ARCTIC SCIENCE REMOTELY PILOTED AIRCRAFT SYSTEMS (RPAS) OPERATOR'S HANDBOOK

Arctic Monitoring and Assessment Programme (AMAP)
Unmanned Aircraft Systems Expert Group

ARCTIC COUNCIL

AMAP
Arctic Monitoring and Assessment Programme

Citation: AMAP, 2015. *Arctic Science Remotely Piloted Aircraft Systems (RPAS) Operator's Handbook*. By: R. Storvold, C. Sweatte, P. Ruel, M. Wuennenberg, K. Tarr, M. Raustein, T. Hillesøy, T. Lundgren, M. Sumich. Arctic Monitoring and Assessment Programme, Oslo. 25 pp.

ISBN – 13 978-82-7971-090-5

Available as an electronic document from www.amap.no

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Cover photo: National Oceanic and Atmospheric Administration (NOAA) Pacific Marine Environmental Laboratory (PMEL) Manta RPAS take-off from Ny-Ålesund with a black-carbon aerosol measurement sensor during the international Collaborative Investigation of Climate Cryosphere Interaction (CICCI) 3 campaign, April 2015.
Photographer: Kjell-Sture Johansen, Norut (Northern Research Institute).

Printing:
Narayana Press, Gylling, DK-8300 Odder, Denmark (www.narayanapress.dk).

FSC www.fsc.org MIX Paper from responsible sources FSC™ C010651

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 gratefully acknowledges the financial support provided by Norway and the United States for the development of this handbook, and the contributions of experts from the United States, Norway, Canada, and Sweden.

This handbook has been subject to a peer review process. The results and any views expressed in this document are the responsibility of those experts engaged in the preparation of the handbook.

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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1. Introduction

1.1. Scope of Handbook

The challenge for any potential operators of remotely piloted aircraft systems (RPAS) in the Arctic region is to identify and understand applicable regulations in the geographic area where they plan to operate. This handbook should be used to develop a process for interfacing with the civil aviation authority (CAA) having jurisdiction in the operation area and obtaining the required permissions to conduct RPAS operations. This handbook is a simplified supplement to the International Civil Aviation Organization (ICAO) Document (Doc) 10019, *Manual on Remotely Piloted Aircraft Systems (RPAS)*, with regard to Arctic operations for science. This handbook should be viewed as a living document. As RPAS technology evolves, so will this handbook and the associated handbooks of the CAAs.

1.2. Recommendations of the Arctic Council AMAP UAS Expert Group

The Arctic Monitoring and Assessment Programme (AMAP) Unmanned Aircraft Systems Expert Group (UASEG) has formulated a list of recommended practices and procedures in order to assist the Arctic air navigation service providers (ANSPs) in mitigating risks to other aircraft operating in the Arctic:

1. Require an operations and communications plan (see Appendix A.6, "Arctic RPAS Operations & Communications Plan") in accordance with national regulations and in a manner that meets the applicable ICAO provisions to ensure the safest possible outcome of each mission.
2. Require the operator to file an ICAO flight plan through the appropriate CAA or ATS unit. Flight plans shall be submitted in accordance with Chapter 3 of ICAO Annex 2.
3. Recommend a common approach to safety risk assessment based on ICAO's framework.
4. Recommend the equipage of a transponder with Automatic Dependent Surveillance-Broadcast (ADS-B) in and out, or future equivalent equipment, for all flights.
5. Require that UAS used for beyond visual line-of-sight (BVLOS) operation be registered in a national aircraft registry.
6. Require that each civil UAS operator provide proof of insurance in Special Drawing Rights (SDR), or equivalent, in accordance with the European Union established policy of EC785/2004, Article 7.1 Table, or each State's equivalent requirements.
7. Recommend that the CAAs approve UAS operators in a similar manner as manned aircraft operators.
8. Require the operator to ensure that each remote pilot is licensed in accordance with national regulations and in a manner that is consistent with the provisions of ICAO Annex 1, *Personnel Licensing*.
9. Require CAA-acceptable proof of proficiency of training or competency for the specific UAS to be flown. If the operator is building and flying their own manufactured UAS, include the proficiency of training and competency of the organization in their accepted operations manual.
10. Recommend CAAs establish type certification and airworthiness certification requirements to enable cross–flight information region (cross-FIR) operations.
11. Any Arctic member nation reserves the right to provide additional requirement(s) for flights in its sovereign airspace at any time on a case-by-case basis.
12. Include Arctic UAS operations in Aeronautical Information Publication (AIP) supplements. Recommend charting of UAS Arctic coastal launch sites. Require deconfliction plans be coordinated with the Arctic CAAs and the operator's approval authority(ies). Attached is a suggested "Arctic RPAS Operations & Communications Plan" that may be used to support this requirement.

Non-Aviation Considerations

13. Recommend States/CAAs to create and maintain an app/website for graphically displaying Notice to Airmen notifications (NOTAMs), pending operations, and other information from AIPs.
14. Develop recommendations for minimizing environmental impacts of Arctic UAS operations.

These recommendations are further discussed by the UASEG in this white paper published in 2015 by the Arctic Monitoring and Assessment Programme: *Implementing Scientific Data Collection across the Arctic Oceanic Region Utilizing Unmanned Aircraft Systems (UAS).*[1]

[1] AMAP, 2015. *Implementing Scientific Data Collection across the Arctic Oceanic Region Utilizing Unmanned Aircraft Systems (UAS)*. By: C. Sweatte, R. Storvold, P. Ruel, M. Wuennenberg, K. Tarr, A. la Cour-Harbo, B. Feldberg, J. Kivinen, H. Hólm, M. Raustein, E. Jangren, B. Mulac, J. Adler, D. Davis, L. Cary, S. Lesenkov. Arctic Monitoring and Assessment Programme, Oslo. 5 pp.

1.3. List of Acronyms

AGL – Above Ground Level

AIP – Aeronautical Information Publication

ALTRV – Altitude Reservation

AMAP – Arctic Monitoring and Assessment Programme

ANSP – Air Navigation Service Provider

AOM – Aircraft Operating Manual

ATC – Air Traffic Control

ATS – Air Traffic Services

BRLOS – Beyond Radio Line-of-Sight

BVLOS – Beyond Visual Line-of-Sight

C2 – Command and Control Link

CAA – Civil Aviation Authority

CONOPS – Concept-of-Operations Plan

CTA – Control Area

CTR – Control Zone

EVLOS – Extended Visual Line-of-Sight

FAA – Federal Aviation Administration

FIR – Flight Information Region

FMRA – FAA Modernization and Reform Act of 2012

GA – General Aviation

GCS – Ground Control Station

GPS – Global Positioning System

ICAO – International Civil Aviation Organization

IFR – Instrument Flight Rules

N/A – Not Applicable

NAS – National Airspace System

NASA – National Aeronautics and Space Administration

NOTAM – Notice to Airmen

OM – Operator's Manual

PF – Pilot Flying

PIC – Pilot in Command

RC – Radio Controlled

RPA – Remotely Piloted Aircraft

RPAS – Remotely Piloted Aircraft System(s)

RPS – Remote Pilot Station(s)

RX/TX – Receiver/Transmitter

SAR – Search and Rescue

SARPs – Standards and Recommended Practices

SMS – Safety Management System

SOP – Standard Operating Procedure

sUAS – Small Unmanned Aircraft Systems

TCA/TMA – Terminal Control Area/Terminal Maneuvering Area

TIA/TIZ – Terminal Information Area/Terminal Information Zone

TOW – Take-Off Weight

TWR – Tower

UAS – Unmanned Aircraft System(s)

UASEG – Unmanned Aircraft Systems Expert Group

VLOS – Visual Line-of-Sight

VFR – Visual Flight Rules

VNE – Never-Exceed Air Speed

1.4. Introduction to RPAS Aviation

International aviation today is regulated through the use of international Standards and Recommended Practices (SARPs). The International Civil Aviation Organization (ICAO), a specialized United Nations agency, develops the SARPs, which are then used by States when they develop their legally binding national civil aviation regulations.

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 (SUPs) contained in ICAO Doc 7030, *Regional Supplementary Procedures*. Each major region is divided into smaller regional FIRs in which flight information and air traffic management services are provided by ICAO Member States.

The Arctic region lies beneath four major FIRs (NAT, EUR, NAM, and MID/ASIA). Six regional FIRs are of greatest interest in Arctic research (Edmonton, Sondrestrom, Reykjavik, Bodø Oceanic, Murmansk/Magadan Oceanic, and Anchorage Arctic), but Finland and Sweden may also be important to scientists. The locations of these FIRs are shown in Figure 1.

A flight information region is divided into portions of airspace, both horizontally and vertically. Each portion has an airspace class type (see Table 1 for classes) corresponding to the level of air traffic control and services provided there. In general, a higher class of airspace provides more services but also imposes more requirements regarding an aircraft's equipment. Classes A–E are called controlled airspace, where an aircraft requires a clearance from air traffic control to operate under instrument flight rules (IFR). Classes F and G are restricted and uncontrolled airspace and may not require any clearances. See Figure 2 for a graphical representation of controlled and uncontrolled FIR airspace and Figure 3 for an example of airspace class division.

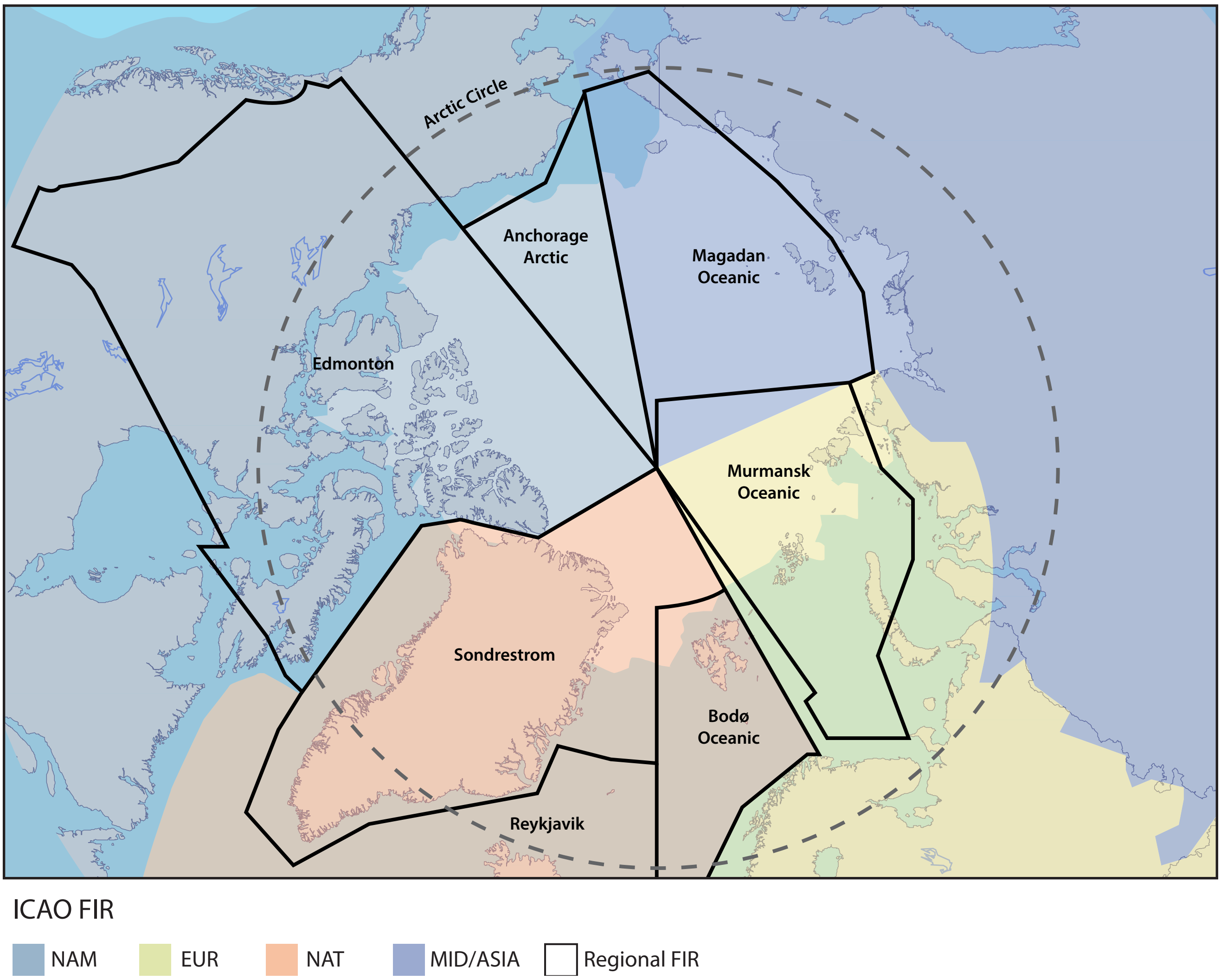

Figure 1. Arctic flight information regions, as designated by the International Civil Aviation Organization. (Source: Based on information from the ICAO website.)

All aircraft are required to comply with ICAO's Annex 2, *Rules of the Air*, including Appendix 4, "Remotely Piloted Aircraft Systems," section 1: "General operating rules." One of the key requirements is the ability to see and avoid other aircraft.

A fundamental principle of manned flight is that the pilot observes other aircraft and applies the rules of the air and right-of-way rules to avoid collisions and maintain safe separation. Use of RPAS beyond visual line-of-sight will require other methods

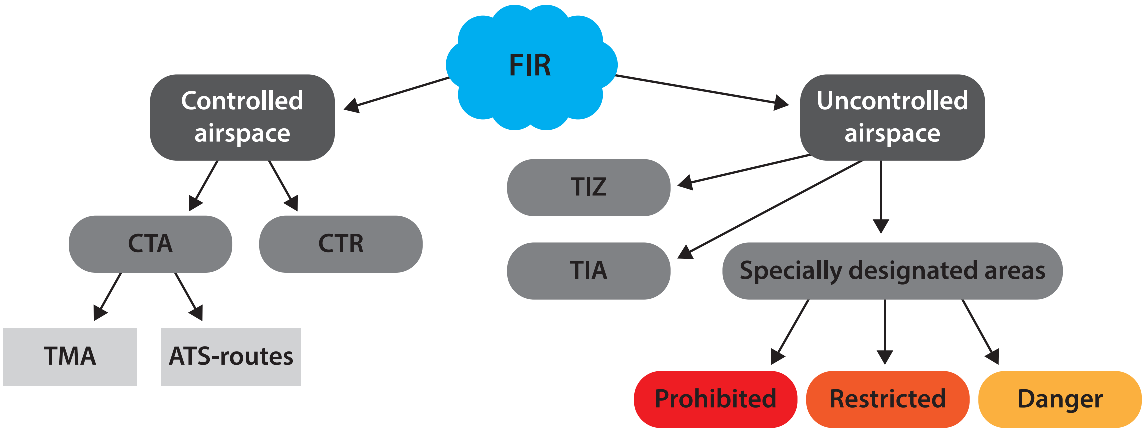

Figure 2. Division of flight information region (FIR) airspace. For a list of acronyms, see section 1.3.

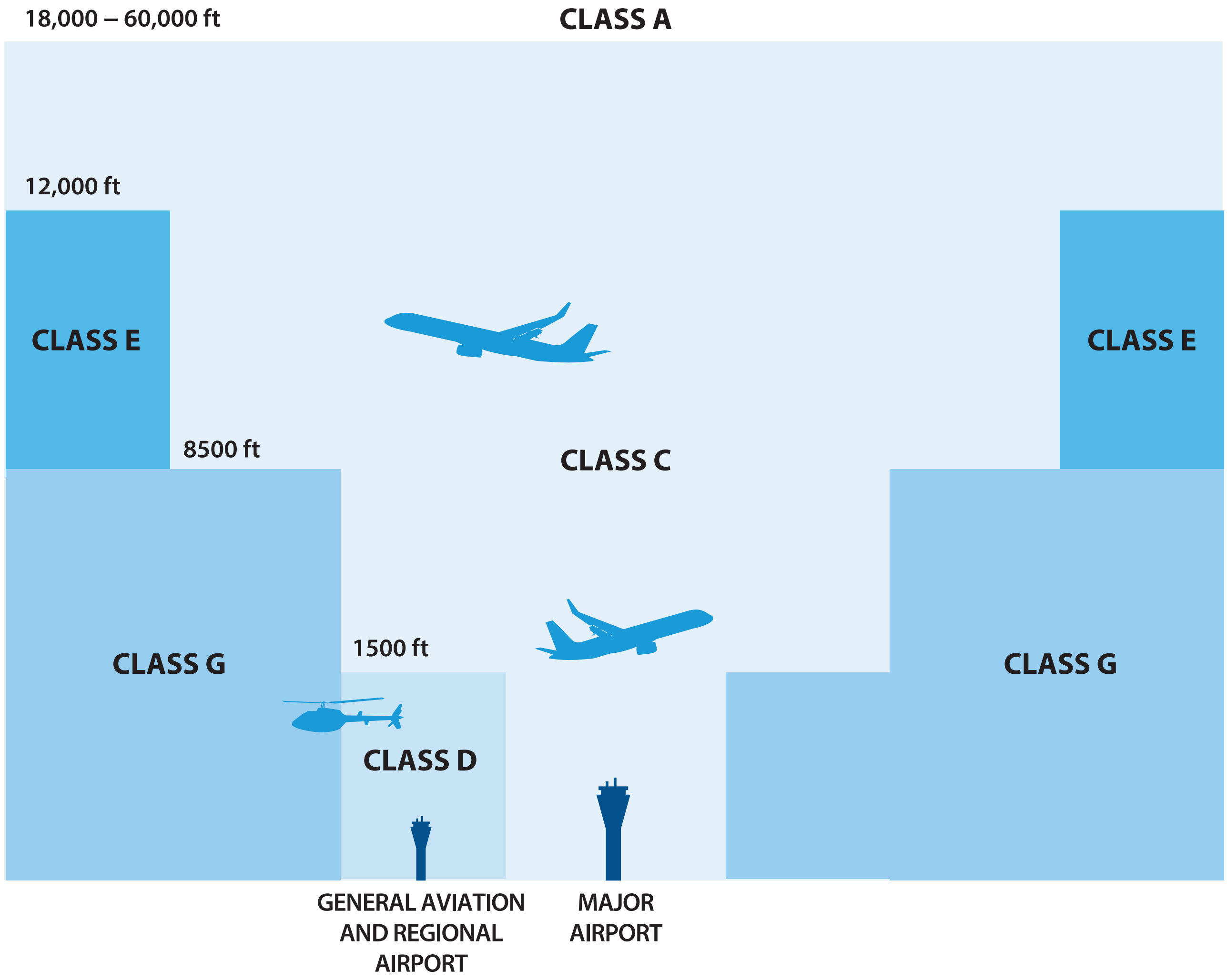

Figure 3. Example of designation of airspace classes.

NOTE: Refer to national AIPs for a description of each nation's airspace structure, as the airspace classification scheme may differ from country to country or across FIR boundaries.

or means of assuring separation. New technologies and SARPs must be developed to enable RPAS to identify and avoid collision hazards, thus allowing for RPAS integration without changing the principles and practices for manned aircraft operations.

Integrating RPAS into non-segregated airspace is a long-term activity that will follow guidelines from ICAO as well as standards organizations and regulatory bodies, both nationally and internationally. RPAS will face similar requirements as manned aviation on topics such as crew licensing, medical requirements, frequency use, and certification, in addition to special requirements currently under development on command and control links and detect and avoid systems.

With regard to response time and all other aspects of navigating in the airspace, an RPAS should perform and respond similarly to manned aircraft when interacting with other aircraft or air traffic control.

The scope of this handbook is to give guidance on how to obtain an authorization or exemption for scientific beyond visual line-of-sight (BVLOS) operations until RPAS regulations are in place.

Table 1. Overview of ICAO airspace classes. For a list of acronyms, see section 1.3.

Class	Permitted traffic	Separation between	Traffic information
A	IFR	All flights	N/A
B	IFR/VFR	All flights	N/A
C	IFR/VFR	IFR to other IFR/VFR traffic	Provided for all VFR traffic
D	IFR/VFR	IFR to other IFR	Provided for all IFR and VFR traffic
E	IFR/VFR	IFR to other IFR	Provided for all IFR and VFR traffic where possible
F	IFR/VFR	IFR to other IFR where possible	Provided where possible if requested
G	IFR/VFR	Not provided	Provided where possible if requested

1.4.1. Notice to Airmen (NOTAM)

As noted in the "Arctic RPAS Operations & Communications Plan" of Appendix A.6, an International Notice to Airmen (NOTAM) should be issued to the flying public before an impending RPAS flight, in order to assist the ANSP in mitigating the risk to other aircraft.

A NOTAM is "the means of communicating aeronautical information (AI) regarding temporary or unanticipated changes to components or hazards in aviation. NOTAMs remain in effect until the hazard has been corrected or the appropriate charts are amended to reflect the change."[2] National authorities issue NOTAMs to alert aviators to events such as GPS outages, temporary runway closures, military parachute jumping exercises, and UAS operations.

For reasons of conciseness and precision, NOTAMs are encoded. The code is usually sufficiently self-evident that the pilot can understand the message and identify the hazard.

Issuing a NOTAM can be achieved by contacting a country's CAA. The guidelines for writing a NOTAM can be found in ICAO's Annex 15, *Aeronautical Information Services*, chapter 5.

Example of NOTAM:

A1897/14 NOTAMN
Q) ENOR/QMRXX/IV/NBO/A /000/999/6716N01422E005
A) ENBO B) 1407150857 C) 1409302359 EST
E) NEW RWY SURFACE PARTLY ESTABLISHED ON RWY 07/25. AREAS WITH NEW
SURFACE ARE DARKER AND HAVE HIGHER FRICTION THAN AREAS WITH ORIGINAL RWY SURFACE

These are the basic elements of a NOTAM:[3]

- The first line contains NOTAM identification (series, sequence number, and year of issue) and the type of operation (new *N*, replace *R*, or cancel *C*); an *R*- or *C*-type NOTAM also refers to the earlier NOTAM that the current one replaces or cancels
- Item Q) is optional, detailing whom the NOTAM affects and giving a basic NOTAM description
- Item A) is the four-letter ICAO code of the affected aerodrome or FIR
- Item B) contains the NOTAM start date and time, and Item C) contains the end date and time; in this example, the date is in the format YYMMDD and the times are in the format HHMM (UTC)
- Item D), if present, indicates the dates and times the NOTAM will be active, if less than 24 hours per day over the duration of the NOTAM (e.g., indicating the brief daytime intervals during which paratroopers may be jumping over the next several days)
- Item E) fully describes the NOTAM event
- Items F) and G), if included, give the lower and upper airspace bounds of the NOTAM

International NOTAMs

Each State has an international NOTAM office for exchange of NOTAMs internationally. NOTAMs exchanged internationally must follow the form specified in ICAO Annex 15, *Aeronautical Information Services*.

[2] U.S. Federal Aviation Administration (FAA), 2013. Flight Standards Information Management System (FSIMS), 8900.1, vol. 3, ch. 26, sect. 6: Notices to Airmen.

[3] Eurocontrol, 2009. *Notices to Airmen – NOTAMS*. Annex to Eurocontrol Guidance Note 3. March 2009.

2. Operation Planning

2.1. Introduction

This chapter briefly describes the process from the time when you, as an RPAS operator, receive a request for collecting data to the time of the start of the operation. The first action is to undertake a fast feasibility assessment before deciding to proceed with more detailed planning and preparation. The "Mission Acceptance Form" (Appendix A.1) is an example of a tool to use to structure such an assessment. If the operation is deemed feasible, the process should end in a concept-of-operations plan (CONOPS). Appendix A.6, "Operations & Communications Plan," can be used as a tool to develop a CONOPS.

2.2. Technical Feasibility

The first question to answer is whether the requested data can be acquired with the RPAS systems and sensors at your disposal. There is always an increased risk for time delays and cost increases when integrating new systems and sensors. The work involved in integration, approval, and testing should not be underestimated.

2.3. Airspace Access

Even when an operation is technically feasible, it may still not be possible, either under the current regulatory regime or one in the future. The area where the data must be collected and the flight operational requirements, including altitude and flight path planning (degree of autonomy/automation needed), determine the type of operation required (VLOS, EVLOS, BVLOS, or BRLOS) and the types of operations allowed. Requirements may differ from country to country. Standard operating procedures (SOPs) and limitations under the different types of operations should be described in your operations manual. The requirements for different types of operations depend on the airspace designation and whether it is controlled or uncontrolled airspace. In the case of uncontrolled airspace, does the ANSP require two-way radio communication, i.e., in terminal information areas or terminal information zones (TIAs/TIZs)? In some high seas areas, there are communication requirements connected to entering and operating in air defense identification zones. A safety assessment of the operation should be prepared and a communication and operations plan set up. If a temporary change in airspace designation is needed to segregate the RPAS operation from other aircraft to maintain an acceptable risk level, i.e., by establishing a temporary danger area or restricted area, the process can require months (3–6 months typically).

2.4. Resource Allocation

From the mission assessment process, one must allocate the material and personnel resources required for preparation of the operation. In general, given the technical requirements for preparing and testing the planned equipment and the logistical requirements for shipping the equipment, supplies, and personnel into the field and sustaining them, operations preparation is challenging in the Arctic, where resupplying may not be an option. Further CONOPS and risk assessments may need to be prepared, and permits may be required from several agencies in addition to the CAAs. Acquiring operational approvals requires time and resources, beginning with preparing applications.

2.5. Operation Planning

If one has not operated in a particular area before, it is strongly advised to contact other operators who have, as most Arctic areas have their unique challenges, logistics, local weather conditions, local communities and traditions, other aircraft activities, and local regulations. A detailed plan for missions and priorities is important because weather and technical challenges limit the flights that can be conducted. Pressure from scientists to get the data they need makes it necessary to predefine the conditions and risk you are willing to accept for the RPAS. Before accepting an operation, it is important to inform scientific partners of the risks and limitations involved. The CONOPS should follow the procedures of the operations manual. It is recommended that short briefings be held daily, prior to start of operations, so that everyone on the team, including both crew and scientists, is informed of the purpose and plans for the day, limitations to the day's operations, and safety requirements. The communication and operations plan and the relevant operations manual (SOP) procedures form the basis for the daily operation and should be briefed to the crew by the operations leader before the start of operations.

3. Permits Required to Operate

3.1. Introduction

The following sections provide a summary of RPAS regulatory activities in each of the eight Arctic States having operational jurisdiction in part or all of one of the four major FIRs that include the Arctic territories. All Arctic Council member States are also members of ICAO: 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 those regulations do not conflict with ICAO regulations.

Much of the information in the following sections was originally provided in a 2012 publication of the UASEG.[4] That material is updated here as appropriate.

3.2. High Seas

The 'high sea' is defined as the area beyond 12 nautical miles (NM) from the shore. In high seas areas, the standards found in ICAO Annex 2, *Rules of the Air*, apply without exception. Chapter 3, Section 3.1.9 ("Remotely Piloted Aircraft") and Appendix 4 ("Remotely Piloted Aircraft Systems") are the most significant. ICAO Doc 10019, *Manual on Remotely Piloted Aircraft Systems (RPAS)*, contains explanatory information related specifically to remotely piloted aircraft systems.

Key points from Doc 10019 and ICAO recommendations and practices:

- The aircraft must have a certificate of airworthiness (or something comparable from the State of Registry since detailed criteria have not been developed yet)
- Certificates for the other components of the system:
  - Type certificate for the system as a whole, to indicate its suitability for use
  - The operator must be certified by the State of the Operator (criteria for this are being developed)
  - The remote pilot must be licensed (a "remote pilot license" is being developed; a Class 3 (ATC) Medical Certificate would likely be sufficient for BVLOS)
- The operation must be approved by each and every State involved: the State of Registry, the State of the Operator (if different), and any States whose sovereign airspace will be overflown
- The ANSPs of the high seas airspace must be coordinated with (coordination does not mean ANSP approval is requested, granted, or denied—it is an exchange of information)

3.3. Operations Crossing FIR Borders

A campaign that would operate across FIR borders presents a particularly difficult challenge, in that neighboring states with jurisdiction over adjoining FIRs may (and often do) have dramatically different regulatory requirements.

For the time being, there exists no common regulation for RPAS in the Arctic region, and operators will have to apply according to the national RPAS regulations for the States in which they want to conduct operations. Obtaining a permit to operate can be a lengthy process, and it is highly recommended that the application process be started at an early stage.

3.4. Canada

A formal process has begun to develop regulations that will determine how RPAS will be permitted to operate within Canadian airspace on a routine basis. In the meantime, a process exists by which RPAS 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 RPAS operation have been prepared by Transport Canada and are available online: http://www.tc.gc.ca/eng/civilaviation/standards/standards-4179.html

3.5. Finland

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

For RPAS 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 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 RPAS activities are not allowed. It is expected that the rules

[4] AMAP, 2012. *Enabling Science Use of Unmanned Aircraft Systems for Arctic Environmental Monitoring*. By: 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, and D. Marshall. Arctic Monitoring and Asessment Programme (AMAP), Oslo. 30 pp.

will change when regulations in European Union countries are harmonized.

3.6. Greenland/Faroe Islands/Denmark

Denmark has developed a relatively comprehensive set of RPAS regulations that apply to mainland Denmark and Greenland and the Faroe Islands. 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 and operation from approved airfields and within altitude limits. Large RPAS (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 RPAS 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 RPAS 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. Aeronautical Information Circular (AIC) B 08/14 provides specific guidelines for dispensations and is based on Swedish regulations (see section 3.10). Dispensation through this AIC allows for aircraft of up to 150 kg and operations outside approved airfields. BVLOS 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.

3.7. Iceland

Iceland has no specific regulations addressing unmanned or remotely piloted aircraft, except for those characterized as 'self-propelled flying models and flying bodies.' 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 (airfields). 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 RPAS other than requesting permission of the controlling authority for an aerodrome. Otherwise, operations of RPAS 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.

3.8. Norway

The Norwegian CAA has been following a roadmap to regulation that was first presented in 2009. The Norwegian CAA is participating in several international efforts on the development of RPAS 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 RPAS 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 13/14. New regulation is currently being finalized and is scheduled to take effect by January 1, 2016. For the latest information, see www.caa.no.

3.9. Russian Federation

There is no readily identifiable body of regulations or standards specifically for the operation of unmanned aircraft within the Russian Federation, but some references to unmanned systems may be found in the several codes and regulations pertaining to aviation, aircraft, and airspace. 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 RPAS operations must be approved by the Russian Federation military.

For civilian (non-state or non-military) RPAS 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; the suitability of ground facilities; and 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 following: 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 RPAS flights unique from other aviation activities, proposals to establish a set of rules, regulations, and requirements for RPAS flights in Federation airspace have been offered.

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

3.10. Sweden

A company or person that wants to operate an RPAS in Swedish airspace must apply for a permit to operate RPAS from the Swedish Transport Agency. To date, the Swedish Transport Agency has issued permits to fly RPAS in civil applications to over 400 companies and individuals. The regulations apply to all civil commercial RPAS activities that are not recreational.

RPAS weighing less than 150 kg are regulated by the Swedish Transport Agency.[5] A comprehensive set of regulations covers design, manufacture, modification, maintenance, and activities with civil RPAS within Sweden. The regulations subdivide RPAS 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 visual line-of-sight (BVLOS) 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.

3.11. United States

All aviation-related activity in the United States, regardless of type, intent, or magnitude, is regulated by the Federal Aviation Administration (FAA), a subdivision of the U.S. Department of Transportation.

Today, RPAS are flying in the National Airspace System (NAS) under very controlled conditions. Public (government) operators are performing border and port surveillance, scientific research, and environmental monitoring; law enforcement agencies support public safety; and public universities conduct research and various other missions. Operations range from ground level to above 50,000 feet, depending on the specific type of aircraft.

Recognizing the demand to expedite integration of RPAS into the NAS, the FAA continues efforts to develop the regulatory framework for safely integrating small RPAS into routine NAS operations. This will primarily be accomplished by the Small Unmanned Aircraft System (sUAS) rule; the public comment period ended in April of 2015.

For civil operators, the FAA is also working to leverage the authority granted under Section 333 of the FAA Modernization and Reform Act of 2012 (FMRA) to establish an interim policy that bridges the gap between the current state and NAS operations as they will be once the notice of proposed rulemaking is finalized. Section 333 provides flexibility for authorizing safe civil operations in the NAS by granting the Secretary of Transportation the authority to determine whether airworthiness certification is required for RPAS to operate in the NAS. The FAA has issued Grants of Exemption under Section 333 to different entities for commercial operations, including movie production, pipeline inspection, and real estate photography. More than a thousand Section 333 applications are now on file. All Section 333 operations require a private pilot license (PPL) but no airworthiness certification.

Civil operators may also obtain a Special Airworthiness Certificate in the experimental category. Experimental certificate regulations preclude carrying people or property for compensation or hire but do allow operations for research and development, flight and sales demonstrations, and crew training. The FAA approved two BVLOS operations in the Arctic in 2013. One of the aircraft had received type and airworthiness certification in the restricted category.

The largest group of civil UAS operators in the U.S. is aircraft modelers. The Academy for Model Aeronautics (AMA) has over 150,000 members who operate under Section 336, Special Rule for Model Aircraft, of the FMRA.

[5] Swedish Transport Agency, 2009. *The Swedish Transport Agency's Regulations on Unmanned Aircraft Systems (UAS)*. The Swedish Transport Agency's Statute Book, TSFS 2009:88.

4. Operator's Manual

4.1. Purpose

The purpose of an operator's manual (OM) is to describe and document the way in which operations are executed within a company, along with the equipment to be used and how it will be operated. The OM should be designed in such a way that new employees joining the company will be able to read the OM and understand the following:

- how operations are conducted
- equipment requirements and restrictions
- the various types of operations, maintenance routines, and training requirements

in order to execute the various types of assignments, the checklists that are used, and what the pilot should attend to before and during the operations the company has been authorized to carry out.

The following sections provide a general template for composing an operator's manual.[6]

4.2. General

This section of the manual describes the organization, roles and responsibilities, procedures for updates and revisions, and a brief overview and summary of the OM and its main content.

4.3. Operational Procedures and Documentation

This section covers operating documentation such as manuals and POHs (pilot's operating handbooks) and other relevant descriptions of the company's different types of platforms and equipment.

4.3.1. System X

Documentation from the manufacturer may be used if it contains the following:

1. *General information*
   a) *Components*
   b) *Characteristics*
   c) *Risk analysis for the relevant system (general identification of weaknesses and restrictions that are unique/special to this system and the measures/procedures used to compensate for these weaknesses—for example, poor flight characteristics, weak engines, limitations in return home function, magnetic fields, radio frequency noise, etc.)*
   d) *Other*
2. *RPS (remote pilot station)*
   a) *If the same ground station is used for several systems, reference can be made to this point for the relevant systems; any unique procedures/settings and uses are described where relevant*
3. *Performance and restrictions*
   a) *Weight and balance restrictions*
   b) *Flying hours*
   c) *Weather restrictions*
   d) *Other*
   e) *Any further restrictions can be self-imposed in connection with special or demanding types of assignments and/or operations and are described in more detail in the section detailing risk analyses and standard operating procedures for authorized operations*
4. *Emergency procedures*
   a) *Background/description of procedures (why the measures shall be executed—i.e., system understanding; expanded emergency checklist, if applicable)*
   b) *This does not cover health, safety, and environment (HSE)–related incidents*
5. *Normal procedures*
   a) *Background/description of procedures (why the measures shall be executed—i.e., system understanding; expanded normal checklist, if applicable)*
   b) *The following rules apply in the event of an emergency situation:*
      i) *MAINTAIN AIRCRAFT CONTROL*
      ii) *ANALYZE THE SITUATION AND TAKE PROPER ACTION*
      iii) *LAND AS SOON AS POSSIBLE/PRACTICAL*
6. *Authorized cargo/sensors*
   a) *Description of installation and use of all cargo/sensors*
   b) *The weight of the sensors*
   c) *Special consideration for CG (center of gravity) where appropriate*
   d) *Laser, consider safety*
   e) *Hazardous materials*
7. *Communication and control link (C2-link)*
   a) *Description of C2-link*
   b) *Loss-of-link procedures and fail-safes*

4.3.2. System Y

To be repeated as above if there are several systems.

4.3.3. Appendices

Checklists for the various systems are to be attached as appendices.

[6] This material is excerpted in part from the "RPAS Operations Manual" template of the Norwegian Civil Aviation Authority. Available in English. http://luftfartstilsynet.no/incoming/article11143.ece/BINARY/Template%20-%20RPAS%20OM.doc.

4.4. Approved Operations

Risk analysis and SOPs for the different types of authorized operations shall be added here. If the same risk factors are recurring in several types of assignments, consideration can be given to whether it would be practical to combine these factors into a "general risk analysis" that applies to all/several types of assignments.

Example: BVLOS and BRLOS operations

1) *Training*
   a) *Risk analysis*
   b) *SOP*
      i) *Application procedures*
      ii) *Restrictions*
      iii) *Relevant areas*
      iv) *Education requirements*
      v) *Maintenance requirements*
   c) *Etc.*
2) *Monitoring*
   a) *Risk analysis*
   b) *SOP*
      i) *Application procedures*
      ii) *Restrictions*
      iii) *Relevant areas*
3) *Sensor testing*
   a) *Risk analysis*
   b) *SOP*
4) *Land surveying*
   a) *Risk analysis*
   b) *SOP*
5) *Infrared (IR) filming*
   a) *Risk analysis*
   b) *SOP*

4.5. Training, Qualification, and Maintenance Requirements

Future regulations will include requirements for documentation of training and currency training for operators in one form or another. Acceptable documentation of training could possibly be used to show that parts or all of the compulsory requirements for education and experience have been completed.

4.5.1. General information on training and maintaining expertise

Brief summary of training, qualification, and maintenance requirements, including a brief description of the system(s) used to develop and maintain the expertise necessary for operators.

4.5.2. Routines for maintenance of certificates/skills

Describe which quality-control system(s) the company uses to ensure that the company's operators possess the necessary certificates and expertise/training to execute the various types of assignments. Some elements may (will) be required by the authorities; some elements will be specific to the individual company and the particular type of assignment.

4.5.3. Simulators or other equipment that can be used

If there are simulators for a system, the opportunities and restrictions relevant to the training are described here.

4.5.4. Helpers, observers, and other crew members

Description of the company's education and training requirements for helpers, observers, and other crew members.

4.5.5. System X

If the manufacturer has published its own training program, that program may be used in whole or in part so long as the following points are included:

1) *General information (if there are several systems, this system-specific information would be more extensive than in the introduction above)*
2) *Theoretical education and training program for new operators, which should cover:*
   a) *RX/TX equipment*
   b) *Battery and recharging equipment and recharging routines*
   c) *Technical review*
   d) *Camera/sensor rig*
   e) *Software/autopilot/gyros*
   f) *GPS*
   g) *Backup/emergency equipment/RTH (return to home), etc.*
   h) *Special types of assignments*
   i) *This list is not exhaustive*
3) *Practical training program for new operators, which should include:*
   a) *Normal operations*
   b) *Emergency procedures*
   c) *System check*
4) *Simulator (if relevant)*
   a) *Normal operations*
   b) *Emergency procedures*
   c) *System check*
   d) *Training for special types of assignments*
5) *Currency/maintenance requirements and training for the company's operators*

4.5.6. Appendices

1) *Training manuals and other relevant materials from the manufacturer(s)*
2) *Checklists for practical tests*
3) *Training profiles*
4) *Etc.*

4.6. Technical and Maintenance

Technical description (brief, if applicable) of the system(s) that the company is using. If the manufacturer has published its own technical description, including maintenance routines, their description can be used in whole or in part. The following points should be included as a minimum.

4.6.1. System X

1) *General information*
   a) *More extensive than in the introduction above if several systems are being used*
   b) *Documentation routines / logging of maintenance, inspections, and repairs (refer to general-description section, if applicable)*
   c) *Components, with technical descriptions and updating/ service intervals*
   d) *Communication RX/TX equipment*
   e) *Battery and recharging equipment and recharging routines*
   f) *Engines*
   g) *Servos (routines for intervals for replacement/running time)*
   h) *Propellers/rotors*
   i) *Camera/sensor rig*
   j) *Software/autopilot/gyros*
   k) *GPS*
   1) *Backup/emergency equipment/RTH (return to home)*
   m) *Other*

2) *Appendices*
   a) *Inspection journal*
   b) *Checklists for maintenance*
   c) *Etc.*

5. Safety Case

5.1. Introduction

A key challenge is ensuring that all risks to people on the ground or within the airspace are adequately considered and mitigated. In today's aviation environment, this is handled through the safety management system (SMS) process or the safety risk management (SRM) process. These processes are globally recognized in the aviation community and are captured in ICAO's Annex 19, *Safety Management*, the supporting *Safety Management Manual* (SMM), ICAO Doc 9859, and other documents listed in Table 2.

The importance of understanding the risk to manned aviation operating in the same airspace as RPAS cannot be overstated. To support the safety risk assessment process that will be required by the civil regulators to substantiate operational approvals, it is recommended that each of the eight Arctic states develop an appropriate SMS document for their RPAS operations and associated airspace.

The operation of unmanned aircraft systems carries risks for other airspace users and for life and property on the ground. An unmanned aircraft could cause serious injury or death to personnel on the ground if they are hit. Therefore a thorough hazard identification and risk analysis of the aircraft and the supporting system must be performed. The report should

Table 2. Examples of standards and guidelines for safety assessments.

Organization	Documents
JAA http://www.jaa.nl	JAR 25.1309: *Equipment, Systems and Installations* AMJ 25.1309: *System Design and Analysis*
ICAO http://www.icao.int	Doc 9422-AN/923: *Accident Prevention Manual* Doc 9689-AN/953: *Manual on Airspace Planning, Methodology for the Determination of Separation Minima* Doc 9274-AN/904: *Manual on the Use of the Collision Risk Model (CRM) for ILS Operations* Annex 19: *Safety Management*
EUROCONTROL http://www.eurocontrol.int	ESARR 2: *Reporting and Assessment of Safety Occurrences in ATM* ESARR 3: *Use of Safety Management Systems by ATM Service Providers* ESARR 4: *Risk Assessment and Mitigation in ATM* EATMP SAM SAF.ET1.ST03.1000-MAN-01-00: *Air Navigation System Safety Assessment Methodology* EATMP Working Draft V. 0.3: *Safety Assessment of ATM Procedures*
SAE http://www.sae.org	ARP4761 (Aerospace Recommended Practice): *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment*
NATS http://www.nats.co.uk	NATS College of ATC: ATC Training Schemes
UK CAA http://www.caa.co.uk	CAP 712: *Safety Management Systems for Commercial Air Transport Operations* CAP 730: *Safety Management Systems for Air Traffic Management*
USA FAA http://www.faa.gov	Advisory Circular (AC) 120-92: *Safety Management Systems for Aviation Service Providers* FAA Order 8040.4: *Safety Risk Management Policy*

describe the RPAS system by documenting the system build, subsystem functionality, and system operations.

The goal is to give a comprehensive understanding of the implications that operations of the RPAS have for safety in regard to other airspace users and to property and life on the ground. Mitigation measures for improving safety should be described; methods for quantifying risk for loss of life should also be described.

A complete safety case consists of two parts: one mission-specific part and one system-specific part (see sections 5.2–5.5).

5.2. Risk Analysis Template

The following template[7] is a summary of the most common parts of a risk analysis; it is not exhaustive.

Initial Phase

Planning, initiation, and system description

The risk analysis is to be performed by a work group that is familiar with the object being analyzed and that has the necessary knowledge of risk analyses. Start by describing the reason and the purpose of the analysis, and *then describe the object in necessary detail*. Include limitations made. Remember to emphasize conditions that may impact safety. As a basis for the object description, use all available sources (AIP, AOM, etc.). To assess the validity of the result, all assumptions, prerequisites, and simplifications must also be included. Describe the process and the methods used, as well as an assessment of their relevance and suitability. Specify data and data sources that are used, and comment on the uncertainty in the results they may yield. Always initiate the process early enough that the result is available when decisions are being made.

Risk identification

Unwanted incidents are those events one wishes to analyze the cause and consequences of such that they may be prevented. Include why the incidents are assessed, where they occur, and when.

Analytic Phase

Consequence analysis

Using the previously identified incidents as a starting point, describe possible consequence chains following these incidents (what are the effects of the incident?). Consider both immediate consequences and consequences arising after a certain amount of time. Specify criteria used to end the mapping. A quantitative analysis shall include calculations of the extent of damages and a quantification of the probability for the consequences from the incidents.

Cause analysis

Using the previously identified incidents as a starting point, describe possible causal chains that can lead up to these incidents (what can incidents arise from?). Account for *cause-removing measures* and conditions that may affect the causal chains. Specify criteria used to end the mapping. A quantitative analysis shall include a quantification of the probability for the incidents.

Risk analysis

From the cause and consequence analyses, the risks can be presented as a list of consequences with associated probabilities; see Tables 5A and 5B for an example.

Sensitivity assessments

Discuss and quantify, if possible, uncertainties in the results following from the data, models, and methods used.

Concluding Phase

Risk evaluation, mitigating actions, and documentation

The risk analysis shall be presented such that it is beneficial for the target audience and is verifiable. Make sure unwanted incidents with the highest risk contributions are especially emphasized. Indicate possible recommendations for mitigating actions and need for further work. The analyses should be quality-ensured by a qualified and independent person. Specify the work group's expertise.

[7] Translated from the Norwegian CAA template 'Risk analysis–Guidance,' http://www.luftfartstilsynet.no/selvbetjening/allmennfly/UAS/article1415.ece (Norwegian language only).

Table 3. Example of a cause-consequence matrix, which here categorizes risk based on four levels of likelihood of occurrence and five levels of potential severity. Green indicates low risk; yellow, medium risk; and red, high risk.

Severity/ Likelihood	No Safety Effect	Minor	Major	Hazardous	Catastrophic
Probable					
Remote					
Extremely Remote					
Extremely Improbable					

5.3. Severity Classifications and Likelihood of Occurrence

Severity definitions related to occupants of an aircraft do not apply to an unmanned system. In RPAS operations, the most severe possible outcomes are those that result in injury to the general public, either in another aircraft or on the ground. As a result of this, NASA[8] has suggested hazard categories for RPAS as shown in Table 4A.

Four categories of likelihood are defined by the FAA, ranging from probable to extremely improbable. Each level of likelihood has a qualitative and quantitative definition. The qualitative definitions from the FAA System Safety Handbook are shown in Table 4B. The quantitative levels vary across FAA advisory material depending on the aircraft system in consideration.

Table 4A. Proposed hazard categories for RPAS.[8]

Severity Level	**Definition**
Catastrophic	Failure conditions that are expected to result in one or more fatalities or serious injury to persons, or the persistent loss of the ability to control the flight path of the aircraft, normally with the loss of the aircraft.
Hazardous	Failure conditions that would reduce the capability of the RPAS or the ability of the flight crew to cope with adverse operating conditions to the extent that there would be the following: (1) A large reduction in safety margins or functional capabilities; (2) Physical distress or higher workload such that the RPAS flight crew cannot be relied upon to perform their tasks accurately or completely; or (3) Physical distress to persons, possibly including injuries.
Major	Failure conditions that would reduce the capability of the RPAS or the ability of the flight crew to cope with adverse operating conditions to the extent that there would be a significant reduction in safety margins or functional capabilities; a significant increase in flight crew workload or in conditions impairing flight crew efficiency; a discomfort to the flight crew, possibly including injuries; or a potential for physical discomfort to persons.
Minor	Failure conditions that would not significantly reduce RPAS safety and would involve flight crew actions well within their capabilities. Minor failure conditions may include a slight reduction in safety margins or functional capabilities or a slight increase in flight crew workload (such as routine flight plan changes).
No Safety Effect	Failure conditions that would have no effect on safety (that is, failure conditions that would not affect the operational capability of the airplane or increase flight crew workload).

[8] Hayhurst, K.L, J.M. Maddalon, P.S. Miner, G.N. Szatkowski, M.L. Ulrey, M.P. DeWalt, and C.R. Spitzer, 2007. *Preliminary Considerations for Classifying Hazards of Unmanned Aircraft Systems*, NASA/TM-2007-214539.

Table 4B. Qualitative definitions of categories of likelihood from the FAA System Safety Handbook.

Likelihood	Definition
Probable	Anticipated to occur one or more times during the entire system/operational life of an item.
Remote	Unlikely to occur to each item during its total life. May occur several times in the life of an entire system or fleet.
Extremely Remote	Not anticipated to occur to each item during its total life. May occur a few times in the life of an entire system or fleet.
Extremely Improbable	So unlikely that it is not anticipated to occur during the entire operational life of an entire system or fleet.

5.4. Hazard Identification

Hazards can be categorized consistent with SAE ARP4761[9] as follows:

1) Aviation (controlling the plane with regard to attitude, speed, etc.)
2) Navigation (ability to fly along a planned route and carry out tasks)
3) Communication (ability to communicate with ATC and other air traffic)
4) Mitigation (ensuring sufficient separation from other aircraft, equipment failure mitigation, etc.)

The results can be summarized as in Tables 5A and 5B. Here, probability and criticality (consequences) are estimated and combined into a preliminary risk ranking, in accordance with Table 3.

5.5. Risk Assessment

A risk assessment must be carried out to quantify the actual threat to human life posed by the RPAS operations. One example of an analysis is based on the approach described by Weibel and Hansman[10] of the Massachusetts Institute of Technology (MIT), with some adaptation to the RPAS in consideration. The analysis covers the two major concerns in RPAS operation with respect to public safety, namely ground impact and midair collision with manned aircraft. For these two main scenarios, calculation models are established to calculate overall risk as the product of incident frequency and consequence with respect to human life. The risk analysis is based on the assumption that necessary mitigation of unacceptable hazards is effectively carried out before the start of operations.

5.5.1. Ground impact risk analysis

This analysis is focused on estimating the risk level of RPAS operation related to loss or crash of the RPA. It is not focused on the technical causes of the incidents. Essential input is (a) the expected consequences in terms of loss of human life and (b) the associated probabilities of such loss/crash incidents. No attempt is made herein to calculate loss/crash frequencies based on a fault tree analysis of the RPAS and the operation.

The analysis is made in line with the methods described by Weibel and Hansman[11] but is extended somewhat to take into account the fact that a certain percentage of people will be outdoors without any shelter or other protection. Furthermore, a parameter "probability of kill at impact" has been introduced to represent the energy/force level of possible impact with a human. For medium-sized RPAs, the level of injury/fatality may depend on which part of the human body (e.g., eye, head, leg) is hit by the RPA. For large RPAs, this may be of lesser importance, as persons located inside the RPA ground impact area may be assumed killed with 100% likelihood. For a slow EPO (expanded polyolefin) foam micro-RPAS of approximately 3 kg with a pusher, a direct hit has the potential for causing grave injury or death, but the likelihood is small—probably less than 10%.

[9] SAE ARP4761, *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment*.

[10] Weibel, R. and J. Hansman, 2005. *Safety Considerations for Operation of Unmanned Aerial Vehicles in the National Airspace System*, Report No. ICAT-2005-1, March 2005.

[11] Idem. pp 65–69.

Table 5A. Identified hazards and mitigations related to aircraft control failure. Risk level is given as low (L), medium (M), or high (H). (This is an example, which must be adjusted to the system in question.)

Function	Hazard Description	Operational Consequences	Suggested Mitigation	After Hazard Mitigation		
				Probability 0–4	Criticality 0–4	Risk L–M–H
AVIATE						
Automatic flight	Link loss	Unable to command RPA, enters fail-safe mode awaiting link return. If not, RPA follows a preprogrammed route that returns to base.	Fail-safe, preprogrammed return to home. If loss of RC link, automated landing at predefined spot.	3	1	L
	Engine failure	Loss of engine power and height, RPA enters glide mode and will try to land automatically. RPA probably not able to reach back to predefined landing spot.	Keep track of battery voltage and time in air.	2	2	M
	Main PSU failure	Will most likely lead to total loss of control. Airframe will spin down to ground at relatively slow speed.	Check load on battery when the complete system is running. Enable battery monitoring through telemetry link.	2	3	M
	Airframe icing	Ice buildup on wings and tail adversely affects the airframe's aerodynamic performance and may, in extreme cases, lead to loss of control.	Avoid flying in icing conditions. Monitor for icing during flight. If icing occurs, change RPA flight pattern to escape icing conditions.	1	2	L
	Structural failure	Due to excessive flight loads or flutter. May lead to loss of control.	Keep airframe speed below VNE. Ensure that programmed airspeeds in autopilot are well below VNE. Due to overall robustness of airframe and control actuators, structural failure during normal operation not very likely.	1	2	L

Table 5B. Identified hazards and mitigations related to navigation, communication, and mitigation activities. Risk level is given as low (L), medium (M), or high (H). (This is an example, which must be adjusted to the system in question.)

Function	Hazard Description	Operational Consequences	Suggested Mitigation	After Hazard Mitigation		
				Probability 0-4	Criticality 0-4	Risk L-M-H
NAVIGATE						
RPAS navigation during mission	GPS failure	Aircraft will not know where it is, hence will not know how to navigate.	Redundant GPS system. Alternative navigation, e.g., through inertial navigation system. Increase flight altitude to get out of shadow areas such as deep valleys and away from radio noise. Terminate flight through use of parachute.	1	3	M
	Incorrect navigation instructions uploaded to autopilot	RPA flyaway possible if link is lost simultaneously. Loss of airframe possible.	Check that correct waypoint file is uploaded.	1	2	L
	Autopilot having problems with keeping within flight pattern due to strong wind	May lead to position inaccuracies due to RPA struggling to keep position because of excessive wind.	Check weather forecasts. Do not fly if actual or forecasted wind speeds exceed maximum allowable operation wind speed.	2	1	L
COMMUNICATE						
Comm with ATC	Failure in primary communication line with ATC	ATC cannot verify if the RPA is airborne within the segregated airspace. This means that the airspace needs to be closed for all air traffic until end of RPAS operation is verified.	Have secondary communication line to ATC at hand at all times during operation. Do not launch RPA until the launch has been approved by ATC.	1	2	L
	Misunderstanding of time	May lead to midair collision.	Indicate time reference when communicating with ATC: "LOCAL" or "UTC" time.	1	2	L
MITIGATE						
Collision avoidance	Other aircraft entering segregated airspace by error	May cause midair collision.	RPA will be equipped with strobe lights. Use observer during manual RC flight to ensure VFR. Abort mission if intruding aircraft is reported or observed. Monitor ADS-B receiver for incoming aircraft.	1	2	L

The formula used to calculate expected fatality rate *EFR* is:

$$EFR = \frac{1}{MTBF} A_{exp}\, \rho (1 - f_{prot} + f_{prot} p_{pen})\, p_{kill}$$

where

EFR	=	expected fatality rate (persons killed per hour of operation)
$MTBF$	=	mean time between failures (i.e., loss/crash of aircraft)
A_{exp}	=	area exposed to aircraft ground crash
ρ	=	population density in the area
f_{prot}	=	fraction of people protected by shelter (e.g., housing)
p_{pen}	=	probability of RPA penetrating shelter
p_{kill}	=	probability of RPA killing a person when hit

Based on the limited RPAS track record, *MTBF* must be estimated. Statistics of military RPAs indicate that the loss/crash rate of RPAs is approximately 100 times that of general aviation (part23/CS-23 aircraft), and for small single-engine general aviation (GA) aircraft, it may be assumed that the loss/crash rate is of magnitude 10^{-4} incidents per flight hour. The value for A_{exp}, the area of exposure, should be set to reflect the ground area believed to be affected by a "worst case" vertical dive impact by the RPA. Population density ρ will vary by the area that is overflown during a campaign and should be set accordingly.

The fatality results (*EFR*) may vary considerably, as one may expect, reflecting variation in the density of people on the ground. For ground impact analysis, Weibel and Hansman have suggested to use a target fatality rate of 10^{-8} fatalities (for non-participating persons) per hour of operation (GA aircraft). Actual values will need to be calculated for each specific campaign and should be submitted in a separate report for each mission.

It must be noted that these *EFR* values are expected values and in real life, large variability must be expected. However, this approach is a rational way to investigate the effect of the risk-governing parameters (e.g., population density) and how they contribute to the estimated *EFR* value.

With time, the calculation formula and input parameter values may be benchmark-tested against various RPAS, and standard values may be tabulated for various RPAS types/classes, to ensure maximum "objectivity" in risk assessments performed in line with standard procedures. One will expect the input values of A_{exp}, P_{pen}, and P_{kill} to increase with increasing RPA size. As previously pointed out,[12] the large/heavy RPAs must therefore be more reliable than the small and light ones, to reach the same target risk level.

5.5.2. Midair collision risk analysis

An analysis has also been made to quantify the expected fatality rate due to midair collision of the RPA with manned aircraft. The approach is based on the midair collision model of Weibel and Hansman,[13] but with some improvements to estimate the fatality rate induced by small RPAS with respect to a wide range of other aircraft and to account for the traffic density (number of other aircraft of various sizes) in the operation airspace.

The midair collision risk formula applied herein is:

$$EFR = \frac{1}{Vol} \sum_{i}^{n} A_i\, v_i\, N_{pi}\, P_{ci}$$

where

EFR	=	expected fatality rate (persons killed per hour of operation)
Vol	=	volume of RPA operation airspace
A_i	=	projected (cross-sectional) area of aircraft *i*
v_i	=	velocity of aircraft *i*
N_{pi}	=	number of persons in aircraft *i*
P_{ci}	=	probability of RPA causing loss of aircraft *i* after midair collision
n	=	number of aircraft in the RPA operation airspace

This equation reflects the fact that the threat posed by a given RPA depends on both the RPA itself and the properties of the other aircraft—e.g., a midair collision with a Global Hawk would probably be 100% fatal for a Piper Cherokee, but a very small and frangible RPA would not cause any serious damage to a B737. The analysis assumes that the RPA and all other air traffic are evenly distributed throughout the airspace. This assumption does not hold in real life, as many aircraft operators will fly standard routes at standard altitudes (flight levels). As long as the RPA is separated from these standard routes, the probability of midair collision will be low, whereas an RPA crossing or following standard routes and leveling off at standard flight levels will have a rather high probability of midair collision. This finding is in agreement with the analyses of Weibel and Hansman, which were based on U.S. inland air traffic radar track-logs.

For some missions, the calculated collision rate is likely to be considerably higher than the common target of the aviation authorities. This is without taking mitigating factors into account.

For those missions that do not meet the criteria required to comply with the safety target, effective mitigations (such as coordination at flight planning stage, see and avoid, air traffic control, and segregation of traffic into different airspaces) will be required.

For most campaigns, airspace segregation alone is an available and sufficient risk mitigation.

[12] FAA Advisory Circular 23.1309-1D - *System Safety Analysis and Assessment for Part 23 Airplanes*.

[13] Weibel, R. and J. Hansman, *Safety Considerations for Operation of Unmanned Aerial Vehicles in the National Airspace System*, Report No. ICAT-2005-1, March 2005, pp 77–79.

Appendices

A.1. Mission Acceptance Form

Date:	Mission type: VLOS ☐ EVLOS ☐ BVLOS ☐	Airspace type:	Need for segregated airspace: Yes ☐ No ☐
Customer:	Campaign duration:	Operations area:	Separate flight permit needed? ☐ Permission from landowner? ☐
Population density: High ☐ Low ☐ None ☐	Airframe type:	Risk assessment:	Application to CAA:
Other airspace users and stakeholders (i.e., property owners, other authorities):			
Planned personnel:			
Campaign/mission description:			
Acceptance (flight operations leader):			

This form is meant for internal planning purposes when a potential mission comes up. The purpose is to help determine feasibility and to give an overview of the preparations that need to be completed.

A.2. Pilot Log Form

Pilot Log, Page 1

Date	Time		Aircraft		Location		Mission	Pilot	Operator
	Start	End	Make & Model	Reg / Name	Flight Area	GCS Location	Remarks & Notes	Name	Name

Pilot Log, Page 2

Type of takeoff	Type of landing	Flight time		Type of piloting time		Total flight duration	Number of flights	Signature
		VLOS	BVLOS	Pilot in command	Instructor/ training			
Total this page								
Total from previous pages								
Totals								

A.3. Flight Log Form

RPAS FLIGHT LOG SHEET

Date		**Time**		Org. LOGO
Airplane				
Flights/hrs since last major inspection		**Flights/hrs remaining until next major inspection**		

Payload (instruments, serial no., comments)
Comm link(s) (type, serial no., comments)

Fuel weight	Payload weight
TOW	Without wings

PIC (start of flight)	
RC Pilot	
GCS Pilot(s)	
Other pers.	

Mission desc: **Type (circle one): VLOS EVLOS BVLOS BRLOS**

Wind [v, dir]		Temperature	
Precip		Visibility	
Air pressure [HPa]		Dew point temperature	
Launcher		Pressure used	
Take-off location		**Battery Voltage**	
Control (TWR)		**TWR notified time start**	

FLIGHT LOG		**HAND-OVERS (PIC or PF)**		
Take-off time		Time	Role	Name
Time	Incidence			
Landing time		**TWR notified time stop**		

Landing Location		**Flight Duration**	
Fuel consumed		Distance flown	
Battery charge		**Battery Voltage**	
Notes		**Signature(s) (all PICs)**	

A.4. Accident Report Form

Accident reporting and investigation should be in accordance with ICAO Annex 13 and national regulations (for both the Flag State and the State where the operation was performed). Below is an example of a report for internal use, containing information needed for further reporting. Authorities should be informed about the accident without unnecessary delay.

RPAS Accident, Incident, and Mishap Report

Date of accident: ______________________________ Time: _________________________

Pilot in command: ______________________________ Phone no.: ____________________

Flight crew: ____

Owner of aircraft: ____

Aircraft type: _______________________________ No: ____________________________

Type of event (circle one): Accident Incident Damage

Flight area: ____

Flight plan/mission: ____

Event location (in reference to an easily defined geographical point): ___________________

____

____

Description of personal injuries (if applicable): _____________________________________

____

Weather conditions (attach weather printout if available):

Wind direction: _________________ Wind velocity: ___________________

Visibility: ______________________ Sky condition: ___________________

Temp/Dewpoint: _________________ Other: __________________________

Eyewitnesses: Name / Phone number

1. _________________________________ _____________________________________

2. _________________________________ _____________________________________

3. _________________________________ _____________________________________

Damage to aircraft/property (if yes, explain): _______________________________________

____

____

Detailed explanation of incident, accident, or damage: _______________________________

____

____

____

____

____

Communications log (time, contact, keywords): _____________________________________

____

____

____

____

____

A.5. Ticket Form

Aircraft:	
Date:	
What:	
How:	
Critical or Non-critical:	
Who:	
	Sign:
Date Fixed:	
By Whom:	
	Sign:

CROSS-ARCTIC HIGH SEAS SCIENTIFIC & SEARCH AND RESCUE
ARCTIC RPAS OPERATIONS & COMMUNICATIONS PLAN

Operator Contact Information: Phone: __________ **Email:** ______________

SATCOM or Telephone #: ______________ **(For Vessel Launches) Radio Call Sign:** __________

Vessel #: __________ **Vessel Phone:** _______ **VSAT:** __________ **Iridium:** __________

A. **7 Days prior:** Distribute email, including authorization from appropriate civil aviation authorities (CAAs), to air traffic service (ATS) providers and appropriate government authorities (e.g., FAA, NavCanada, Transport Canada, U.S. Coast Guard, State Department, Defense Department, etc.). Area commercial aircraft operators shall also be notified of the pending operation.

B. **7 Days to 24 Hours in advance:** Contact appropriate ATS provider, phone # _____________________, to request a Notice to Airmen (NOTAM) be issued for the operation area. Emergency and National Disaster Operations authorizations may not be able to comply with standard NOTAM issuance timelines.

C. **1 Day prior (NLT 2200 hours):** Provide operation area manned aircraft operator's schedule for next day.

D. **By ________ (local time) on day of flight, prior to flight:** Participating manned aircraft operators will confirm their flight plan(s).

E. **1 Hour prior:**

1. Operator files an ICAO flight plan through appropriate CAA or ATS unit. Flight plans shall be submitted in accordance with Chapter 3 of ICAO Annex 2, *Rules of the Air*.
2. Receive weather briefing, review NOTAMs, and determine if there are any other flight plans on file for the operating area.
3. Check Receiver Autonomous Integrity Monitoring (RAIM) notices (http://www.nstb.tc.faa.gov/24Hr_RAIM.htm) or appropriate agency website.
4. Contact appropriate ATS unit via SATCOM or other acceptable means to confirm that any special use airspace or ALTRV is active.

F. **10 Minutes prior to UAS launch:** In preparation for launch, broadcast a warning announcement on Marine Common FM Ch 16 and VHF _____ MHz common traffic advisory frequency (CTAF); e.g., "UAS flight operations are commencing from LAT/LONG of research vessel or coastal launch site." Maintain a listening watch on VHF _____ MHz (CTAF) and _____ MHz for any area traffic.

G. **During flight operations:** Periodically broadcast a warning announcement on Marine Common FM Ch 16 and VHF _____ MHz (CTAF); e.g., "UAS operations are in effect between the surface and 2000 feet within 10 nautical miles of LAT/LONG."

H. **Lost Link/Lost Comms (Emergency Comms):** PIC will comply with the lost link/lost comms procedures stipulated in their authorization. Operator will immediately contact appropriate ATS unit via SATCOM and report the Lost Link condition, time, and LAT/LONG. Immediately broadcast on Marine Common FM Ch 16, VHF _____ MHz (CTAF), and VHF _____ MHz or other acceptable means; e.g., "UAS flight operations are commencing emergency return at 500 feet AGL."

I. **Coordination with Coast Guard protocols:** Operator/research vessel will maintain continuous listening watch on Marine Common FM Ch 16 and the VHF and UHF 122.5 and 243.0 guard frequencies. All UAS operations will comply with Coast Guard and any other official SAR-participating aircraft or vessel requests.

ISBN: 13 978-82-7971-090-5

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