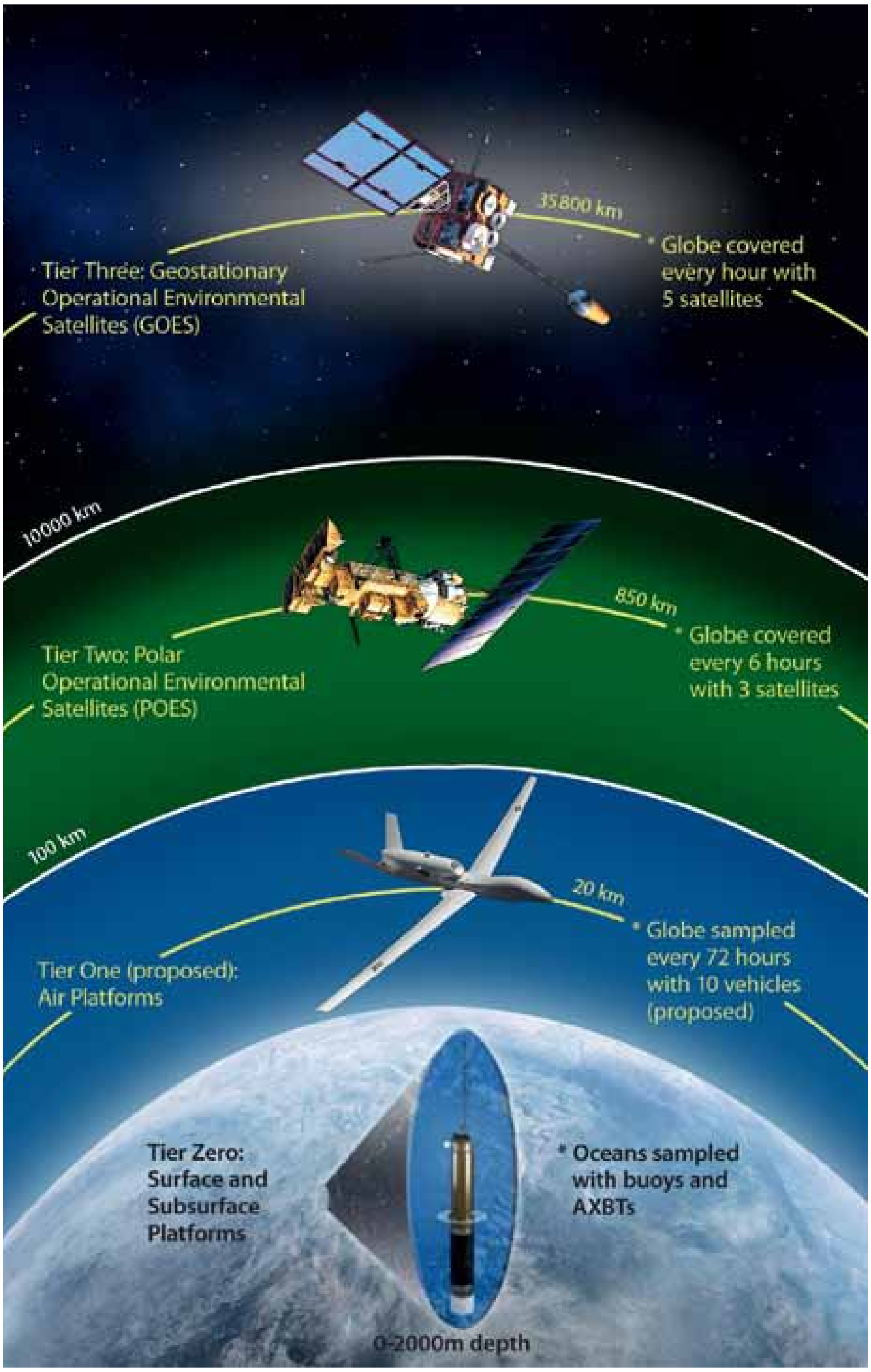


**Figure 1.1.** A graphic illustration of earth observation systems architecture, and how UAS complement and augment current remote and *in situ* observing technologies and capabilities. Based on an illustration supplied by NOAA (U.S. National Oceanic and Atmospheric Administration).

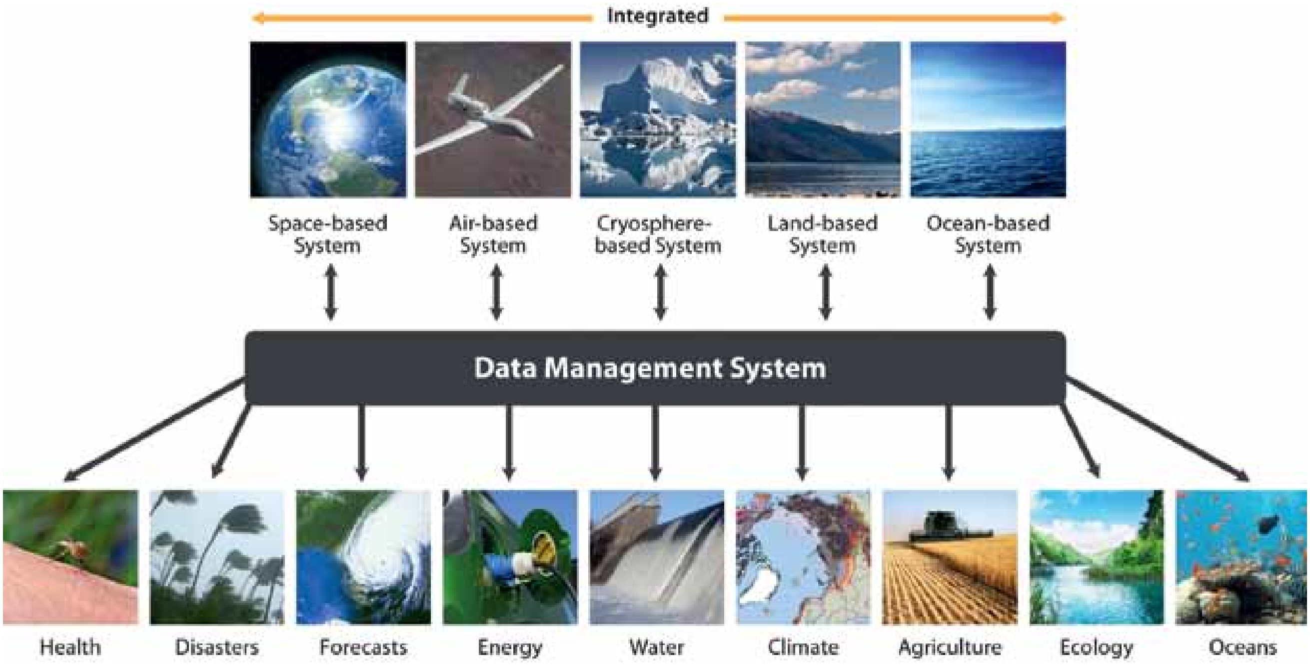


**Figure 1.2.** Eighty governments and 56 international organizations are collaborating to coordinate their observation strategies and interlink their observation, computing and modelling capabilities. The resulting Global Earth Observation System of Systems (GEOSS) is supporting decision-makers, managers and researchers as they address the challenges of global environmental change. GEOSS provides a broad range of societal benefits to which UAS could make a significant contribution, including understanding, assessing, predicting, mitigating, and adapting to climate variability and change. Based on an illustration supplied by GOE (Group on Earth Observations).

contribute to GEOSS – the Global Earth Observation System of Systems). The measurements can fill gaps in knowledge about weather, sea ice, ocean currents, pollution, marine mammals and fish. Scientists across the Arctic are embracing this technology as a means of addressing questions that previously could not be effectively answered.

Use of UAS for environmental research in the Arctic began in 1999, when researchers at the University of Colorado-Boulder received funding from the U.S. Department of Energy's Atmospheric Radiation Measurement program and later the U.S. National Science Foundation (2000-2005), to deploy the Aerosonde UAS from Barrow, Alaska over a five year period (Curry et al., 2004). The number of UAS-augmented science missions in the Arctic has gradually increased over the past decade. In 2010 and 2011, Arctic UAS missions were undertaken in the United States (Alaska), Norway, Greenland, Iceland, Canada, Sweden, Finland and Russia by a number of different operators of scientific UAS (see Figures 1.3 and 1.4). In many ways the Arctic has become the proving ground for

**Figure 1.3.** *Cryowing* Norut coming in to land at Summit Research Station, Greenland in 2010. Photo courtesy of Rune Storvold, Norut.

civilian use of UAS. Scientifically, UAS are supplying data that would be difficult, impossible, risky or expensive to gather in any other manner. In addition to the great scientific value of the operations, the flight activities themselves contribute to gathering experience, both for operators and regulators, on how to perform safe operations and air traffic management in an area where manned aviation is minimally impacted and the risk to life and property can be kept within acceptable regulatory standards. Gaining access to the airspace required to fly UAS in the areas of interest continues to be a major hurdle to their full utilization as an Arctic observing platform. The lack of regulations specific to UAS, as well as the low priority given to UAS by Civil Aviation Authorities (CAAs), has made it difficult to conduct operations even in remote regions like the Arctic. These barriers are not insignificant and require much work to overcome.

In 2008, scientists from the eight Arctic nations and observer countries came together and unanimously agreed that UAS represent a key tool for understanding the climate change underway in the Arctic and its impact on the global environment. As a result of recommendations to the Arctic Council, a UAS Expert Group was formed under AMAP to assist scientists studying the Arctic environment to more readily utilize UAS in their research.

**Figure 1.4.** Takeoff of *Eleron-10* AARI in Ny-Ålesund, Svalbard and Ny-Ålesund town from the air. Photos courtesy of Kjell-Sture Johansen, Norut (upper) and Sergey Lesenkov, AARI (lower).

# 2. Overview of AMAP UAS Expert Group

The Arctic Monitoring Assessment Programme (AMAP) has been an active advocate for gathering critical Arctic monitoring data, and prepares assessments and reports on findings as required by the Arctic Council. AMAP first addressed the issue of using unmanned aircraft to examine the significant data gaps present in Arctic studies, as well as their potential for helping fill these gaps, in spring 2008 at a meeting of concerned Arctic scientists in Stockholm. While the group strongly recommended the benefits of UAS, it acknowledged that the technology is not without challenges, and that understanding these challenges is necessary to realize their potential as an environmental monitoring tool. One of the most significant challenges is gaining access to airspace in order to fly the science missions. At the meeting the group agreed that the potential of UAS far outweighed the challenges, that airspace access was the greatest of these challenges, and that this should be addressed at the Arctic Council level. First, however, it was suggested that a meeting be held with the civil aviation authorities to determine the feasibility of improving access for UAS flights to conduct environmental monitoring. As a result, AMAP convened a second meeting, held in Oslo in autumn 2008, at which representatives of several CAAs, Arctic scientists and UAS operators met to discuss how access to airspace over the Arctic for UAS flights could be achieved more quickly but without sacrificing safety. The CAAs present agreed that they would be able to work with the science community to grant better access. Based on these discussions, AMAP recommended to the Arctic Council that it establish a formal group to assist the work on issues related to airspace. In April 2009, the Arctic Council duly established a UAS Expert Group under AMAP.

The UAS Expert Group is currently co-led by the United States and Norway. Representatives from each of the eight Arctic nations make up the group and include CAAs, individuals from scientific research institutes and universities who have experience flying UAS, and scientists interested in UAS for environmental monitoring.

The UAS Expert Group has focused on assisting the international Arctic science community with an understanding of the challenges associated with flying UAS, with particular emphasis on airspace access. While there is significant interest in flying UAS for environmental monitoring purposes, the best approach to secure the airspace access required to safely, yet successfully, conduct a science mission is not at all clear for many would-be UAS users within the science community. Regulations vary from country to country across the Arctic and this increases the challenge of understanding the steps involved. The UAS Expert Group has attempted to work with CAAs from each of the Arctic nations, although with limited success, to understand their current policies regarding access and to establish what options may exist to expand access safely to allow for greater environmental observation. Efforts by the Expert Group in this regard have been fairly limited owing to the lack of participation in the Group's activities and meetings by some Arctic nation CAAs.

To assist scientists in organizing and performing UAS missions in the Arctic, the Expert Group is compiling information from planned and completed missions, with particular emphasis on how airspace access is or was granted for these missions. Sharing this type of information is expected to help in understanding how much activity is ongoing in the different countries and can be used to promote science cooperation among the organizations involved. The shared information will also serve to inform CAAs of how much activity there really is to help push for higher priority and more resources for UAS, and could function as a resource for individuals within the CAAs who can be persuaded to promote the use of UAS technology within their service areas.

# 3. UAS airspace access and regulation

## 3.1 Regulatory challenges associated with use of UAS in the Arctic

The world's airspace is divided into eight major Flight Information Regions (FIRs) that are designated under the Convention on International Civil Aviation and its associated Annexes, the Procedures for Air Navigation Services (PANS), and various Supplemental Agreements. Each major region is divided into smaller regional FIRs in which flight information and air traffic management services are provided by member states. The Arctic region lies beneath four major FIRs (NAT, EUR, NAM , MID/ASIA). Six regional FIRs are of greatest interest in Arctic research (EDMONTON, SONDRESTROM, REYKJAVIK, BODO OCEANIC, MURMANSK/MAGADAN OCEANIC, and ANCHORAGE ARCTIC), but Finland and Sweden may also be important to scientists. The positions of these FIRs are shown in Figure 3.1.

A single FIR typically encompasses the airspace of smaller countries, while the airspace of larger countries may be subdivided into a number of regional FIRs. Some FIRs may include the territorial airspace of several countries. Oceanic airspace is divided into Oceanic Information Regions and delegated to a controlling authority bordering that region. There is no standard size for FIRs, as it is a matter for the administrative convenience of the country concerned. In some cases the FIR may be divided horizontally, in which case the lower part remains the designated FIR, while the airspace above is named Upper Information Region, or UIR. An information service and an alerting service are the basic levels of air traffic service, providing information for the safe and efficient conduct of flights and alerting the relevant authorities should an aircraft be in distress. These services are available to all aircraft operating through a FIR. Higher levels of air traffic advisory and control services may be available in certain parts of the airspace within a FIR, according to the International Civil Aviation Organization (ICAO) class of that portion of airspace (with regard to national regulations), and the existence of a suitably equipped authority to provide the services.

The member states providing services in the eight Arctic regional FIRs are Canada, the Russian Federation, Denmark, Norway, Finland, Iceland, Sweden, and the United States. Each State is permitted, under agreements negotiated and implemented by the ICAO, to apply its own domestic civil aviation regulations for the regions in which it provides flight information or air traffic control services, provided that those regulations do not conflict with ICAO regulations.

The Annexes to the Convention, particularly Annex 2 (Rules of the Air) and Annex 8 (Airworthiness of Aircraft) establish minimum standards for operating aircraft so as to avoid the hazard of collision with other aircraft or persons or property on the ground, as well as providing a baseline for the integrity of the design, construction and maintenance of aircraft. Article 8 prohibits overflights of the territory of another State with pilotless aircraft without the permission of the State having authority over that territory. However, most countries require operators of aircraft registered in that country to follow its national rules and regulations, unless doing so conflicts with ICAO Standards and Recommended Practices (SARPs) when operating over 'the High Seas'. This means the regulations, if any, in the operator's native country may present the limiting factor for operations, rather than the country from which the operations take place.

The challenge for any potential UAS operator in the Arctic region is to identify and understand the applicable regulations in the geographic area where they want to deploy their system, and to develop a process for interfacing with the CAA having jurisdiction in that region so as to obtain the appropriate permissions to conduct those operations. A proposed campaign that would operate across FIR borders presents a particularly difficult challenge, in that neighboring states having jurisdiction over adjoining FIRs may (and often do) have dramatically different regulatory requirements. Harmonizing the across-border concept of operations for such an undertaking presents unique issues, but they are not insurmountable, since commercial airline services have been doing this routinely and successfully for over 70 years. The

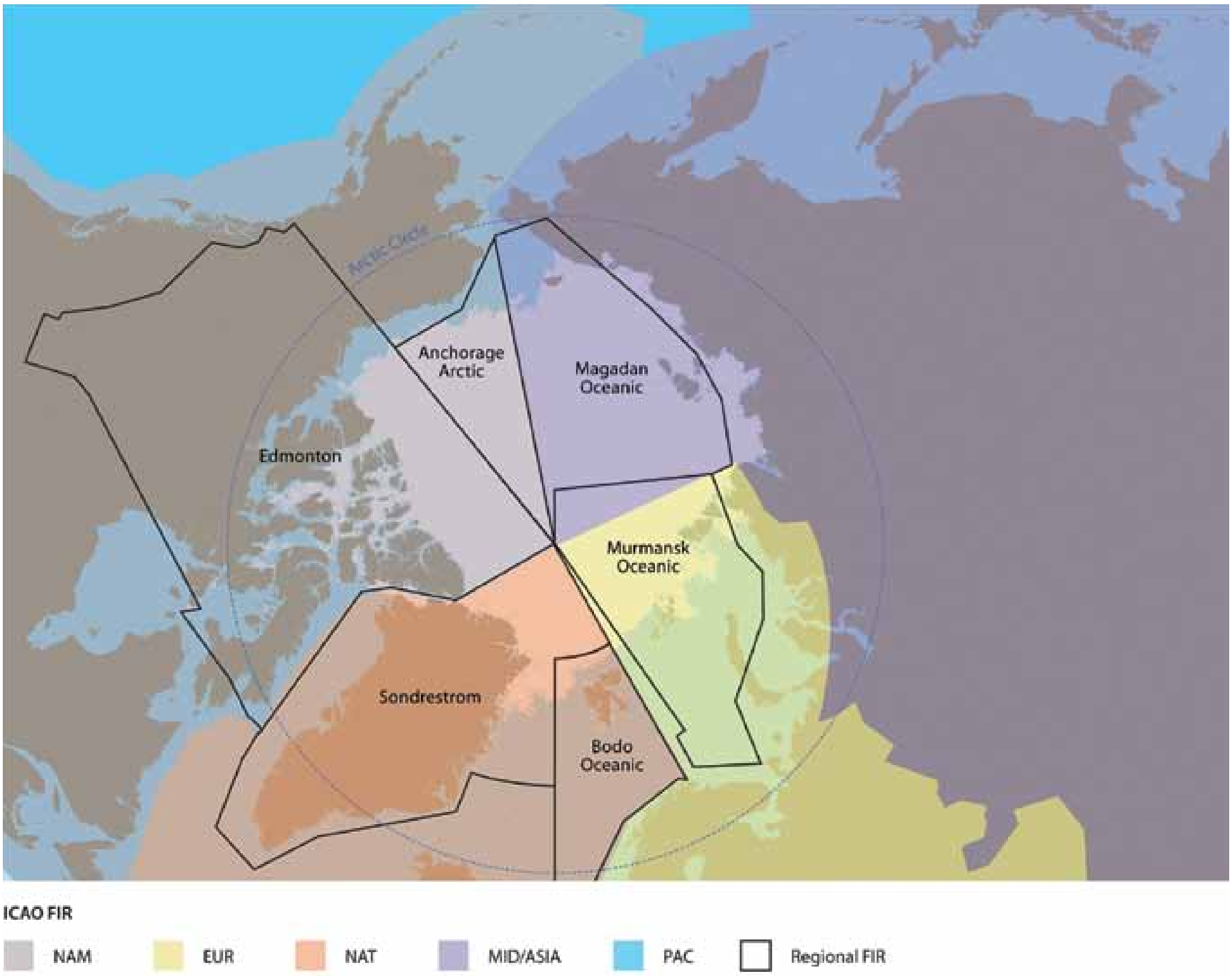


**Figure 3.1.** Arctic Flight Information Regions as designated by the International Civil Aviation Organization. Source: based on information from the ICAO website.

problem is that ICAO has not introduced a set of common regulatory requirements for UAS operations in international airspace, and so each member state has developed separate regulations, or in many cases has failed to address the issue at all.

The ICAO recently published a report on Unmanned Aircraft Systems as a first step towards a harmonized regulatory environment (ICAO, 2011). Annex 2 to the Convention on International Civil Aviation is currently under revision and *A Proposed Amendment To International Standards, Rules of the Air, Annex 2, and Annex 7, International Standards and Recommended Practices, Aircraft Nationality and Registration Marks* has been circulated for comments. The proposed amendments describe broad standards for remotely piloted aircraft operating in ICAO airspace. (It should be noted that ICAO has adopted the term 'remotely piloted aircraft' in place of 'UAS' or 'UAV'). Almost simultaneously, the European Organisation for Civil Aviation Equipment (EUROCAE) released a report and recommendations for UAS operations in European airspace. The stated purpose of Circular 328 published by the ICAO (ICAO, 2011) is to apprise states of the emerging ICAO perspective on the integration of UAS into non-segregated airspace and at aerodromes, to consider the fundamental differences from manned aviation that such integration will involve, and to encourage States to help with the development of ICAO policy on UAS by providing information on their own experiences associated with these aircraft. The report states that *Unmanned aircraft (UA) are, indeed, aircraft; therefore, existing SARPs apply to a very great extent. The complete integration of UAS at aerodromes and in the various airspace classes will, however, necessitate the development of UAS-specific SARPs to supplement those already existing.*

Other relevant information includes a report published by RTCA addressing all UAS and UAS operations being considered for realistic implementation in the United States National Airspace System in the foreseeable future (RTCA, 2007). The purpose of the report is to facilitate future discussion on UAS standards. The guidance material provides a framework for developing standards through RTCA Special Committee 203.

The European Aviation Safety Agency (EASA) released a policy statement on airworthiness certification of UAS that establishes general principles for type-certification (including environmental protection) of a UAS (EASA, 2009). The policy represents a first step in the development of a comprehensive civil UAS regulation. This policy statement is an interim solution to help with the acceptance and standardization of UAS certification procedures in Europe.

The challenges associated with the use of UAS in the Arctic are thus regulatory compliance and enforcement, diplomatic considerations, possibly internal national politics, security concerns, pressure from other current or potential users of the airspace, and of course funding, which is often heavily influenced by the cost of overcoming the regulatory and legal barriers to such operations.

## 3.2 Current status of UAS regulatory activities in the Arctic nations

The following sections provide a summary of UAS regulatory activities in each of the eight Arctic nations having operational jurisdiction in part or all of one of the four major FIRs that include the Arctic territories. Those regions are designated by the ICAO as North Atlantic (NAT), North America (NAM), Europe (EUR) and Mid Asia (MID ASIA). Each FIR is subdivided into smaller sectors, each of which is under the operational control of the CAA of a member state. The states providing flight information services in FIRs have accepted responsibility for oceanic air traffic control services within the boundaries of the FIR. The FIR is designated as international airspace of defined dimensions within which flight information service and alerting service are provided. ICAO member states, by regional air navigation agreement with ICAO, are the air traffic services (ATS) authority for the FIR. The ICAO has authorized any state that provides ATS over the High Seas to apply the ICAO Rules of the Air (Annex 2 to the Convention on International Civil Aviation) in a manner consistent with the domestic general operating and flight rules of the controlling state (ICAO Council Document 7030, 1951). In the case of the United States these are applied as 'Title 14 CFR Part 91', i.e. Code of Federal Regulations, Title 14 *Aeronautics and Space,* Part 91 *General Operating and Flight Rules.* For example, the NAT FIR includes the BODO OCEANIC, GANDER OCEANIC, NEW YORK OCEANIC, REYKJAVIK, SANTA MARIA OCEANIC, SHANWICK OCEANIC and SONDRESTROM FIRs. UAS operations in Arctic airspace in the NAT FIR (70° N) would include the SONDRESTROM, REYKJAVIK and BODO OCEANIC FIRs. SONDRESTROM is controlled by Greenland (Denmark). Traffic above FL195 (flight level 195, or 19 000 ft MSL) is controlled by Reykjavik (Iceland) and Gander (Canada). REYKJAVIK is controlled by Iceland. The BODO OCEANIC FIR is controlled by Norway.

Forming a narrow strip between the SONDRESTROM and BODO OCEANIC and MURMANSK OCEANIC FIRS is a NO-FIR zone that is Russian airspace. While no services are provided, permission from the Russian Federation authorities must be obtained before transiting.

**Annex A** presents the current status of UAS regulations in the eight Arctic nations, a breakdown of the major operational elements required by each nation, if any, and a summary of the Arctic FIRs and their respective contact information.

**Annex B** provides a detailed overview of the regulatory environments in each of the eight Arctic nations as they pertain to UAS operations within their respective territories or ICAO designated jurisdictions. This annex is designed to support the summary material presented in Sections 3.2.1 to 3.2.8.

Commercial UAS operations are allowed in some countries and are specifically prohibited in others. Controversy and uncertainty exists over the definition of 'commercial'. The distinction between a 'UAS for hire' business model and UAS flown to demonstrate system capabilities or for marketing purposes is blurred and no consensus has emerged.

Little or no regulatory harmonization exists between Arctic nations with regard to UAS operations or certification. Regulatory treatment varies from none (Finland) to the fully implemented (Sweden and Greenland/Denmark). Regulations and standards are under development in Canada, Norway, the Russian Federation, and the United States. All but one (the Russian Federation) have either specific provisions for model or recreational aircraft activities or guidelines exempting these activities from regulatory treatment.

Those States that have developed regulations or guidelines for operating UAS in their jurisdictions have defined certain procedures to obtain the permissions to operate. Those procedures range in complexity from merely contacting the local aerodrome or civil aeronautical authority to gain permission to enter the airspace (Iceland) to a relatively rigorous application, approval and oversight process that could take months to complete (Canada, United States).

Cross-border or trans-FIR UAS operations would require coordination between the respective CAAs, and there is no established protocol or set of guidelines to inform the potential users and CAAs of the procedure to obtain the necessary permissions.

EU Member States may look to the efforts of EUROCAE WG-73 and the ICAO UAS Study Group for guidance on harmonization of local regulations with the other member states and the global community. In the meantime, Canada, the United States, (and purportedly the Russian Federation) are moving forward with programs to establish comprehensive rules, standards and guidelines for civil UAS operations. The approach thus far has been to advance incrementally, beginning with rules for smaller category UAS. Due to the unique characteristics of the airspace managed by each State, overarching rules that develop in individual countries are unlikely to migrate to other countries without significant modification. Recent legislation enacted in the United States specifically addresses unmanned aircraft missions in the Arctic regions of Alaska (the U.S. zones of the Chukchi Sea, the Beaufort Sea and the Bering Sea north of the Aleutian Chain), and directs the Federal Aviation Administration (FAA) to develop a plan and initiate a process to designate permanent areas in the Arctic where small unmanned aircraft can operate 24 hours per day for research and commercial purposes.

UAS users and proponents are cautioned to carefully examine the rules, if any, that apply to UAS activities in the FIRs in which they wish to operate, and equally important, to establish an individual point of contact in the targeted CAA who is most knowledgeable about the applicable rules and who can be of assistance in obtaining the necessary permissions. This may appear self-evident, but it is a detail that may be overlooked by proponents who become so focused on the mission that the fundamental issue of access to the airspace is deemed less important, which in turn puts the entire campaign at risk. Airspace access will always depend upon the nature of the proposed operation, the capabilities of the aircraft and supporting systems, and the qualifications of the operators, and operations that cannot meet minimum safety and reliability standards are likely to be denied permission to fly in the desired region.

### 3.2.1 Canada

A formal process has begun to develop regulations that will determine how UAS will be permitted to operate within Canadian airspace on a routine basis; however this process is expected to take several years to complete. In the meantime a process exists by which UAS operations may be given operating approval under a Special Flight Operations Certificate (SFOC). General guidelines for the review and processing of an application for an SFOC for UAS operation have been prepared by Transport Canada (Transport Canada, 2008). Appendix B1 lists the minimum information that must be provided in applying for an SFOC.

### 3.2.2 Finland

Finland has not implemented any comprehensive regulations addressing UAS. Use of radio controlled (RC) model aircraft is allowed without the need to obtain special permission, if certain conditions are met. These conditions generally apply to RC aircraft over a certain size (5 kg) operated within 1.5 km of an airport. Finland's national regulations exempt UAS under 150 kg from most regulations, and provide for exemptions from others, upon application.

For UAS operations utilizing an autopilot system, permission to fly in a specific region and for a specific period of time must be requested from the Finnish Transport Safety Agency. The permit will only be valid for a maximum of two weeks. If permission is granted, all other aviation activities will be prohibited or restricted in the affected region for the defined period of time. A permission once obtained is no guarantee of future permissions for similar activities, as each application is evaluated individually and on its own merits. Commercial UAS activities are not allowed. It is expected that the rules will change when the regulations in EU countries are harmonized.

### 3.2.3 Greenland/Faroe Islands/Denmark

Denmark has developed a relatively comprehensive set of UAS regulations that apply both to mainland Denmark and Greenland and the Faroe Islands (see also Appendix B3). The regulations apparently derive from the model (recreational) aircraft community. As the aircraft get larger (weighing more than 7 kg) the restrictions become tighter, requiring pilot certification, operation from approved airfields and with altitude limits. Large UAS (weighing between 25 and 150 kg) are prohibited in the regulations. Foreign operators can obtain permissions if they are authorized in their country of origin and can meet all relevant Danish requirements. A unique feature of Denmark's system is the requirement that UAS operators flying larger aircraft (weighing between 7 and 25 kg) secure liability insurance coverage. The penalties for failing to do so are severe (imprisonment for up to two years). All classes of UAS are restricted to a 100 m above ground level (AGL) altitude limit. Exceptions to the various restrictions and requirements may be made for research operations and commercial operators. AIC B 22/12 (published 15 August 2012) provides specific guidelines for dispensations, and is based on the Swedish regulations (see section 3.2.7). Dispensation through this AIC allows for up to 150 kg aircraft and operations outside approved airfields. BLOS flight is not yet possible, but is described in AIC B 22/12 and will probably be permitted in the future. Danish regulations and AICs are not officially available in English. Another unique feature of the Danish system is the imposition of a high service fee (150 Euro per hour) for processing applications, even for applications that are denied.

### 3.2.4 Iceland

Iceland has no specific regulations addressing unmanned or remotely piloted aircraft, except for what is characterized as 'self propelled flying models and flying bodies,' and the regulations dealing with RC aircraft apply to aircraft weighing more than 5 kg that are to be flown within 1.5 km of populated areas or aerodromes. Even small RC aircraft (weighing less than 5 kg) require permission from the aeronautical authority if operated within 1.5 km of an aerodrome. There are no published procedures for applying for permission to operate models or UAS other than requesting permission of the controlling authority for an aerodrome. Otherwise, operations of UAS outside populated areas and away from aerodromes (and presumably in Arctic regions where Iceland provides air navigation services) may be conducted without restriction other than the standard ICAO Class 'G' airspace rules. See also Appendix B4 for more information concerning Iceland.

### 3.2.5 Norway

As of March 2011, the Norwegian CAA is following a roadmap to regulation first presented in 2009. The Norwegian CAA is participating in several international efforts on the development of UAS regulations, including the ICAO UAS Study Group and the EUROCAE WG 73 committees. The CAA wants Norway's national regulations to be similar to regulations adopted in other countries. The CAA sees the importance of developing regulations in close cooperation with the industry, as technology is rapidly evolving and making it challenging to create regulations that will enable the industry to develop its potential and at the same time maintain the highest level of safety. The guiding principle for the requirements for UAS equipment, operations, and personnel qualifications must be such that the total risk level for other air traffic and persons and equipment on the ground is acceptable. The total risk level shall not be higher than for similar operations with manned aircraft.

Pending implementation of new regulations, access to airspace is granted on a case-by-case basis and by segregation of airspace, where appropriate. The current procedures and requirements are described in AIC-N 25/09 (see Appendix B5 for a summary of the information contained), which is expected to be replaced by an updated Aeronautical Information Circular in 2012.

### 3.2.6 Russian Federation

There is no readily identifiable body of regulations or standards specifically for the operation of unmanned aircraft in the Russian Federation, but some references to unmanned systems may be found in the several codes and regulations pertaining to aviation, aircraft and airspace (see Appendix B6 for a summary of sources). Remotely piloted aircraft are considered to be integrated systems that include the aircraft itself, the ground control station, and related communications and data link equipment ('functionally linked technical assets'). All UAS operations must be approved by the Russian Federation military.

For civilian (non-state or non-military) UAS operations, regulations or policies addressing certification of systems of aircraft, aviation engines, aircrews and ground systems, registration of systems with unmanned aircraft, training and certification of aviation personnel, and certification of users to carry out activities based on use of airspace have yet to be developed.

For certification of systems with unmanned aircraft, it is necessary to determine the appropriate agencies for certification, and to establish through the federal aviation regulations the requirements for flight readiness of unmanned aircraft, aviation engines, and aircrews, and for the suitability of ground facilities as well as standards of certification.

Permission to operate remotely piloted aircraft in Russian Federation airspace is contingent upon the proponent's ability to comply with all relevant regulations that apply to manned aviation. The sources of aviation regulation in the Russian Federation are: The Aviation Code of the Russian Federation, Federal Aviation Regulations for Use of Russian Federation Air Space, Federal Aviation Regulations for Flights in Russian Federation Air Space, Federal Aviation Regulations For Conduct Of State Aviation Flights, Federal Aviation Regulations for Aeronautical Engineering Support of State Aviation, and Federal Aviation Regulations for State Registration of State Aircraft.

While there is no formal process for obtaining permissions for UAS flights that is unique from other aviation activities, proposals to establish a set of rules, regulations and requirements for UAS flights in Federation airspace have been offered, as described in the Appendix B6.

The Russian Federation controls over 40% of the Arctic Region airspace, and harmonization of its UAS regulatory process with ICAO regulations and other Arctic nations is of great importance to the scientific community.

### 3.2.7 Sweden

The company or person that wants to operate a UAS in Swedish airspace must apply for a permit to operate UAS from the Swedish Transport Agency. To date, the Swedish Transport Agency has issued permits to fly UAS in civil applications to over 40 companies and individuals. The regulations apply to all civil commercial UAS activities that are not recreational.

UAS weighing less than 150 kg are regulated by the Swedish Transport Agency (Swedish Transport Agency, 2009). This comprehensive set of regulations covers design, manufacture, modification, maintenance and activities with civil UAS within Sweden. The regulations subdivide UAS into four classes. The first three classes cover Visual Line of Sight (VLOS) operations with aircraft weighing up to 150 kg. The fourth covers all Beyond Line of Sight (BLOS) operations, regardless of weight and total energy. The Swedish regulations also detail airspace rules, pilot competency and qualifications, procedures for all phases of flight, system airworthiness, insurance, registration and markings, oversight of operations and an approval process. See Appendix B7 for further details.

### 3.2.8 United States

All aviation related activity in the United States, regardless of type, intent or magnitude, is regulated by the FAA, a subdivision of the Department of Transportation. The FAA has put considerable effort into responding to the demands of the military, the science community, law enforcement, civil operators and academia for permissions to operate UAS or RPA in domestic U.S. airspace and in the FIRs where the United States provides services. There are no specific regulations addressing remotely piloted aircraft, but there is a substantial body of regulations that deal with all aspects of commercial and civil aviation that clearly do or could potentially apply to UAS/RPA activities. Due to the uncertainties of interpretation and application of specific regulations to the many emerging uses of these systems, the FAA has initiated a number of regulatory and standards setting efforts, and is participating in many others on a global basis. Currently, no commercial UAS activities are allowed in the U.S. National Airspace (NAS). The Department of Defense obtains authorizations to operate their systems outside of restricted airspace through the Certificate of Waiver or Authorization (COA) process. Public entities (federal, state and local governments, state universities, other governmental agencies) may also obtain COAs to operate in the NAS. These COAs are time limited, restricted to one specific platform or system, and permit line-of-sight operations only. Civil proponents may also apply for a Special Airworthiness Certificate (SAC) in the Experimental Category, and must operate their systems in strict accordance with applicable regulations pertaining to experimental aircraft and airspace rules. The FAA has approved over 300 COAs in the past five years, most of them to the Department of Defense, Customs and Border Protection, academia, and law enforcement agencies. Fewer than a dozen SACs have been issued to private entities.

Rules specifically addressing small UAS are under development, along with underlying standards, but the process is slow and cumbersome, and the new rules are not likely to be in place before the end of 2013. Additional rules for larger systems are also at an early stage of development.

The U.S. Congress recently passed legislation (summarized in Appendix B8) specifically mandating the FAA to address the growing demand for UAS operational authorities, and also establishing aggressive timelines for creating rules and procedures for scientific and commercial UAS activities in the Arctic.

Presently, the FAA secures compliance through publication of guidance documents (which are arguably not legally enforceable) and interpretations of existing aviation regulations. The RC recreational community also operates under a 31 year old guidance document (Advisory Circular 91-57) that is occasionally relied upon by commercial operators that choose not to go through the COA or SAC process.

The FAA applies the relevant sections of the Federal Aviation Regulations to UAS operations in international airspace FIRs in which the United States provides air traffic services. The Arctic airspace in the Anchorage Arctic sector of the NAM FIR is included in that policy. It remains to be seen how this policy may change in response to the legislative mandate, but for the immediate future, it is reasonable to assume that the only way for a UAS proponent to gain access to the Arctic FIR managed by the FAA is to qualify as a public entity (or partnered with one) with an approved COA.

## 3.3 Best practices and safety assessments

UAS are aircraft and the use of aircraft across national borders and over the High Seas is regulated through the UN agency ICAO. The challenge in the use of UAS is two-fold. First, UAS typically do not fulfill airworthiness and 'see and avoid' requirements. Second, to fly over another country's territory the operator will need an approval from that state. On the first issue, the CAA in charge of the FIR will have the authority to give permissions to operate UAS in that region and to set the conditions for such access to airspace. The second requirement (permissions) may or may not issue from the CAAs, but could be a diplomatic function that involves a very different process, depending upon the nature of the flight and the capabilities of the system to be used.

The requirements for getting such access vary from country to country as described in Section 3.2. One necessary condition to secure airspace access is for the operator to document its ability to perform safe operations and to show that the risks involved would be within acceptable limits.

A guiding principle in aviation is risk management. All aviation creates risk, and through regulation we seek to mitigate and minimize the risk to a level that is considered acceptable. Hence, use of UAS should not increase risk compared to similar manned aircraft operations, either to other airspace users or to personnel and property on the ground.

**Table 3.1**. Main elements of best practices and safety assessment documentation.

1 **UAS system description**
A technical description of the UAS
- Aircraft platform
- Communication links
- Ground control system

2 **Manuals and documentation description**
List and reference manuals
- UAS manual (Aircraft Handbook)
- Maintenance manual
- Flight journal
- Checklists

3 **Operation procedures**
Describe standard operating procedure
- Pre-flight
- During flight
- Post flight

4 **UAS crew**
List crew roles, qualifications and experience
- Pilot in command
- Safety pilot
- Flight engineer

5 **System safety, hazard analysis, mitigations and risk assessment**
Methodology used
Identify hazards
Evaluate severity
Evaluate probability
Identify mitigations
Describe operational risk mitigation

6 **Operational risk**
Calculate fatality rate mid-air
Calculate fatality rate ground strike

Development of best practices is a process that requires the operator to thoroughly consider and document the system being used and the procedures developed for planning and executing operations. The main elements to be addressed in the development of best practices are listed in Table 3.1. Safe operations must be the objective from the design phase to the operations. The focus should be to minimize the risk associated with the operation of the system. The first four elements of Table 3.1 describe areas that should be addressed in the development of best practices for the system, while elements 5 and 6 are the key topics to be contained in the safety assessment.

The CAAs need a thorough description of all the elements listed in Table 3.1 to evaluate the safety of the system. The level of detail can be adapted to the complexity and maturity of the system and the risks they pose. There are significant differences between a long endurance, high altitude Global Hawk and a small quad-copter that only operates within line of sight.

One of the objectives of the UAS Expert Group is to arrive at a common understanding across the Arctic nations as to the documentation requirements for best practices and safety assessments. That does not mean that the requirements should or will be the same but should be compatible so the same documentation approach can be used even though the level of detail could be different.

# 4. UAS technology for science

Unmanned aircraft are particularly important and useful for monitoring the Arctic because of the vast and little-understood Arctic environment. The Arctic has long been an under-monitored environment: surface stations, including over the ocean, are extremely limited and satellites have difficulty in monitoring near the surface of the Arctic. Low cloud cover, icing conditions and lack of appropriate search and rescue operations making flying over much of the Arctic risky to pilots and therefore limits the operations that can be flown. Unmanned aircraft, therefore, offer a unique capability to fill critical data gaps for the Arctic.

# 5. Gaps in knowledge

A comprehensive analysis of gaps in knowledge for future observation needs has been performed in connection with the planning of the Svalbard Integrated Arctic Observing System (SIOS). This work was funded by the EU and national research funding agencies and also included all the non-European Arctic countries. Even though the focus of this work has been the Svalbard region (Hansen, 2011), the observational needs and gaps described are also valid for other parts of the Arctic. UAS could play a vital role in collecting data that will help fill these gaps. The means by which UAS could support scientific data collection in several key topics with regard to the Arctic is addressed in Section 7. Developing and using UAS-based capabilities will also help meet the recommendations arising from AMAP's new assessment of the impacts of climate change on snow, water, ice and permafrost in the Arctic (the 'SWIPA' project) (AMAP, 2011). AMAP made the following recommendations to Arctic countries and international organizations with regard to developing observational capabilities:

- Improve and expand systematic, comprehensive surface-based monitoring of the cryosphere.

- Maintain and support development of remote sensing methods for observing the cryosphere.
- Develop and enhance systems to observe the cascading effects of cryospheric change on ecosystems and human society.
- Expand research into processes that are important for modeling the cryosphere, to reduce uncertainty in predicting cryospheric change. In particular, improvements are needed in modeling permafrost dynamics, snow-vegetation interactions, and mass loss from glaciers, ice caps, and the Greenland Ice Sheet.

# 6. Platforms and capabilities

Critical capabilities for UAS in the Arctic include the ability to fly when in danger of icing conditions, to fly set paths autonomously, to fly long distances and to be launched and recovered from ships or other remote locations (see Figure 6.1). Poor communication infrastructure in these remote areas sets strong requirements for the ability to operate on low bandwidths (satellite communication, for example iridium) and therefore a large degree of automation of the system. Exploring the remote areas of the Arctic, particularly over the Arctic Ocean, will require either long endurance capabilities or the ability to launch and recover from ships. These more remote measurements are some of the most needed measurements for Arctic science.



**Figure 6.1.** UAS platforms are versatile and portable. The upper photo shows *Scan Eagle* being deployed from a launching system onboard a research vessel at sea, while the lower photo shows *Cryowing* and *Mantra* ready for takeoff on land in Ny-Ålesund, Svalbard, 2011. Photos courtesy of the U.S. National Oceanic and Atmospheric Administration (NOAA) (upper) and Kjelle-Sture Johansen, Norut (lower).

# 7. UAS capabilities in key topics

Presently there are UAS platforms ranging from 0.5 to 5000 kg used in Arctic research. The UAS is first and foremost a carrier platform for a scientific sensor payload. The choice of platform must be based on the capability needed. Determining factors are compromises between: sensor weight and size, endurance and altitude required, power requirements, available platforms, airspace access, logistical constraints, and cost.

## Key topic: Arctic lower atmosphere – boundary layer system; Dynamical and radiation feedback systems

The Arctic cloud cover and boundary layer to surface couplings are some of the most important topics to be dealt with in both observations and modeling. All models still show substantial deviations of these parameters from observations.

### UAS sensor capbilities

**Aerosols and BC**

- Optical particle counters for measuring aerosol concentration and size distribution.
- Filter samplers for aerosol composition.
- Cloud Condensation Nuclei (CCN).
- Spectrometers for measuring aerosol and surface spectral radiative properties.

**Clouds**

- Cloud particle imager for measuring cloud particle size and shape distribution in water, mixed phase and ice clouds.
- Radiometers for measuring cloud radiative properties.

**Surface energy fluxes**

- Turbulent flux probes and radiometers for measuring ocean-ice-atmosphere energy exchange and characterizing the effects of leads and melt ponds.

**Meteorology**

- Standard meteorological pack for measuring air temperature, humidity, wind and air pressure.
- Drop sondes for profile measurements through the atmospheric boundary layer.

## Key topic: Oceanic and sea-ice processes

Changes in sea-ice cover have an impact on oceanic and atmospheric processes, leading to fundamental changes in the Arctic climate system. Over the past two decades, Arctic sea ice has changed significantly, from being dominated by thick multi-year ice to thinner first-year ice. The most significant change however, has been the decline in summer sea ice extent (Figure 7.1).

### UAS sensor capabilities

**Sea-ice properties**

- Precision GPS and laser altimeter for measuring sea-ice thickness (freeboard) and roughness.
- Ground penetrating radar (GPR) for measuring snow on ice.
- Camera for characterizing sea-ice types, concentrations and melt pond fractions.
- Spectrometers for sea-ice spectral albedo measurements.

**Ocean properties**

- IR thermometer for measuring sea surface temperature.
- Synthetic aperture radar (SAR) for measuring surface winds and waves.

## Key topic: Marine transport of energy, nutrients and pollution

Observations indicate that the Arctic Ocean is in transition to a warmer state with reduced sea-ice cover (AMAP, 2011; Chapter 9). There is also high natural annual, decadal and multi-decadal variability in flow to and from the Arctic Ocean that is related to large-scale atmospheric weather patterns such as the North Atlantic Oscillation and the Arctic Oscillation.

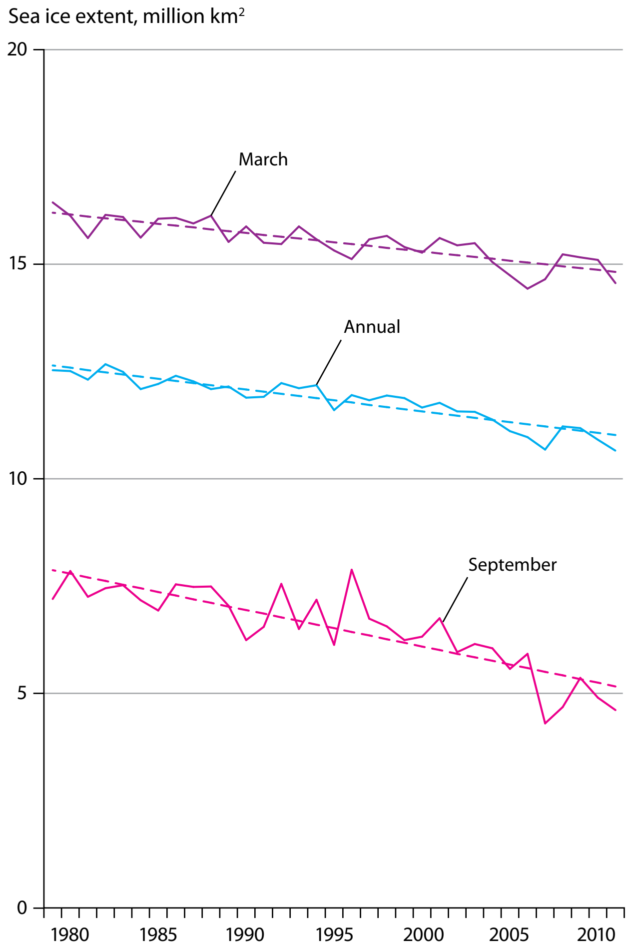


**Figure 7.1.** Average sea-ice extent in the Arctic in March (winter), September (summer), and annually for 1979 to 2011, including trend lines. Updated from Fetterer et al. (2011).

**Figure 7.2.** The heavily crevassed calving front of Kronebreen Glacier on the western edge of Svalbard as seen from *Cryowing* on 11 May 2011 from an altitude of 400 metres. Kronebreen is a grounded tidewater glacier that moves at an average speed of about 2 metres per day. This calving front is one of the most active in Svalbard. Photo courtesy of Norut.

The Arctic Ocean will undergo the greatest changes in pH of the global ocean this century due to ocean acidification through the uptake of excess carbon from the increasing atmospheric carbon dioxide ($CO_2$) load. The present ability to predict the ecological consequences of increased climatic variability and ocean acidification in the Arctic is limited.

### UAS sensor capabilities

**Ocean color**

- Imaging spectrometer for measuring ocean color to determine nutrient and chlorophyll concentrations.

**Energy transport**

- Infrared probe for measuring sea surface temperature.
- Synthetic aperture radar (SAR) for measuring ocean currents (along track interferometry).

## Key topic: Glacier and ice cap mass balance and dynamics

Glaciers are important stores of freshwater. Melting of Arctic glaciers and ice caps (including the Greenland Ice Sheet) currently contributes about 1.3 mm/y to global sea-level rise (AMAP, 2012; Chapter 11). This large influx of freshwater from melting land ice also has an impact on ocean salinity and ocean dynamics. Glaciers lose mass through melting and through dynamic transport and gain through snow accumulation. To understand the development of glaciers and how they might respond to climate change, it is necessary to measure the changes in surface elevation and rate of dynamic loss throughout the year (see Figure 7.2)

### UAS sensor capabilities

**Glacier mass balance**

- Laser altimeter or laser scanner for mapping surface elevation and thereby glacier mass and year to year total glacier mass changes.
- Ground penetrating radar for facies characterization and changes in accumulation and melt.

**Glacier dynamics**

- Camera (visual or infrared), for estimating calving rates and dynamic mass loss rates compared to mass loss by melting.
- Synthetic aperture radar (SAR) feature tracking for estimating glacier flow velocities.

## Key topic: Greenhouse gas processes and feedbacks in the Arctic climate system

The Arctic has the potential to significantly affect the budget of the most important greenhouse gases besides water vapor: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$) and tropospheric ozone. The North Atlantic is already an important sink of $CO_2$ and the Arctic Ocean may become an important sink in the future as a result of its rapidly declining sea-ice cover. There are strong indications, however, that due to the rapid increase in atmospheric $CO_2$ and increasing water temperature, the sink function or buffer capacity of these ocean areas may decrease rapidly over the coming decades.

Another consequence of $CO_2$ uptake in the Arctic Ocean, which is receiving increasing attention from the scientific community, is a gradual fall in ocean water pH values (ocean acidification). Initial model results indicate that ocean acidification could reach a critical level for marine ecosystems in the European Arctic by about 2030. The Arctic contains two large natural $CH_4$ reservoirs which might destabilize under continued warming. Depending on a number of geophysical and biological conditions, such as temperature, humidity, vegetation, soil properties and microbial activities, these reservoirs may partly decompose and result in large emissions of $CH_4$, $CO_2$ or $N_2O$ to the atmosphere. Furthermore, there are large $CH_4$ reservoirs in the form of clathrates and free gas trapped under clathrates in the seabed

**Figure 7.3.** Image of a male ribbon seal hauled out onto sea ice taken from *ScanEagle* at an altitide of 300 ft. during the 2009 McArthur UAS ice seal cruise in the Bering Sea. Photo courtesy of NOAA Fisheries.

of the large shallow seas in the Arctic Ocean and along the shelf edge. These may destabilize under the substantial ocean warming projected by models and suggested by observations in recent years.

### UAS sensor capabilities

**Methane, carbon dioxide and nitrous oxide concentrations**

- $CH_4$, $CO_2$ and $N_2O$ sensors for *in situ* concentrations and flux estimates from cavity ring-down laser absorption instruments.

## Key topic: Arctic ecosystem resilience to climate variability and change

Arctic ecosystems are predicted to experience some of the most rapid changes in climate over the coming decades. Changes in growth season, seasonal snow cover, and permafrost will cause changes in biodiversity. Changes in sea-ice cover will affect food access and habitats for marine mammals.

### UAS sensor capabilities

**Terrestrial**

- Hyperspectral imagers with very high resolution for vegetation mapping.

**Marine**

- Cameras (visual or infrared) for marine mammal surveys.

Marine mammals can be observed by cameras mounted on UAS (Figure 7.3). Thousands of images can be recorded and analyzed using state-of-the-art software and can result in a better understanding of the health of the populations. Coordinated flights and synthesized analysis across the Arctic can give unprecedented understanding of the populations and whether the changes in sea ice pose a critical threat to Arctic ecosystems.

The very rapid changes taking place in the Arctic sea ice indicate that it is now more critical than ever to understand the role played by sea ice in the Arctic system. Key issues include an understanding of the interactions between sea ice and global climate, the influence of sea ice on biological activity, and the health of the Arctic ecosystem. Because of the critical need for more data, and the unique capability of unmanned aircraft to help meet this need, scientists began using UAS technologies in the Arctic as early as 1999 and continue to look for new methodologies to advance understanding of this important and changing system. The data and scientific results obtained from these flights can often not be obtained safely from any other platform.

# 8. Past UAS science operations

The list of past UAS science operations given in Table 8.1 is not comprehensive but reveals the range of science applications, platforms and locations throughout the Arctic where unmanned aircraft have flown.

**Table 8.1.** Science applications, platforms and locations throughout the Arctic where unmanned aircraft have been flown.

| Year | Location / permissions | Science issue / Aircraft | Contact |
|---|---|---|---|
| 1999-2004 | Alaska, USA<br>Local FAA approval | Sea ice characterization / ***Aerosondes*** | Jim Maslanik, Univ. Colorado |
| 2007 | Greenland<br>Greenlandic and Danish CAA | Glacial melt ponds / ***Manta*** | John Adler, NOAA; Betsy Weatherhead, Univ. Colorado |
| 2007 | Icelandic CAA | FLOHOF campaign/***KALI & SUMO*** | Joachim Reuder, Univ. Bergen |
| 2008 | Longyearbyen, Svalbard<br>Norwegian CAA Danger Area & Notam BLOS ops | Polar Lows / ***Cryowing*** | Rune Storvold, Norut |
| 2008 | Part ship-based part Longyearbyen, Svalbard<br>Norwegian CAA | Polar Lows / ***SUMO*** | Joachim Reuder, Univ. Bergen |
| 2008 | Ny-Ålesund, Svalbard<br>Norwegian CAA Danger Area & Notam BLOS ops | Glacier dynamics / ***Cryowing*** | Rune Storvold, Norut |
| 2008 | Ny-Ålesund, Svalbard<br>Norwegian CAA Danger Area & Notam BLOS ops | Polar meteorology/ ***Cryowing*** | Rune Storvold, Norut |
| 2009 | Bering Sea<br>US FAA / safety case allowed 3-5 miles | Ice seal populations / ***Scan Eagle*** | Robyn Angliss, NOAA |
| 2009 | Longyearbyen, Svalbard<br>Norwegian CAA Danger Area & Notam BLOS ops | Boundary layer meteorology / ***SUMO*** | Joachim Reuder, Univ. Bergen |
| 2009 and 2011 | Ny-Ålesund, Svalbard<br>Norwegian CAA Danger Area & Notam BLOS ops | Ice albedo feedback / pollution / ***Cryowing*** | Rune Storvold, Norut; John Burkhart, NILU |
| 2010 | US Arctic<br>US FAA – flew above commercial airspace | Atmospheric chemistry / ***Global Hawk*** | Dave Fahey, NOAA; Paul Newman, NASA |
| 2010 | Summit Camp, Greenland<br>Danish CAA Danger Area & Notam BLOS ops | Ice albedo feedback / pollution / ***Cryowing*** | Rune Storvold, Norut; John Burkhart, NILU |
| 2011 | Ny-Ålesund, Svalbard<br>Norwegian CAA Danger Area & Notam BLOS ops | Ice albedo feedback / pollution / ***Cryowing***, ***Manta***, ***Eleron*** | Rune Storvold, Norut; Tim Bates, NOAA; Sergey Lesenkov, AARI |

# 9. Future work

As scientists continue to work to understand the Arctic, unmanned aircraft have become one of the most important new tools to fill critical data gaps. The need for further data continues to increase as scientists begin to understand the full capabilities of these platforms. Efforts are needed to coordinate existing flights, to coordinate the analysis of results, and to allow for more regular and longer flights. Cooperation between scientists, aviation engineers, UAS operators and CAAs will allow for scientific questions to be addressed in a timely, safe and responsible manner. With Arctic conditions changing more rapidly than predicted just a few years ago, the situation requires immediate action and the coordination of all involved. For example, Arctic sea-ice extent in spring has declined by over 1 million km$^2$ since 1979 (see Figure 7.1) and the longer the delay in gathering such essential baseline information the less baseline data there will be for future analyses.

**Figure 9.1.** CICCI flight crews in Ny-Ålesund, Svalbard in 2011. From left: *Cryowing* Norut (Norway), *Manta* NOAA (USA) and *Eleron-10* AARI (Russia). Photo: Kjell Sture Johansen, Norut.

To facilitate the increased use of UAS in Arctic research the UAS Expert Group has taken on a coordinating role to increase the involvement of scientists in field programs using UAS-based sensors as part of their data collection tools. A framework for such coordination has been established from work in the Svalbard area. The Coordinated Investigation of Climate - Cryosphere Interactions (CICCI) framework was established by John Burkhart of NILU prior to the 2011 field season (see Figure 9.1). Nine institutes from six countries participated, the research focus was on black carbon ('soot') and albedo, and data were collected using satellites, balloons, manned and unmanned airplanes and ground crews with a combination of in situ and remote sensing sensors. The framework had no independent funding; so all participants had their own funding either from grants or contracts. Therefore the consortium is open to all interested parties. This framework will also be used in future field campaigns. In 2012 the focus will be on sea-ice properties. Coordination has also started for 2013 where plans are already being formed, also focusing on sea ice in the Chukchi and Beaufort Sea area. By pooling resources and by contacting and coordinating with other large programs, such as the Study of Environmental Arctic Change (SEARCH), the UAS Expert Group expects to increase awareness of the potential for using UAS and enhance the value of efforts planned by increasing access to supporting data from multiple sources.

Other harmonization efforts are also ongoing, in particular one coordinating images of sea ice that is being planned at the University of Colorado, Boulder. This could bring together sea ice images from UAS generated by researchers from participating Arctic countries.

Coordination of the efforts adds to the usefulness of each UAS mission deployment by increasing the value of the data gathered on individually funded projects. Deploying UAS in the field is costly, and optimizing the scientific value of each mission cannot be overemphasized.

# 10. Conclusions and recommendations

The scientific community has only recently begun to use unmanned aircraft for data collection in the Arctic, but activity is growing rapidly as scientists become increasingly aware of their potential and the associated technology becomes more affordable. This report outlines a wide range of applications where UAS could make a significant contribution to scientific programs. The sensors and aircraft platforms needed for most types of scientific data collection in the Arctic already exist and could be made available to the scientific community. Unmanned aircraft used in Arctic programs range in weight from about 50 grams to 5 tonnes. Most scientific missions are flown by small aircraft and are undertaken through universities and research institutes, typically by groups with little or no prior experience or competence as aircraft operators, although some government agencies, such as NASA and NOAA in the United States have more extensive experience with UAS in the Arctic regions.

The main challenge identified to date and the main reason for having established the UAS Expert Group under AMAP is to gain access to airspace for scientific use of UAS in the Arctic. While scientists need access to the entire Arctic airspace for their data collection activities, the safety of other airspace users and people and property on the ground must be maintained. To this end the Expert Group offers three recommendations to AMAP, the scientific and aviation communities and the civil aviation authorities and policy makers:

- The first recommendation is that a treaty be established among Arctic States regulating access to the High Seas of the Arctic Basin by UAS for scientific purposes.

- The second recommendation is that ICAO member States providing services to the FIRs should establish a common approach for integrating scientific UAS operations into Arctic Basin airspace crossing one or more FIRs, and facilitate the acceptance of UAS approved by a member State.

- The last recommendation is that a handbook for scientific users of UAS in the Arctic be developed that includes best practices, safety guidelines and risk assessment guidelines. The purpose of the handbook would be to help scientific operators meet the requirements for UAS operations over the High Seas of the Arctic Basin. The Expert Group has begun work on such a handbook, as it will be integral to the development of requirements set by the CAAs of the Arctic States.

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# Annex A: Resources for users of remotely piloted aircraft in Arctic airspace

## Appendix A1: Current status of UAS regulations in the eight Arctic nations

**Canada**

| | |
|---|---|
| Contact: | Karen Tarr |
| Agency: | Transport Canada |
| Phone: | +1 613 990 1033 |
| Email: | karen.tarr@tc.gc.ca |
| Web address: | www.tc.gc.ca/eng/civilaviation/opssvs/managementservices-referencecentre-documents-600-623-001-972.htm |
| Guidance document: | Staff Instruction (SI) No. 623-001. The review and processing of an application for a Special Flight Operations Certificate for the Operation of an Unmanned Air Vehicle (UAV) System |
| Classes: | Non-military |
| Categories: | All |
| Certification: | SFOC- SPECIAL FLIGHT CLEARANCE |
| Requirements: | As per the guidance document |

**Denmark/Greenland**

| | |
|---|---|
| Contact: | Henrik Michelsen |
| Agency: | Danish Transport Authority |
| Phone: | +45 36 18 63 52 |
| Email: | hemi@slv.dk |
| Web address: | www.trafikstyrelsen.dk/EN/Civil-aviation/Air-law-and-Regulation.aspx |
| Guidance document: | BL 9-04 from January 2004, along with amendments AIC B 20/09 (on First Person View flight), AIC B 21/09 (on Frequencies), and AIC B 24/10 (on UAS) |
| Classes: | None. There is no official distinction between commercial, research/science, governmental, and hobby UAS operations |
| Categories: | 7 kg / 25 kg / 150 kg |
| Certification: | >7 kg need certificate for flight |
| Requirements: | As per the guidance document |

**Finland**

| | |
|---|---|
| Contact: | Mika Saalasti |
| Agency: | Finavia-Transport Safety Agency, TraFi (NSA/CAA Finland) |
| Phone: | +358 20 618 6108 |
| Email: | mika.saalasti@trafi.fi |
| Web address: | www.trafi.fi/en/aviation/regulations/national_legislation |
| Guidance document: | Finnish aviation regulations can be ordered from the CAA by telephone +358 (0)9 4250 2406 or using an order form |
| Classes: | None. RC allowed with restriction. No commercial allowed |
| Categories: | All |
| Certification: | For UAS operations utilizing an autopilot system, permission to fly in a specific region and for a specific period of time must be requested from the Finnish Transport Safety Agency |
| Requirements: | As per the Finish Transportation Agency |

**Iceland**

| | |
|---|---|
| Contact: | Hlin Holm |
| Agency: | Icelandic Civil Aviation Authority |
| Phone: | + 354 569 4431 |
| Email: | hlinh@caa.is |
| Web address: | www.caa.is/FlugmalahandbokinAIP/ |
| Guidance document: | Aeronautical Information Publication (AIP) for Iceland |
| Classes: | RC < 5 kg permitted with restrictions. No similar provisions for UAS >5 kg |
| Categories: | All |
| Certification: | >5 kg RC requires permission if within 1.5 km of aerodrome or houses |
| Requirements: | As per AIP for Iceland |

**Norway**

| | |
|---|---|
| Contact: | Morten Raustein |
| Agency: | Civil Aviation Authority Norway |
| Phone: | +47 982 61 665 |
| Email: | mra@caa.no |
| Web address: | www.caa.no<br>www.luftfartstilsynet.no/caa_no |
| Guidance document: | Current procedures and requirements are described in AIC-N 25/09 |
| Classes: | Non-military |
| Categories: | 150 kg and below |
| Certification: | CAA permission required for all operations |
| Requirements: | As per AIP language. Liability insurance |

**Russia**

| | |
|---|---|
| Contact: | Andrey Schnyrev |
| Agency: | State Aviation Authority of Russia State Unitary Enterprise |
| Phone: | +7 095 492 3131 |
| Email: | SchnyrevAG@mintrans.ru |
| Web address: | None |
| Guidance document: | Aviation Code of the Russian Federation Federal; Aviation Regulations for Use of Russian Federation Air Space; Federal Aviation Regulations for Flights in Russian Federation Air Space; Federal Aviation Regulations For Conduct Of State Aviation Flights; Federal Aviation Regulations for Aeronautical Engineering Support of State Aviation. |
| Classes: | Non-military |
| Categories: | All |
| Certification: | Permissions required for all UAS operations |
| Requirements: | As per regulations |

**Sweden**

| | |
|---|---|
| Contact: | Erik Bergdahl |
| Agency: | Swedish Transport Agency |
| Phone: | +46 10-495 37 54 |
| Email: | erik.bergdahl@transportstyrelsen.se |
| Web address: | www.transportstyrelsen.se |
| Guidance document: | The Swedish Transport Agency's regulations on unmanned aircraft systems (UAS). The Swedish Transport Agency's Statute Book, TSFS 2009: 88. |
| Classes: | Non-military |
| Categories: | 150 kg and below |
| Certification: | Permit issued by Swedish Transportation Agency. Four categories of operation, depending upon size, weight and whether VLOS or BLOS |
| Requirements: | As per Swedish Transportation Agency |

**USA**

| | |
|---|---|
| Contact: | Clifford Sweatte |
| Agency: | Federal Aviation Administration |
| Phone: | +1 703 230 7664 extn. 271 |
| Email: | clifford.sweatte@faa.gov |
| Web address: | www.faa.gov/about/office_org/headquarters_offices/ato/service_units/systemops/aaim/organizations/uas/ |
| Guidance document: | Interim Operational Approval Guidance 08-01. Aviation Safety: Unmanned Aircraft Program Office, AIR-160. Federal Aviation Administration (currently under revision, new document will be 10-01; small UAS Notice of Proposed Rulemaking to be published spring 2013) |
| Classes: | Must be public use; No commercial UAS allowed except in the Arctic region |
| Categories: | All |
| Certification: | Certificate of Waiver or Authorization for public aircraft, Special Airworthiness Certificate for civil aircraft required for ops in National Airspace System |
| Requirements: | As per the guidance document and the FAA Modernization and Reform Act of 2012 |

## Appendix A2: Major operational elements required by each of the eight Arctic nations

| | Canada | Finland | Greenland/ Denmark | Iceland | Norway | Russian Federation | Sweden | USA |
|---|---|---|---|---|---|---|---|---|
| UAS regulations | Yes | Yes | Yes | No | No[a] | Yes[b] | Yes | No |
| Regulations in process[c] | Yes | No | No | No | Yes | Yes | No | Yes |
| Ops history | Yes | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Commercial allowed | Yes | No | ? | ? | Yes | Yes | Yes | No |
| BLOS allowed | Yes | No | Yes[c] | ? | Yes[d] | ? | Yes | No |
| RC allowed | Yes | Yes | Yes | Yes | Yes | Unknown | Yes | Yes |
| Ground observers required | Yes | Yes | Yes | ? | Yes | ? | Yes | Yes |
| Size limits | No | 20 kg | 25 kg | 5 kg[e] | No | ? | Yes | Yes |
| Altitude limits | As specified in SFOC | 150 m | 100 m[f] | ? | No | ? | Yes | Yes |
| Time limited | Yes | Yes | Yes | ? | No | ? | ? | Yes |
| Pilot certification required | Yes | ? | ? | ? | No | ? | Yes | Yes |
| Insurance required | Yes | ? | Yes | No | Yes | ? | ? | No |

[a] Following and participating in EUROCAE and ICAO harmonization efforts, no specific regulations in Norway.
[b] Regulations, if they exist at all, are unclear in this translation. Some UAS activities appear to be allowed, but the unit(s) of Russian Federation Government that has/have authority over those activities is also unclear. Clarification is desired.
[c] BLOS not allowed on mainland Denmark and Greenland, may be allowed in Arctic and away from airfields/populated areas.
[d] If within segregated airspace or danger areas.
[e] For RC aircraft. No stated weight limit or other restrictions on non-RC UAVs.
[f] Flight above 100 m AGL may be allowed in Arctic and away from airfields/populated areas.

## Appendix A3: Summary of the Arctic FIRs and their respective contact information

**Canada**

| | |
|---|---|
| CAA: | Transport Canada |
| Contact/Resource: | www.tc.gc.ca/eng/civilaviation/opssvs/managementservices-referencecentre-documents-600-623-001-972.htm |
| Arctic FIRs: | Edmonton-CZEG |

**Finland**

| | |
|---|---|
| CAA: | Finavia |
| Contact/Resource: | www.trafi.fi |
| Arctic FIRs: | Finland-EFIN |

**Greenland/Denmark**

| | |
|---|---|
| CAA: | Danish Transport Authority |
| Contact/Resource: | www.uavlab.org<br>www.trafikstyrelsen.dk/EN/Civil-aviation/Air-law-and-Regulation.aspx |
| Arctic FIRs: | Sondrestrom-BGGL |

**Iceland**

| | |
|---|---|
| CAA: | Icelandic CAA |
| Contact/Resource: | www.caa.is/FlugmalahandbokinAIP/ |
| Arctic FIRs: | Reykjavic-BIRD |

**Norway**

| | |
|---|---|
| CAA: | Norwegian CAA |
| Contact/Resource: | www.luftfartstilsynet.no/caa_no |
| Arctic FIRs: | Bodo Oceanic-ENBD |

**Russian Federation**

| | |
|---|---|
| CAA: | State Aviation Authority of Russia State Unitary Enterprise |
| Contact/Resource: | Centre of Aeronautical Information of Civil Aviation (SUE CAI CA), 67 Svobody str. Moscow, 125364, Russia. Phone: +7 095 492 3131 Fax: +7 095 948 5909 |
| Arctic FIRs: | Murmansk Oceanic-ULMM; Magadan Oceanic-UHMM |

**Sweden**

| | |
|---|---|
| CAA: | Swedish Transport Agency |
| Contact/Resource: | www.transportstyrelsen.se/Global/Luftfart/Luftfartyg/The%20Swedisk%20UAS-regulation%20(TSFS%202009-88).pdf |
| Arctic FIRs: | Sweden-ESAA |

**USA**

| | |
|---|---|
| CAA: | Federal Aviation Administration |
| Contact/Resource: | www.faa.gov/regulations_policies/faa_regulations |
| Arctic FIRs: | Anchorage Arctic CTA/PAZA |

# Annex B:

## Detailed overview of the regulatory environments in each of the eight Arctic nations as pertaining to UAS operations within their respective territories or ICAO designated jurisdictions

The following summary of UAS-related regulations represents the best information available as of the date this report was prepared. Regulatory activity is ongoing in several jurisdictions and at a multi-national level, such as within EUROCAE WG-73 and the ICAO UAS Working Group, and the regulations described below may change in the near future to reflect harmonization efforts.

### Appendix B1. Canada

In Canada the formal process has begun to develop regulations that will determine how UAS will be permitted to operate within Canadian airspace on a routine basis; however, this process is expected to take several years to complete. In the meantime a process exists by which UAS operations may be given operating approval under an SFOC. General guidelines for the review and processing of an application for an SFOC for UAS operation are available in may be found in Transport Canada Staff Instruction No. 623-001 (Transport Canada, 2008).

At a minimum, the following information must be provided in an application for an SFOC:

- The name, address, and where applicable, the telephone number and facsimile number of the applicant.
- The name, address, and where applicable the telephone number and facsimile number of the person designated by the applicant to have operational control over the operation (Operation Manager).
- The method by which the Operation Manager may be contacted directly during operation.
- The type and purpose of the operation.
- The dates, alternate dates and times of the proposed operation.
- A complete description, including all pertinent flight data on the aircraft to be flown.
- The security plan for the area(s) of operation and security plan for the area(s) to be overflown to ensure no hazard is created to persons or property on the surface.
- The emergency contingency plan to deal with any disaster resulting from the operation.
- The name, address, telephone and facsimile numbers of the person designated to be responsible for supervision of the operation area (Ground Supervisor), if different from the Operation Manager during the operation.
- A detailed plan describing how the operation shall be carried out. The plan shall include a clear, legible presentation of the area to be used during the operation. The presentation may be in the form of a scale diagram, aerial photograph or large scale topographical chart and must include at least the following information:
    - the location and height above ground of all obstacles in the approach and departure path to the areas where the operation will be carried out;
    - the exact boundaries of the area where the actual operation will be carried out;
    - the altitudes and routes to be used while carrying out the operation.
- Any other information pertinent to the safe conduct of the operation as may be requested by the Minister.

Key to approval of an SFOC is the risk management approach. The SFOC applicant is expected to evaluate the risks associated with the proposed operation and indicate the associated risk mitigation measures in their application. Depending on the nature of the operation, consideration should be given to events such as:

- Degradation or loss of:
    - command and control links
    - telemetry data links
    - communication links with air traffic control, with flight crew
    - sense and avoid links
    - payload links
    - propulsion system
    - control station power
    - software system
    - visual contact with aircraft when operating within visual range.
- UAS encounters with:
    - another aircraft
    - varying weather conditions
    - airframe and engine icing.
- Aborted take-off (launch)/ landing (recovery)
    - aborted take-off or aborted landing of the air vehicle.

## Appendix B2. Finland

Finland has not implemented any specific regulations addressing UAS. Use of a RC model aircraft is allowed without the requirement to obtain a special permission, if the following conditions are met:

- The flight altitude does not exceed 150 m.
- The aircraft is operated within the visual line of sight of the operator.
- The aircraft weighs less than 20 kg.
- The operation does not create a hazard for other aviation users.

Restrictions greater than those outlined above may be applied in the vicinity of airports.

Some UAS operations may be exempt from most regulations, or may be granted waivers from others, if the aircraft weighs less than 150 kg.

For UAS operations utilizing an autopilot system, permission to fly in a specific region and for a specific period of time must be requested from the Finnish Transport Safety Agency (www.trafi.fi). The permit issued cannot be permanent in duration, and will only be valid for a maximum of two weeks. If permission is granted, all other aviation activities will be prohibited or restricted in the affected region for the defined period of time. A permission once obtained is no guarantee of future permissions for similar activities, as each application is evaluated individually and on its own merits. The applications should be submitted approximately ten weeks before the planned operation period.

Commercial UAS activities are not allowed.

The rules may change when the regulations in EU countries are harmonized.

## Appendix B3. Greenland/Faroe Islands/Denmark

The UAS operational rules for Denmark are found at BL 9-4 from January 2004, along with amendments AIC B 20/09 (on First Person View flight), AIC B 21/09 (on Frequencies), and AIC B 24/10 (on UAS). All documents are found (in Danish along with an unofficial English translation on www.uavlab.org under Regulations).

UAS weighing less than 7 kg maximum takeoff weight can be flown most places in Denmark, whereas unmanned aircraft weighing between 7 and 25 kg (officially termed 'large models') require individual certification of each model, and can only be flown from approved hobby airfields. The pilot must also be properly certificated. This class of UAS includes all jet turbine engine models regardless of weight. Certification is given in accordance with BL 9-4 by the hobby flight association in Denmark, Modelflyvning Danmark (www.modelflyvning.dk; the site is entirely in Danish). Unmanned aircraft weighing between 25 and 150 kg are prohibited from flying in Denmark.

Traditionally, 35 MHz was (and to some extent still is) used in Denmark for all airborne models, but 2.4 GHz is now also allowed.

The maximum flight altitude for all classes of UAS is 100 m AGL.

*Automatic flight*

There is no distinction between manually piloted aircraft and one flown with an autopilot system. In all cases the aircraft must be equipped with a remote control radio receiver, which must be turned on. However, according to AIC B 24/10, it is permissible for a model aircraft to fly automatically under the conditions that it always remains in the visual line of sight of the pilot, and that the pilot is at all times able to take control of the vehicle without delay. The pilot is responsible for the safety of the flight and for compliance with BL 9-4. Further, the airspace used for the UAS flight must be observed for other traffic, and the UAS flight must be terminated in the event that other traffic presents a conflict. This implies that there may be observers other than the pilot assisting in observing the airspace, and it also opens the possibility of extending the operational range if the safety case is convincing.

*Foreigners flying in Danish airspace*

Foreigners may operate RC model aircraft in Denmark, provided that:

- They are approved to do so in their country of origin.
- They have liability insurance (for models over 7 kg).
- The model and operation of the model is in accordance with BL 9-4 and any other relevant regulation (such as regulation on frequencies).

The operational rules for foreigners in Denmark are not part of BL 9-4 and are based on guidelines from Modelflyvning Danmark. Flying a large model aircraft with no liability insurance subjects the violator to a penalty by imprisonment for up to two years.

*Dispensation*

There is no official distinction between commercial, research/science, governmental, and hobby UAS operations. All must adhere to the same rules. However, dispensation from the rules can sometimes be achieved for research purposes, but usually not for hobby or commercial purposes. Applications for dispensation must be sent to the Danish Transport Authority, attention Henrik Michelsen (per May 2011).

There is a processing fee, regardless of whether or not a permit is issued, of ~ 150 EUR/hour. While this is high compared with most (if not all) other countries, the actual time spent processing applications is often limited, and consequently, so is the cost. Permits are usually limited to 1 year and geographically to very small areas. Permits for flying over urban areas or above 100 m are usually not given.

While the same rules apply to mainland Denmark and to Greenland, it is usually easier to get permission for flight above 100 m, for BLOS flight, and for operating large models outside of approved airfields, in the Arctic region.

## Appendix B4. Iceland

The Icelandic CAA is the regulatory authority for Iceland. The Aeronautical Information Publication (AIP) for Iceland is published by authority of the CAA of Iceland and is prepared in accordance with the SARPs of Annex 15 to the Convention on International Civil Aviation and the Aeronautical Information Services Manual (ICAO Doc 8126). The AIP is made up of three parts (General, Enroute, Aerodromes), each divided into sections and subsections as applicable. Charts contained in the AIP are produced in accordance with Annex 4 to the Convention on International Civil Aviation and the Aeronautical Chart Manual (ICAO Doc 8697). Differences from ICAO SARPs are given in subsection GEN 1.7.

Research has not revealed any regulations or standards for UAS operations in Iceland's territorial airspace. Iceland has been unable to actively participate in AMAP activities due to economic and budget constraints, so this summary is based upon review of available Internet resources.

Iceland does have airspace regulations in place governing the operation of recreational model aircraft:

> *The ascent of flying models of less than 5 kg total weight requires no permission, with the exception of rocket propelled models. The operation of flying models with combustion engines within a distance of less than 1.5 km from housing areas is permitted only with the consent of the aeronautical authority. The same applies to flying models of all types within a distance of less than 1.5 km from the boundary of aerodromes. The operation of all types of flying models on aerodromes is permitted only with the consent of the air traffic services.* (AIP Iceland ENR Section 1.1.10 'Ascents of balloons, kites, self-propelled flying models and flying bodies'.)

There are no similar provisions for model aircraft activities more than 1.5 km from aerodromes or populated areas, so the assumption is that such activities would not be specifically prohibited. For models weighing over 5 kg, permission to fly in any domestic airspace may be inferred, but there are no defined procedures for obtaining permissions for unmanned aircraft or models exceeding the weight limit. VFR (visual flight rules) and IFR (instrument flight rules) flights in uncontrolled Class G airspace require no permissions and no two-way radio communications, as long as maximum 250 kts IAS (knots indicated airspeed) below 10 000 ft AMSL (above mean sea level) is observed.

The internet address for the AIP is www.caa.is/FlugmalahandbokinAIP

The internet address for Aeronautical Information Services, Reykjavík Airport, and International NOTAM Service is www.flugstodir.is

## Appendix B5. Norway

As of March 2011, the Norwegian CAA is following a roadmap to regulation first presented in 2009. The Norwegian CAA is participating in several international efforts on the development of UAS regulations, including the ICAO UAS Study Group and EUROCAE WG 73. The CAA wants Norway's national regulations to be similar to regulations adopted in other countries. The

CAA sees the importance of developing regulations in close cooperation with the industry as technology is rapidly evolving, making it challenging to create regulations that will enable the industry to develop its potential and at the same time maintain the highest level of safety. The guiding principle for the requirements for UAS equipment, operations, and personnel qualifications must be such that the total risk level for other air traffic and persons and equipment on the ground is acceptable. The total risk level shall not be higher than for similar operations with manned aircraft.

Pending implementation of new regulations, access to airspace is granted on a case-by-case basis and segregation of airspace, where appropriate. The current procedures and requirements are described in AIC-N 25/09 (*Bruk av ubemannede luftfartøy i Norge* – Usage of UAS in Norway), which is expected to be replaced with an updated AIC summer 2011.

*Summary of AIC-N 25/09*

- The Norwegian CAA reports incidents and accidents involving UAS, similar to manned aviation.
- Those who are planning operations of UAS in Norwegian airspace are requested to contact the CAA at an early stage, such that plans can be adjusted with existing regulations.
- Until a dedicated UAS regulation is in force, the CAA intends to be constructive in finding solutions that enable UAS operations in Norwegian airspace. Each application will be evaluated on an individual basis to determine whether it is covered by existing regulations.
- The requirements to maintain safety of third parties, on the ground, on the water or in the air, will be the determining factor for technical solutions and any necessary adaptations.
- All UAS operators need a CAA approval before commencing UAS operations, and an applicant must provide a detailed description of planned operations, and a relevant risk analysis, with description of corrective measures taken to mitigate the risks of the operation.
- All unmanned aircraft operations shall be covered by liability insurance, regardless of takeoff weight.
- UAS operations are only permitted in segregated airspace, unless the flight can be carried out below 400 ft AGL and within VLOS, meaning such that the aircraft can be continuously controlled and monitored visually without any aids other than prescriptive glasses. Use of binoculars, camera, etc. is not accepted. In this context, segregated airspace means a specified airspace, either a temporary or permanent danger or restricted area.
- It shall always be possible for the pilot to take manual control of the aircraft so as to avoid collisions with other aircraft, persons, marine vessels, vehicles and structures on the ground.
- For all flights above 400 ft AGL, or BLOS a specific CAA permission is required. Permission may be issued for a single flight, a series of flights or a defined period, whichever is most practical. Normally, such operation will require issuance of a NOTAM at least 48 hours before the operation(s). The objective is to inform other air traffic of the activity within the danger area, or to separate other air traffic from the unmanned aircraft by creation of a restricted area.

Establishing a temporary danger area may take a few weeks. Establishing a restricted area is more involved and will take at least six months.

## Appendix B6. Russian Federation

The sources of aviation regulation in the Russian Federation are as follows:

1. Aviation Code of the Russian Federation (adopted as Federal Law № 60-FZ by the State Duma in 1997).

Special policies on unmanned aviation are not provided for in the Aviation Code of the Russian Federation. The following general rules therefore apply to all UAS operations:

- As there is no onboard aircraft crew, the operation of an unmanned aircraft is carried out by the system's ground crew.
- Since there is no airfield, the operation of an unmanned aircraft is carried out from the region where the unit is positioned and where the system is set up in working condition.
- The commander of the aircraft has no responsibility for a flight; instead the responsibility falls to the director of the subunit for unmanned aircraft.
- UAS are considered as assets of increased risk and their use is subject to special regulation and control with development of additional legal norms.

2. Federal Aviation Regulations for Use of Russian Federation Air Space (approved by Resolution of the Government of the Russian Federation № 138, 11 March 2010, and effective as of 1 November 2010).

In general, the current rules allow unmanned aircraft to carry out flights by establishing temporary local conditions, and also short-term limitations in the interests of users of the airspace that organize flights by unmanned aircraft.

Relevant sections in the classification of airspace:

*Section 10. The air space above the territory of the Russian Federation and also beyond its boundaries where responsibility for organizing air traffic is charged to the Russian Federation is classified as follows:*

*a) Class A – flights carried out exclusively under instrument flight rules are allowed. All aircraft are provided with dispatch service and are echeloned. Limitations on speeds are not used. Continuous two-way radio communications with the air traffic control agency (flight control) is mandatory. All flights are carried out under clearance for use of the airspace with the exception of situations set forth by point 114 of these Federal Regulations;*

*b) Class C – flights carried out under instrument flight rules and visual flight rules are allowed. All aircraft are provided with air traffic control service. Aircraft performing flights under instrument flight rules are echeloned relative to other aircraft performing flights under instrument and visual flight rules and receive information on traffic in relation to other aircraft flying under visual flight rules. Limitations on speeds are not used. Two-way radio communications with the air traffic control agency (flight control) is mandatory. All flights are carried out under clearance for the use of air space with the exception of cases set forth by point 114 of these Federal regulations.*

*c) Class G – flights carried out under instrument flight rules and visual flight rules are allowed. Stacking of aircraft is not carried out. All flights are provided with flight-information service as requested. A limitation on speed consisting of not more than 450 km/hr is in effect for all flights at altitudes below 3000 meters. Aircraft performing flights under instrument flight rules are obligated to have continuous two-way radio communications with the air traffic control agency (flight control). During flights by aircraft under visual flight rules, the presence of continuous two-way radio-communications with the air traffic control agency (flight control) is not required. During all flights performed by aircraft, the existence of clearance for use of the air space is not required.*

*43. A frontier zone – air space that lies next to the state boundary of the Russian Federation with a width of 25 km and special conditions for its use is established above the territory of the Russian Federation along its state boundary. No frontier zone has been established along the state boundary of the Russian Federation in the northern Arctic Ocean.*

*46. During performance of aviation operations, use of the air space in the frontier zone is carried out with the authorization of a territorial agency of the Federal Security Service of the Russian Federation for users of the air space.*

*47. In order to prevent unintentional violation of the state boundary of the Russian Federation, air fields (helicopter fields), and control points for unmanned aircraft situated in the frontier zone must have a system for air traffic control observation that will make it possible to carryout control over aircraft flights.*

*48. Flights of aircraft over populated places for the purpose of taking measures aimed at saving the lives and protecting the health of people, suppressing and detecting crimes may be carried out at an altitude that will ensure realization of the noted measures while entrusting responsibility for ensuring the safe conduct of flight to the authorized entity organizing such flights.*

*49. Aviation operations, parachute jumps, the ascents of tethered balloons over populated areas shall be carried with authorizations to users of the airspace from the appropriate agency of local self-government.*

*52. Use of the air space by unmanned aircraft in air space of classes A, C and G shall be carried out on the basis of an aircraft flight plan and authorization for use of the air space. Use of air space by unmanned aircraft shall be carried out by establishing time and place conditions and also by short-term limitations in the interests of users of the air space operating flights by unmanned aircraft.*

3. Federal Aviation Regulations for Flights in Russian Federation Air Space (approved by joint decree № 136/42/51, 2002, of the Ministry of Defense, Russian Federation, Ministry of Transport, Russian Federation and the Russian Aero-Space Agency).

Regulations shall establish general procedures for conduct of manned aircraft flights by civilian, state and experimental aviation in Russian Federation air space.

The regulations stipulate that flights of automatic balloons and aircraft that are piloted remotely shall take place under regulations established by a specially authorized agency in the field of defense.

4. Federal Aviation Regulations For Conduct Of State Aviation Flights (rules approved by decree of the Ministry of Defense, Russian Federation № 275, 2004).

Regulations are applicable exclusively to piloted aviation; separate regulation of the activity of unmanned aviation by rules is not anticipated.

Regulations shall not establish procedures for access by personnel of drone subunits, they shall not regulate verification of the training of managers, and they shall not establish accessible standards for breaks and rest of personnel involved in the conduct and control of drone flights.

Aspects of flight conduct during operations under field conditions are not included in the Regulations.

5. Federal Aviation Regulations for Aeronautical Engineering Support of State Aviation.

While preparation of the drone for use shall directly consider operation of the aircraft itself, a system that includes drones is the totality of functionally linked technical assets. Flights are not possible without using all elements of the system.

It is suggested: That equipment for the preparation and launch of a drone, its control during flight, equipment for transport and evacuation of the drone, equipment for the use, processing and transmission of information obtained be included as part of the general and special use service equipment. It is advisable to consider this equipment to be on a par with the aircraft as basic elements of the system and count as aviation technology.

6. Other Normative-Legal Documents of Ministries and Departments.

7. Procedures for use of airspace to meet the needs of various airspace users are regulated by the following instructions:

- Instructions for drawing up formalized applications for use of air space.
- Instructions for conduct of firing on a test range.
- Instructions for conduct of explosives operations.
- Instructions on conduct of anti-hail firing within the territory of the Russian Federation.
- Instructions on conducting launches of sound balloons within the territory of the Russian Federation.
- Instructions on preparing for and conducting flights of automatic and ascent of tethered balloons.

8. Federal aviation regulations for state registration of state aircraft.

Shall establish a mandatory numerical count of unmanned aircraft without being entered in the State registry.

It is suggested that a numerical count of the existence and technical description of unmanned aircraft be carried out by a single agency on the basis of information submitted, with inclusion of the side [registration] number and designations that determine the affiliation of the unmanned aircraft with a specific user of the air space.

*Instructions on drawing up formalized applications for use of airspace*

In order to organize training and certification of aviation personnel for systems using unmanned aircraft, it will be necessary to introduce changes in the resolution of the Government of the Russian Federation defining the list of duties of the aviation personnel in systems using drones and requirements for aviation personnel in systems using drones under Federal Aviation Rules.

*Basic problems in organizing the use of systems with drones in the civilian sector:*

- Certification of systems of aircraft, aviation engines, aircrews and ground systems;
- Registration of systems with unmanned aircraft;
- Training and certification of aviation personnel;
- Certification of users to carry out activities based on use of air space.
- For certification of systems with unmanned aircraft, it will be necessary to:
  - Determine agencies for certification;
  - Establish through federal aviation regulations the requirements for flight readiness of unmanned aircraft, aviation engines, and aircrews, and for the suitability of ground facilities as well as standards of certification.

http://base.garant.ru/197839

## Appendix B7. Sweden

In Sweden, UAS weighing less than 150 kg are regulated by the Swedish Transport Agency's regulations on UAS (Swedish Transport Agency, 2009). The regulations cover design, manufacture, modification, maintenance and activities with civil UAS within Sweden.

The regulations subdivide UAS into four different classes. The first three cover VLOS operations with aircraft weighing up to 150 kg.

- Classes 1A and 1B are for relatively small UAS weighing less than 1.5 kg and up to 7 kg (1B). Both classes have limitations on total kinetic energy and are limited to VLOS only.
- Class 2 covers VLOS-only operations with aircraft weighing more than 7 kg, and up to 150 kg. This class has no limitations on total kinetic energy.
- Class 3 covers all BLOS operations, regardless of weight and total energy.

The company or person that wants to operate a UAS in Swedish airspace must apply for a permit to operate UAS from the Swedish Transport Agency.

The regulations for BLOS flight demand a high level of competence from the operator, similar to what is required in manned civil aviation. This means that it is almost impossible for smaller companies to operate a UAS BLOS under the Class 3 regulations. This will have a limiting effect on the use of UAS in scientific campaigns, as these are usually carried out by smaller groups belonging to universities, or smaller research companies.

To date, the Swedish Transport Agency has issued permits to fly UAS in civil applications to around 40 companies and individuals. Most of the permits are in classes 1A and 1B, with some permits in Class 2. There have been no permits issued for Class 3, according to the Swedish Transport Agency web page.

The Swedish regulations can be found at: www.transportstyrelsen.se/Global/Luftfart/Luftfartyg/The%20Swedisk%20UAS-regulation%20(TSFS%202009-88).pdf

## Appendix B8. United States

UAS regulations are under development in the USA. Currently the FAA encourages compliance with existing Federal Aviation Regulations with policy statements and guidance documents, neither of which carry the enforcement weight of regulations. Most of the investment in UAS systems and technology flows through the military and Customs and Border Protection. Aircraft of any type are generally exempt from federal aviation regulations if operated by a governmental entity (federal, state or local). These are characterized as 'public aircraft' as long as the operation is not conducted for commercial purposes. However, even public aircraft operations are required to comply with the airspace regulations found in 14 CFR Part 91, and may not occupy navigable airspace without permission of air traffic authorities, which is secured by a Certificate of Waiver or Authorization (COA). Civil UAS operations are not allowed unless the aircraft has been granted a Special Airworthiness Certificate in the Experimental Category, and the pilot is appropriately certificated for the type of operation flown.

The FAA has issued a series of guidance documents and advisory circulars that are intended to encourage UAS operators to comply with the pertinent regulations for manned aviation. Interim Operational Approval Guidance 08-01 is the current guidance document describing the application process and eligibility for authorized civil UAS operations for public entities by way of a COA. The alternative authorization for non-public UAS operations is a Special Airworthiness Certificate in the Experimental Category. The FAA has advised that this guidance document is due to be superseded in the near future by an Order that will further clarify the requirements for UAS operations in the U.S. National Airspace System, but thus far no new policy has been issued, and recent legislation and reorganization within the FAA's UAS Program Office have assumed a higher priority.

The FAA has issued several hundred COAs to public operators, including Department of Defense operations outside of restricted or segregated airspace. With the exception of NASA's Ikhana and Global Hawk airborne science platforms, and Customs and Border Protection's Predator B surveillance aircraft, the majority of public aircraft COAs have been issued to smaller systems (weighing less than 55 lbs). The COAs require strict compliance with geographic borders of operations, airworthiness standards, lost link and flight termination strategies, communications requirements, pilot and observer certification and all relevant sections of the General Operating Rules of Part 91 of the Code of Federal Regulations. The COAs are generally issued for a limited period of time, but for no longer than one year. The COA can be renewed through the FAA's internet-based application and renewal process. No civil or commercial UAS operations are allowed; so the only eligible proponents are public entities such as government, state universities and state and local agencies, including law enforcement, fire fighting and search and rescue organizations.

The FAA applies the relevant sections of the Federal Aviation Regulations to UAS operations in international airspace FIRs in which the United States provides air traffic services. The Arctic airspace in the Anchorage Arctic sector of the NAM FIR is included in that policy.

The U.S. Congress passed legislation (H.R. 658) signed into law in February 2012 entitled The FAA Modernization and Reform Act of 2012. The new law establishes a mandate to the FAA to initiate and successfully complete a series of efforts to facilitate integration of unmanned aircraft systems into the National Airspace System, and specifically addresses the issue of the use of unmanned aircraft in the Arctic.

SEC. 332. INTEGRATION OF CIVIL UNMANNED AIRCRAFT SYSTEMS INTO NATIONAL AIRSPACE SYSTEM.

*EXPANDING USE OF UNMANNED AIRCRAFT SYSTEMS IN ARCTIC.—*

*(1) IN GENERAL. —Not later than 180 days after the date of enactment of this Act, the Secretary shall develop a plan and initiate a process to work with relevant Federal agencies and national and international communities to designate permanent areas in the Arctic where small unmanned aircraft may operate 24 hours per day for research and commercial purposes. The plan for operations in these permanent areas shall include the development of processes to facilitate the safe operation of unmanned aircraft beyond line of sight. Such areas shall enable over-water flights from the surface to at least 2,000 feet in altitude, with ingress and egress routes from selected coastal launch sites.*
*(2) AGREEMENTS.—To implement the plan under paragraph (1), the Secretary may enter into an agreement with relevant national and international communities.*
*(3) AIRCRAFT APPROVAL.—Not later than 1 year after the entry into force of an agreement necessary to effectuate the purposes of this subsection, the Secretary shall work with relevant national and international communities to establish and implement a process, or may apply an applicable process already established, for approving the use of unmanned aircraft in the designated permanent areas in the Arctic without regard to whether an unmanned aircraft is used as a public aircraft, a civil aircraft, or a model aircraft.*

U.S. Federal Aviation Regulations may be found atwww.faa.gov/regulations_policies/faa_regulations

The text of The FAA Modernization and Reform Act of 2012 may be found at http://thomas.loc.gov/cgi-bin/query/F?c112:6:./temp/~c112zJfgEC:e200458

# Acronyms and Abbreviations

| | |
|---|---|
| AARI | Arctic and Antarctic Research Institute, Russian Federation |
| AGL | Above Ground Level |
| AMAP | Arctic Monitoring and Assessment Programme |
| AXBT | Airborne EXpendable Bathy Thermograph |
| CAA | Civil Aviation Authority |
| $CH_4$ | Methane |
| CICCI | The Coordinated Investigation of Climate – Cryosphere Interactions framework |
| $CO_2$ | Carbon dioxide |
| COA | Certificate of Waiver or Authorization (U.S. only) |
| EUR | European Flight Information Region |
| FAA | Federal Aviation Administration (US) |
| FIR | Flight Information Region |
| ICAO | International Civil Aviation Organization |
| MID/ASIA | Mid-Asia and Asia Flight Information Region |
| $N_2O$ | Nitrous oxide |
| NAM | North American Flight Information Region |
| NAT | North Atlantic Flight Information Region |
| NILU | Norwegian Institute for Air Research |
| Norut | Northern Research Institute, Norway |
| Notam/NOTAM | Notice to Airmen |
| RC | Radio Controlled (model aircraft) |
| SARPS | Standards and Recommended Practices (ICAO) |
| SAR | Synthetic Aperture Radar |
| SFOC | Special Flight Operations Certificate (Canada) |
| SST | Sea Surface Temperature |
| UAS | Unmanned Aerial System or Unmanned Aircraft System |
| VLOS | Visual Line of Sight |

AMAP

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