Chukchi and Beaufort Seas Airspace Traffic and Safety Study

Study Report

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SAIC
From Science to Solutions

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Chukchi and Beaufort Seas
Airspace Traffic and Safety Study

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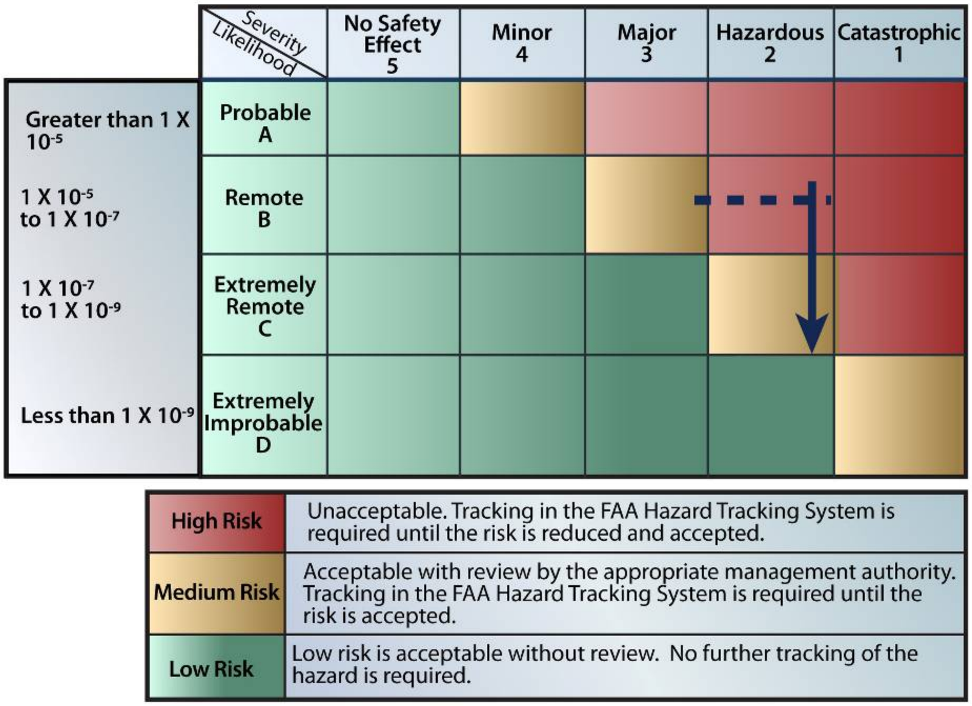
Executive Summary

This report describes the Science Applications International Corporation study of unmanned aircraft (UA) flight risk and safety in support of requests to the Federal Aviation Administration for one or more Certificates of Authorization. The focus of the study was to characterize airspace traffic density and the resulting risk of midair collision in order to assess the risks of over-the-horizon UA flight operations beyond the visual line of sight of an operator and/or observer in the Beaufort and Chukchi Seas off the northern coast of Alaska. Findings and recommendations will be used to support Certificates of Authorization requests for flights over the Beaufort and Chukchi Seas in support of marine life research, climatology, sea ice, and science missions performed by an appropriate United States government agency. The Insitu A-20 UA, a small, lightweight UA, is the initial UA intended for Arctic flight operations. The A-20 can be operated without need of a runway, including shipboard applications, due to its small launch and recovery footprint.

The majority of the study area falls within oceanic airspace that begins 12 nautical miles off the coast of Alaska within the Chukchi and Beaufort Seas. In addition to these two regions of oceanic airspace, two narrow corridors from airstrips at Wainwright (near the Chukchi Sea) and Oliktok Point (near the Beaufort Sea) were included in the study. These corridors will be used for potential land-based UA launches and recoveries. Within these study areas, the team obtained data from multiple sources, including radar data, civil aviation information, commercial aircraft operating schedules, marine mammal survey flight records, and population data.

The team evaluated the radar and civil aviation data to determine the number, location, and types of aircraft transiting the study areas. Based upon the characterization of transiting aircraft, the team completed a risk analysis combining both the risk of midair collision with a transiting aircraft and the risk of surface casualties. To calculate the risk of midair collision based on a single UA operating hour, the team used an airspace volume 48 nautical miles in diameter and 10,000 feet in altitude. These bounds were defined by the maximum distance the A-20 can fly in an hour at its standard cruise speed (48 nautical miles) and the maximum possible operating altitude for the UA. The resulting risks were evaluated using the Federal Aviation Administration severity and likelihood matrix, as shown in Figure 1. Within this matrix, a catastrophic UA failure correlates to a hazardous event.



	Severity / Likelihood	No Safety Effect 5	Minor 4	Major 3	Hazardous 2	Catastrophic 1
Greater than 1 X 10^{-5}	Probable A	🟩	🟨	🟥	🟥	🟥
1 X 10^{-5} to 1 X 10^{-7}	Remote B	🟩	🟩	🟨	🟥	🟥
1 X 10^{-7} to 1 X 10^{-9}	Extremely Remote C	🟩	🟩	🟩	🟨	🟥
Less than 1 X 10^{-9}	Extremely Improbable D	🟩	🟩	🟩	🟩	🟨

🟥 High Risk	Unacceptable. Tracking in the FAA Hazard Tracking System is required until the risk is reduced and accepted.
🟨 Medium Risk	Acceptable with review by the appropriate management authority. Tracking in the FAA Hazard Tracking System is required until the risk is accepted.
🟩 Low Risk	Low risk is acceptable without review. No further tracking of the hazard is required.

Figure 1. FAA Risk Assessment Matrix

Within both the Chukchi Sea and Beaufort Sea oceanic operating regions, the vast majority of the observed flights (1,046 out of 1,350 identified flights) were commercial flights transiting through the operating regions. Most of these flights were located less than 20 nautical miles from the Alaskan coast, minimizing the impact of the commercial aviation activities on the study areas. Of the 197 flights observed in the Chukchi and Beaufort Seas that were not transiting flights, most were marine mammal survey flights and 5 were A-20 UA flights documented in 2008. For the purposes of the risk analysis, the team characterized the transiting aircraft and excluded the marine mammal and UA flights, as the proposed UA missions that this study is intended to support are in essence part of the marine mammal surveys, and UA flight planners will already be coordinating with the survey operators. Aircraft were present in the oceanic operating areas at an average rate of less than one aircraft per day in each area, and the total dwell time within the operating regions averaged 2.1 percent of the year (average of 30 minutes of flight time per day). Throughout the year of historical air traffic, there was only one transiting aircraft operating at a time in the study area, with one exception. There was only one instance of two transiting aircraft observed within 48 nautical miles of each other, and that occurred in the Beaufort Sea near the Barrow airport approach during September 2008. Almost all transiting air traffic was observed at altitudes above 1,200 feet mean sea level in controlled airspace (Class E). Exceptions included aircraft taking off and landing from the Wainwright airport.

Within the launch and recovery corridors, the average number of daily flights ranged from zero in May 2009 in the Chukchi to 1.87 flights per day observed in August 2008 in both the Wainwright and Oliktok Point corridors. Throughout the year, there were aircraft observed in the Wainwright corridor for only 3 hours and 39 minutes and for 29 hours 26 minutes in the Oliktok Point corridor. These correspond to 0.04 percent and 0.34 percent of time occupied, respectively.

Based upon commercial aviation information and the flight speeds calculated from the radar data, the team was able to identify three common types of aircraft used by transiting flights, the Cessna 172, Twin Otter, and Boeing 737. The sizes and cruise speeds of these three aircraft were then used in the risk of midair collision calculations. When the most common plane type, the Twin Otter, was used in the probability of a midair collision calculation, the probability of midair collision was calculated to be 2.21 x 10^{-7} (2.21 collisions per 10 million operating hours), which correlates to a "Remote" likelihood of a hazardous event, based on the FAA severity and likelihood matrix. This calculated probability of a midair collision assumes that no mitigation of any sort is in place; that is, that the UA and the aircraft are on entirely random, entirely unknown, flight paths, with no communication or awareness.

Based upon the completed safety study, the study team identified simple risk mitigation strategies that may further reduce the potential risks of operating a UA in the Chukchi or Beaufort Seas. The key recommendations are:

- Oceanic operating regions:
    - UA operating plans should avoid the common routes of transiting aircraft to provide lateral separation from civilian aircraft.
    - UA flight planning procedures must ensure coordination with Barrow-based air traffic control personnel and any manned marine mammal surveys operating in the region.
    - UA flights should operate in uncontrolled airspace below 1,200 feet mean sea level to provide vertical separation below transiting aircraft.
    - UA flight planners should be aware of the schedules of commercial aircraft operating in the region to be able to employ time separation of UA flights relative to the commercial flights.
- Launch and recovery corridors:
    - If launching and/or recovering from land, the UA should be operated at a low altitude to ensure vertical separation from any civil aircraft potentially operating in the region.
    - Launch and recovery planning should incorporate lost-link procedures, as well as addressing fly-around procedures in case multiple recovery attempts are needed.
    - If available, supplemental ground- or ship-based air search radar should be used to provide additional situational awareness during operations, including launch and recovery.

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Overview

Purpose

This report describes the Science Applications International Corporation (SAIC) study of unmanned aircraft (UA) flight risk and safety in support of requests to the Federal Aviation Administration (FAA) for one or more Certificates of Authorization (CoA) for UA flights over the Beaufort and Chukchi Seas (Figure 2) in support of marine life research, climatology, sea ice, and science missions performed by an appropriate United States (US) government agency. This study estimates the probability of a midair collision (P[MAC]) in two operating areas of interest based upon an analysis of one year of historical air traffic data provided to the study team. The potential risk of surface casualties is also addressed. In conjunction with the P(MAC) and surface casualty risk analyses, the study team also identifies associated mitigation procedures adapted to the specific challenges of unmanned flights in northern Alaska airspace.

Mi = miles

Figure 2. Beaufort and Chukchi Seas off the Northern Coast of Alaska

The focus of the study was to characterize airspace traffic density and the resulting risk of midair collision in order to assess the risks of over-the-horizon UA flight operations beyond the visual line of sight of an operator and/or observer. The potential consequences of a midair collision with a manned aircraft are significant and may include fatalities and high-cost property damage. Although flight rules have evolved for manned aircraft to avoid collision, a UA cannot take advantage of the onboard see-and-avoid tactics of manned aircraft. For a UA, collision avoidance will result primarily from a combination of avoiding areas frequently used by manned aircraft and airspace separation provided by the UA operators in response to locally provided real-time radar information (when available). In addition to evaluating the risk of midair collision, this study also addressed the risk of surface casualties in the event of a UA system failure resulting in a crash.

This unclassified study report and associated For Official Use Only appendices provides data to supplement one or more CoA requests to the FAA on behalf of an appropriate government agency to allow UA flights in the Beaufort and Chukchi Seas. The FAA will authorize UA flights in the operating area only after a CoA application has been submitted and has been approved by the appropriate offices within the FAA.

Background

Manned aerial surveys are often used to complete marine mammal monitoring in the US Arctic. These monitoring surveys are required for offshore oil and gas exploration, as well as supporting basic marine mammal population research. Manned overflights in small aircraft at great distances from shore put personnel at risk and are often limited by altitude and weather restrictions. The use of UA systems could potentially replace manned aerial overflights, decreasing risk to personnel and increasing data acquisition opportunities.[1] An initial analysis of the relative efficiency to perform aerial surveys between standard manned aircraft and the A-20 UA was performed in the Beaufort and Chukchi Seas by the University of North Dakota in 2008, and in the Bering Strait/Gulf of Alaska by a joint University of Alaska and National Oceanographic and Atmospheric Agency (NOAA) team in 2009. The results from this study indicated that the A-20 UA performed very well in support of marine mammal surveys, and can fly at a lower altitude than the manned aircraft because it does not startle the mammals. Therefore, the survey team was able to count actual mammals on ice floes instead of relying on estimates generated by splash density when mammals entered the water in response to the manned aircraft overflights.[2]

Aviation Authorities

The current oceanic air traffic control (ATC) system is procedurally based, relying heavily on filed flight plan data. There are no common standards and practices to permit “state” (International Civil Aviation Organization [ICAO] terminology) or “public” (FAA terminology) UA flight operations in oceanic areas. Oceanic airspace is airspace over the high seas, which is defined as beyond 12 nautical miles (nm) from territorial boundaries. Within oceanic airspace, the ICAO delegates responsibility for the provision of ATC to various sovereign nations and

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[1] 2009 (Draft dated March 2009), Unmanned Aerial Surveys (Chapter 8), in Joint Monitoring Program in Chukchi and Beaufort Seas, Open Water Season, 2006 – 2008, Prepared by LGL Ltd., Greeneridge Sciences, and Jasco Research for the National Marine Fisheries Service and US Fish and Wildlife Service.

[2] ibid

establishes minimum standards and recommended practices. The ATC-responsible agencies may set more stringent regulations, although they cannot relax the minima set by ICAO.

In the US, the FAA has been delegated responsibility to provide ATC services for flight information regions (FIR) and oceanic airspace off the coast of the US. In some US coastal areas, a US Air Defense Information Zone (ADIZ) has been established. In an ADIZ, aircraft must comply with all FAA-mandated requirements as well as additional identification requirements set forth by the North American Aerospace Defense Command (NORAD). A Defense Visual Flight Rules (DVFR) flight plan is a requirement for any aircraft operating in or entering the Alaska ADIZ. Under a DVFR flight plan, a pilot is required to notify ATC personnel prior to deviating from the filed DVFR flight plan and must maintain two-way radio communication while inside the ADIZ, ensuring that no unknown aircraft operate within the US defense zone, regardless of altitude of operation. In locations where the Alaska ADIZ overlaps the FIR within the Chukchi and Beaufort Seas, both sets of regulations must be followed; one does not overrule the other.

FAA-Required CoA

The FAA requires that any UA operating in FAA-managed airspace, including domestic and oceanic airspace, have an approved CoA on record prior to commencement of flight operations. The CoA application for UA operations must be submitted by a military, governmental, or other public agency. This study is intended to compile the various airspace regulations and requirements for manned aircraft as well as to assess the historical air traffic density to determine the necessary steps to submit a CoA application and safely operate a low-altitude UA flight in support of Arctic missions. The airspace traffic and safety study results included in this document are intended to support any oceanic mission and related CoA in the areas of interest.

The major tasks to support any CoA application for UA operations in FAA-managed airspace are:

- Research and document air traffic density in the operating area.
- Develop operational solutions for airspace deconfliction during UA flight operations.
- Provide documentation in support of the CoA application for UA flight operations for FAA consideration. This documentation includes an airspace traffic density analysis that supports over-the-horizon UA flight operations beyond the visual line of sight of an operator and/or observer.

An approved CoA is a prerequisite for operating a UA within FAA-managed airspace. The FAA’s UA program office has its own processes and procedures that employ a Safety Management System (SMS) approach, which will be used to assess the submitted materials. This study, which follows SMS principles and documents a safety case for UA flight operations in FAA-managed airspace, is intended to support a CoA application. To mitigate the risk of a denied CoA application, Naval Surface Warfare Center – Crane is supplementing the CoA application with empirical data derived from this study that clearly lays out the safety case for UA operations within the FAA’s required safety limits in specific operating regions.

UA systems other than the A-20 may later be proposed for Arctic flight operations, at which time an additional UA-specific risk analysis must be completed for a new CoA application. The risk analysis will involve updated air traffic characterization if the proposed operating area is outside of the current study areas. In addition, the P(MAC) will have to be updated to reflect the proposed UA specifications and possible concept of employment.

UA System Description

The Insitu A-20 ScanEagle UA, is considered a Class 2UA. Class 2 UA are characterized as having a maximum takeoff weight between 21 and 55 pounds, cruises at airspeeds less than 250 knots and has a maximum operating altitude of 3,500 AGL. The ScanEagle is the initial UA system intended for Arctic flight operations. The transponder-equipped A-20 is a small, lightweight UA (Figure 3). The A-20 can be launched and recovered within a small footprint using a catapult launcher and trademarked Insitu Skyhook recovery system. The small launch and recovery footprint means that the A-20 can be operated without need of a runway and can be launched/recovered in shipboard applications.

Figure 3. A-20 UA in Launcher

Table 1 summarizes the characteristics of the A-20 UA.

Table 1. A-20 Specifications

A-20 Specifications	
Operating Ceiling	19,500 feet
Endurance	24+ hours
Speed	48 knots (cruise) 80 knots (maximum)
Weight	28.8 pounds (empty) 44.0 pounds (maximum launch weight)
Size	Wingspan 10.2 feet Length 4.5 feet Height 2.25 feet

The ground-control station of the A-20, which can be installed either at a stationary location or onboard a ship, consists of two operator stations: a flight-control station and/or optional sensor monitoring station. The flight-control operator manages the flight settings, including programming pre-set flight tracks and monitoring the aircraft status (e.g., location relative to the ground-control station). When the A-20 is operating on a pre-programmed flight path, the flight control operator can take manual control to provide closer visual inspection for items of interest. The sensor monitor operator primarily serves to monitor the real-time video imagery that is relayed from the UA.

UA Operations

In August and September of 2008, 10 A-20 test flights were completed in the Beaufort Sea and one was completed in the Chukchi Sea. These flights represented the first non-military use of UA systems in unrestricted airspace within US and were intended to support marine mammal surveys for environmental impact studies as well as basic population research. The CoA granted by the FAA for these flights permitted limited flights in certain areas in daylight hours under Visual Flight Rules (VFR) meteorological conditions. The UA could not fly closer than 19 kilometers (km) (12 mi) from shore and 8 km (5 mi) west of the Canadian border and had to remain within 1 mile laterally and 3,000 feet (ft) vertically of the control station. In addition, the A-20 operators were required to file a Notice to Airmen (NOTAM) before each flight, and had to have visual observers in contact with UA at all times.

During these field tests, the A-20 was launched and recovered from a ship in open waters. The UA was operated at approximately 1,000 ft mean sea level (MSL), but due to differences between the speed of the ship and the UA, flight paths were limited to either a zipper circular pattern or racetrack pattern with a 1.6 km (1 mi) radius around the vessel in order to meet the visual observer requirement. As a result of the constrained flight path, the operating team was unable to collect data to provide a direct comparison to manned aerial survey data collection efforts. During the 2009 field tests in the Bering Strait and Gulf of Alaska, the CoA granted by the FAA permitted UA flights within a 5 mile radius of the control station. Each of these UA flights were safely conducted, and set a precedent for safe operations within unrestricted airspace over the Arctic Ocean, Bering Strait, and Gulf of Alaska.

For the purposes of this airspace traffic and safety study, the proposed UA flights would initially launch from shore, and the UA would fly autonomously in a straight line out beyond the 12 nautical mile limit of domestic airspace. Once within communication range of the support ship, control will be transferred from the launch ground station to the ship-based ground station. The UA would then fly in a geometric grid pattern at low altitude, similar to the current method of manned marine mammal surveys (Figure 4). The proposed operations are planned to be conducted at 1,000 ft MSL or below in altitude, to maximize the sensor performance. For maximum regional coverage, UA operations are ultimately planned to occur beyond line-of-sight, using satellite-based communications with the UA, rather than limiting the UA’s flight path based on the speed of the support ship. There are current published UA operating procedures for operating an UA in civil airspace to include such operations as communications, launch and recovery, and mission planning, etc.

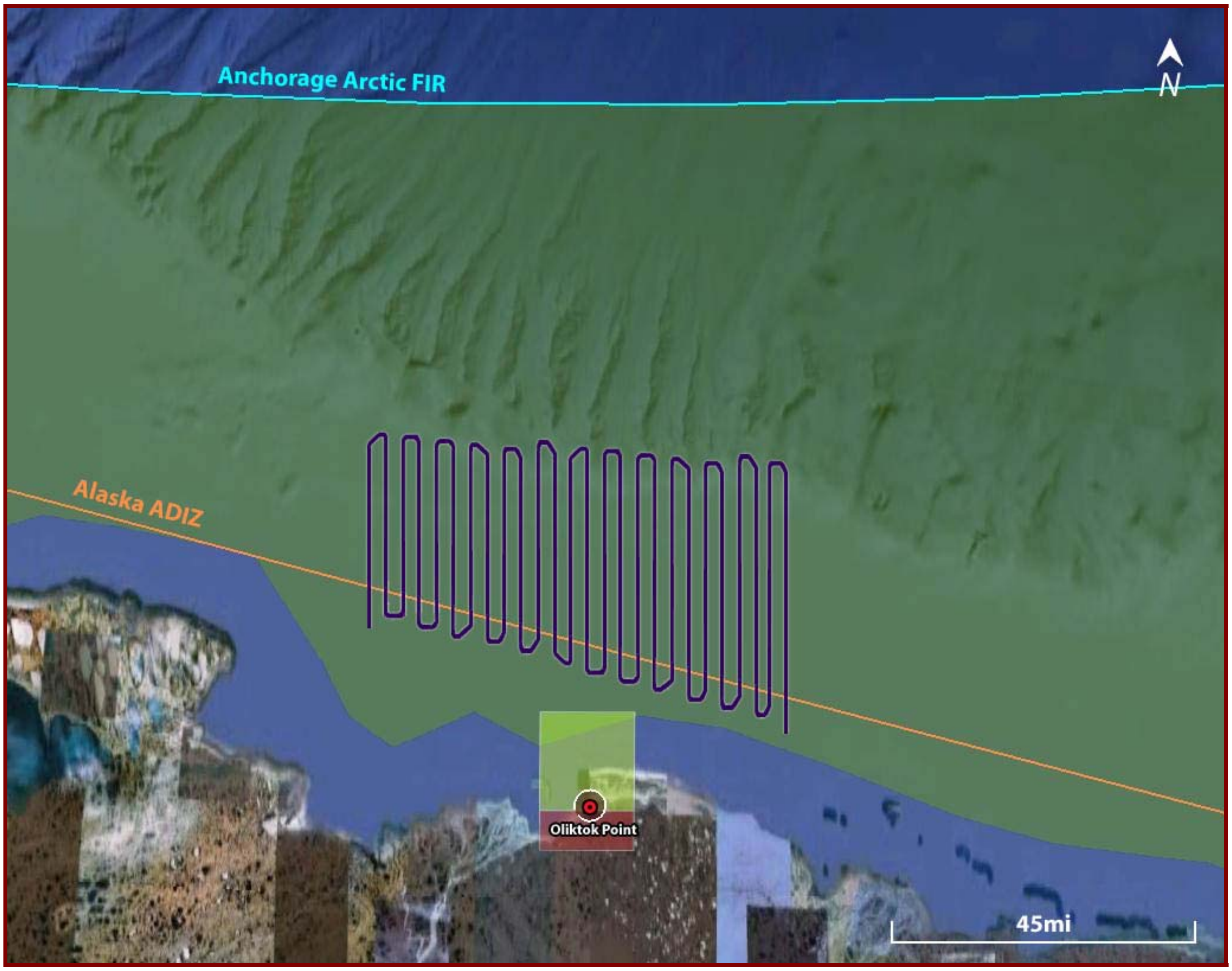

Figure 4. Notional A-20 Flight Path for Marine Mammal Survey Operations

Study Areas

The areas of interest lie off the northern coast of Alaska south of 72°N latitude. The majority of these operating areas fall within oceanic airspace that begins 12 nautical miles off the coast of Alaska within the Chukchi and Beaufort Seas. These are the areas in which manned marine mammal study flights typically are required. Within these operating areas, the study focused on altitudes up to 10,000 ft MSL as that is the anticipated maximum operating altitude of Class 2 UA during Arctic missions. In addition to two regions of oceanic airspace within the Chukchi and Beaufort Seas, two narrow corridors from airstrips at Wainwright and Oliktok Point into the regions of oceanic airspace were included in the study. These corridors will potentially be used for land-based UA launches and recoveries. Within these operating areas and corridors, there are a variety of oceanic airspace regions and airspace classes. In addition, there are published flight routes used by commercial civilian air traffic in and near the operating regions. Each of these sets of parameters were included in the airspace traffic and safety study and are described below.

Oceanic Airspace

There are three regions of oceanic airspace in the Beaufort and Chukchi Seas:

- **The Alaska ADIZ:** All aircraft operating in this region must be identifiable to NORAD, either through ATC communication or transponder use. The vast majority of the operating areas lie within the Alaska ADIZ.
- **The FAA-managed oceanic airspace outside of both the Anchorage Arctic FIR and the Alaska ADIZ:** Within this region, airspace separation and ATC services are provided based upon the class of airspace, as over land.
- **The FAA-managed Anchorage Arctic FIR:** Within the FIR, uncontrolled airspace extends up to 23,000 ft MSL, and ATC services are available only in the controlled airspace above 23,000 ft MSL. Within the Chukchi Sea, the regions within the FIR are also located within the ADIZ.

Figure 5 shows the boundaries of the Anchorage Arctic FIR and the Alaska ADIZ, including the region where they overlap.

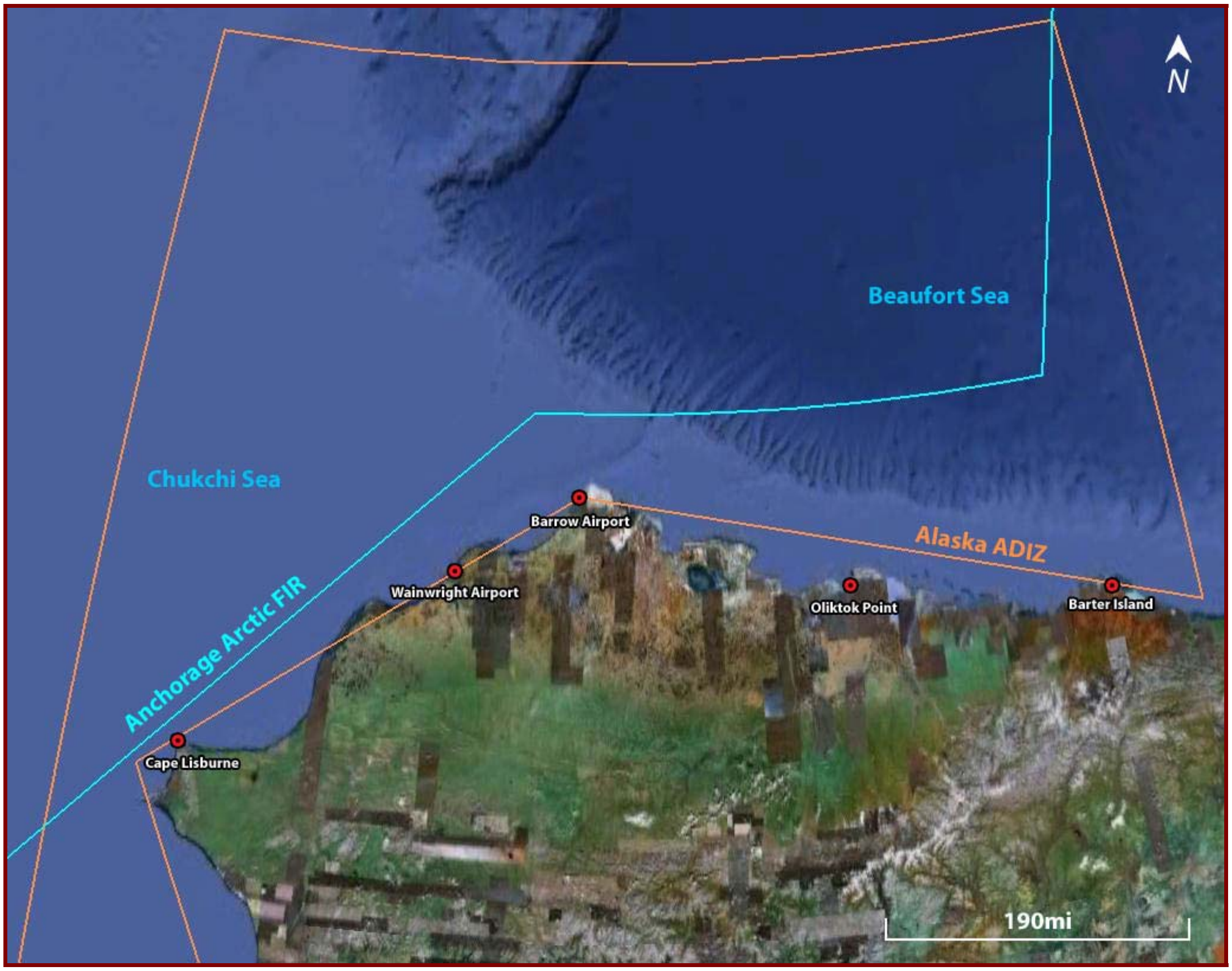

Figure 5. Alaska ADIZ and Anchorage Arctic FIR Boundaries in the Chukchi and Beaufort Seas

Airspace classes

The requirements for operating manned aircraft in the Beaufort and Chukchi Seas depend on the FAA-defined airspace class at various altitudes as well as whether an operating area is within the ADIZ and/or FIR. Within the Chukchi and Beaufort operating regions, there are three classes of vertical airspace: Class A, Class E, and Class G. Class A airspace is located above 23,000 ft in altitude. However, all UA flights will be conducted at or below 10,000 ft altitude, therefore falling within either Class E or Class G airspace. ATC controls instrument flight rules (IFR) traffic separation in Class E airspace, but does not control VFR separation. There is no ATC-provided separation available in Class G airspace for either VFR or IFR flights. However, all traffic operating within the ADIZ must have either a DVFR or IFR flight plan, guaranteeing that there is notification to air traffic authorities of all traffic within the ADIZ regardless of operating altitude or airspace. Specific Class E and G airspace altitude parameters within the operating areas are discussed in more detail below.

Table 2 summarizes the operating requirements for manned aircraft within Class E and Class G airspace in both the Chukchi and Beaufort Seas.

Table 2. Operating Requirements in Class E and Class G Airspace (10,000 ft and Below)

Operating Requirement	Class G Airspace	Class E Airspace
Separation Controlled by ATC	No	• VFR – No • IFR – Yes
Pilot Qualifications	Either IFR- or VFR-certified	
Transponder Required	Yes, if operating within Alaska ADIZ	
Radio Comm with ATC Required	Yes, if operating within Alaska ADIZ	
VFR Visibility Minimums	3 miles visibility	
VFR Distance from Clouds	Remain clear of clouds	• 500 feet below clouds • 1,000 feet above clouds • 2,000 feet horizontal from clouds
Flight Plan Required	IFR – yes VFR – no (outside of the ADIZ)	
ADIZ	All aircraft operating in the ADIZ must file a flight plan (IFR or DVFR) with the FAA, DoD, or both.	

Chukchi Sea Operating Region

The Chukchi Sea operating region begins 12 nm off the northern coast of Alaska, at the beginning of oceanic airspace. Figure 6 illustrates the Chukchi Sea operating region (shown in teal), including the boundaries of the Anchorage Arctic FIR, ADIZ, and Wainwright launch and recovery corridor (small green rectangles). The bounds of the Wainwright launch and recovery corridor were defined to avoid overflying the town of Wainwright. The entire Wainwright corridor, including the overland portion, falls within the ADIZ, so all manned aircraft operating in the vicinity of Wainwright must, therefore, have filed DVFR flight plans. For the portion of the study that falls within the Anchorage Arctic FIR, manned aircraft are provided flight information services by ATC that includes information pertinent to the safe and efficient conduct of flight, such as information on other possible conflicting traffic in the region as seen by radar.

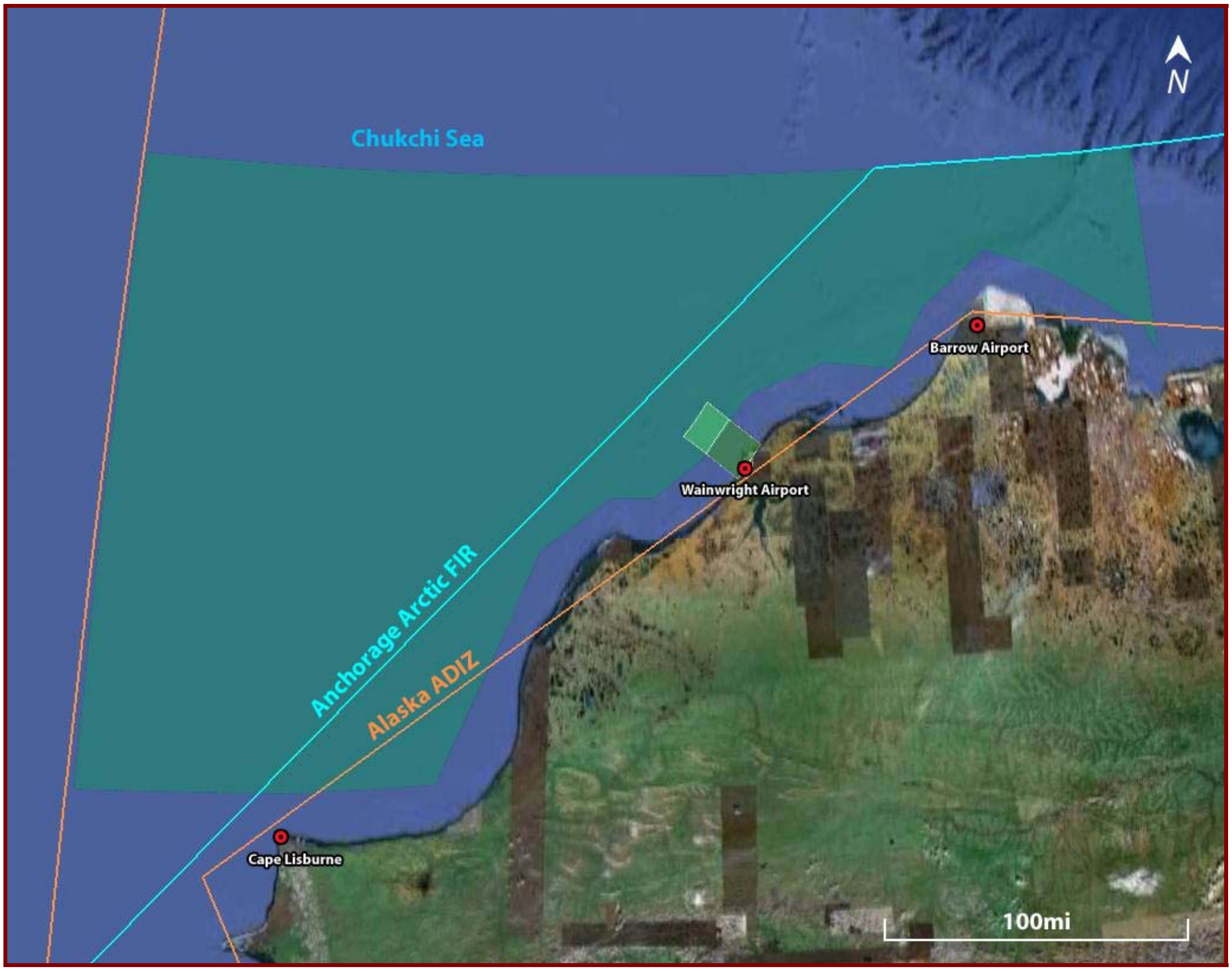

Figure 6. Operating Region within the Chukchi Sea Encompassing the Wainwright Corridor

Table 3 summarizes the altitudes of Class E and Class G airspace in the Chukchi Sea operating region and Wainwright launch and recovery corridor.

Table 3. Altitude of Class E and Class G Airspace in the Chukchi Sea Operating Region and Wainwright Launch and Recovery Corridor (10,000 ft and Below)

Description	Altitude	
	Class G Airspace	Class E Airspace
Within 7 miles of Wainwright airport (overland and over water)	• Surface to 700 ft MSL within 7 miles of airport	• 700 ft to 18,000 ft MSL within 7 miles of airport
Beyond 7 miles of Wainwright airport within 12 nm of the coast	• Surface to 1,200 ft MSL	• 1,200 ft to 18,000 ft MSL
Beyond 12 nm of the coast (oceanic airspace)		
Within Anchorage Arctic FIR	• Surface to 18,000 ft MSL	• Not Applicable

The narrow northbound egress/ingress route to the coast was based on the ends of the Wainwright runway with the launch/recovery point at the center of the runway, and a 1 nautical mile buffer zone on each side of the center of the Wainwright runway. When the UA path reaches the coastline, it turns northwest to take the shortest route to the Chukchi Sea. Once over the ocean, the operating area buffer zone expands to 12 nm in width and 20 nm seaward to ensure that near shore traffic was included in the airspace traffic study and risk analysis. Figure 7 illustrates the geometry of the Wainwright corridor and the location of the airspace class boundaries associated with the Wainwright corridor and Chukchi Sea oceanic operating area.

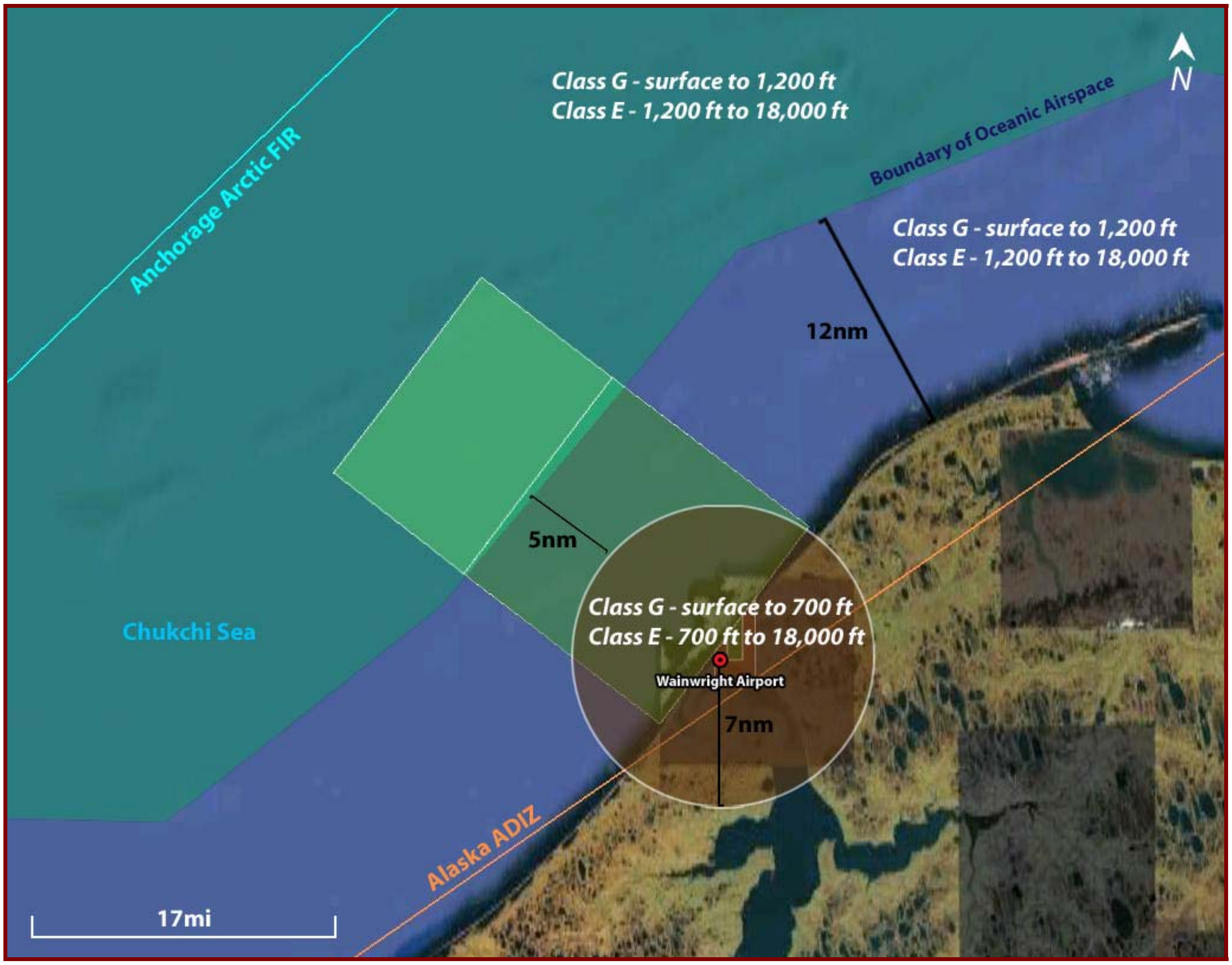

Figure 7. Wainwright Corridor and Classes of Airspace

There are several VFR flight routes used by scheduled commercial flights in and near the Chukchi Sea operating region as they fly into and out of Barrow (near the eastern edge of the Chukchi operating region). Figure 8 illustrates the VFR flight routes (in blue) in the Chukchi Sea operating region, and Figure 9 shows the detail of the flight routes impinging on the Wainwright launch and recovery corridor.

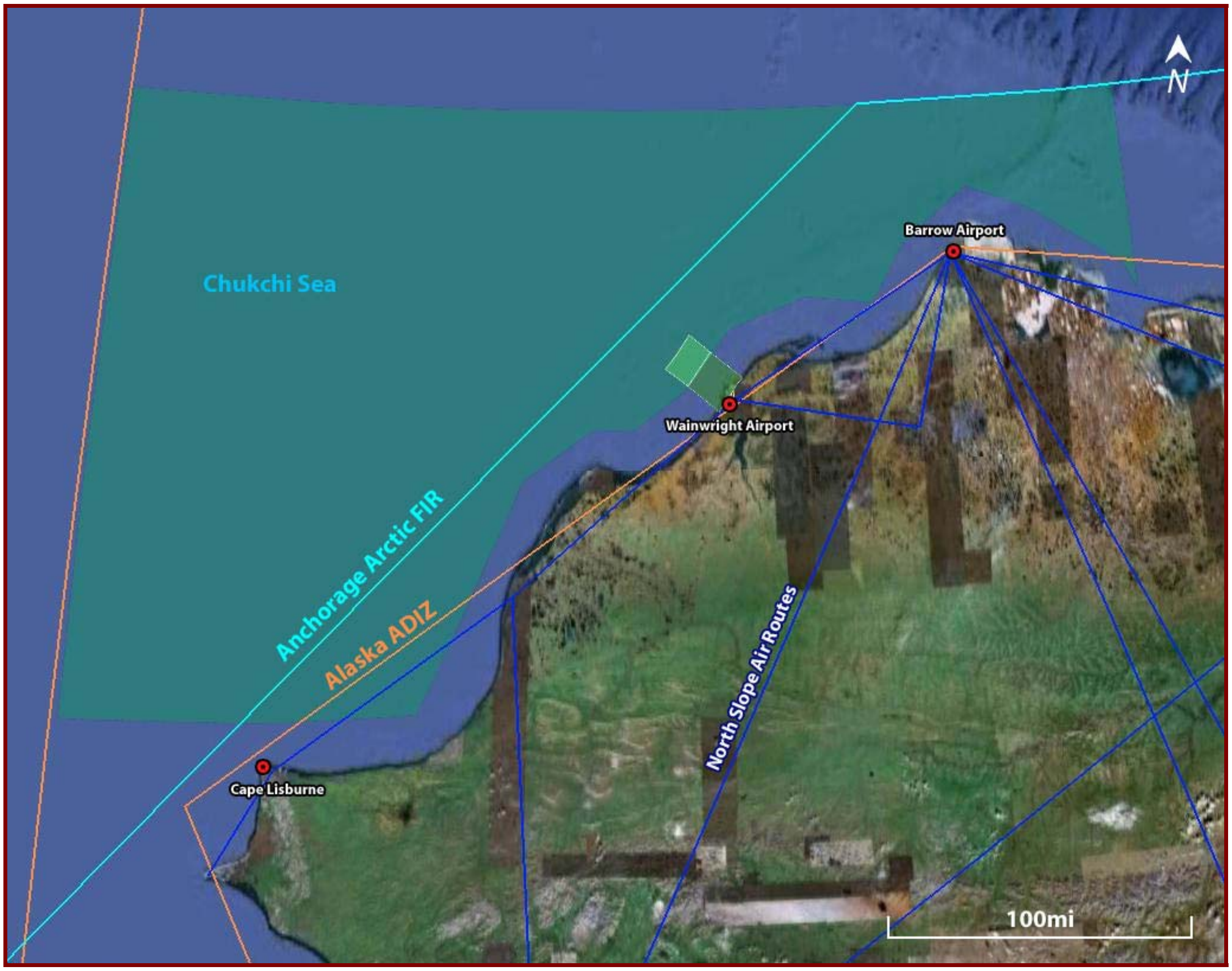

Figure 8. VFR Flight Routes in the Chukchi Sea Operating Region

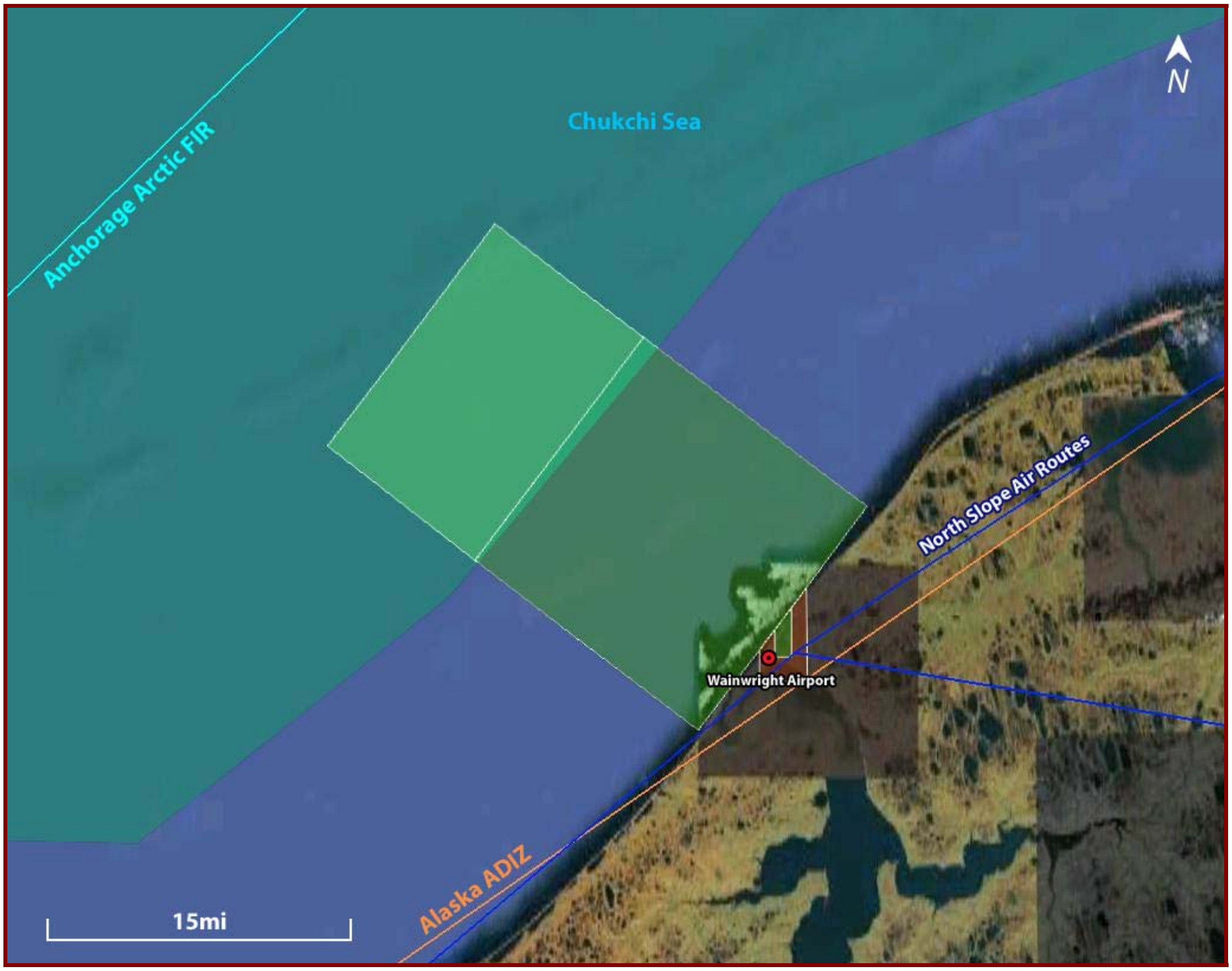

Figure 9. VFR Flight Routes in and near the Wainwright Corridor

Beaufort Sea Operating Region

Figure 10 illustrates the Beaufort Sea operating region (shown in green), including boundaries of the ADIZ, FIR, and Oliktok Point launch and recovery corridor. The bounds of the Oliktok Point corridor were developed to provide the shortest path between the potential launch area and oceanic airspace. The Oliktok Point corridor is a simple rectangle because there are no populated areas to avoid near the Oliktok Point launch area. The majority of the Beaufort Sea operating area falls within the ADIZ, so all manned aircraft must file DVFR flight plans before entering much of the operating region.

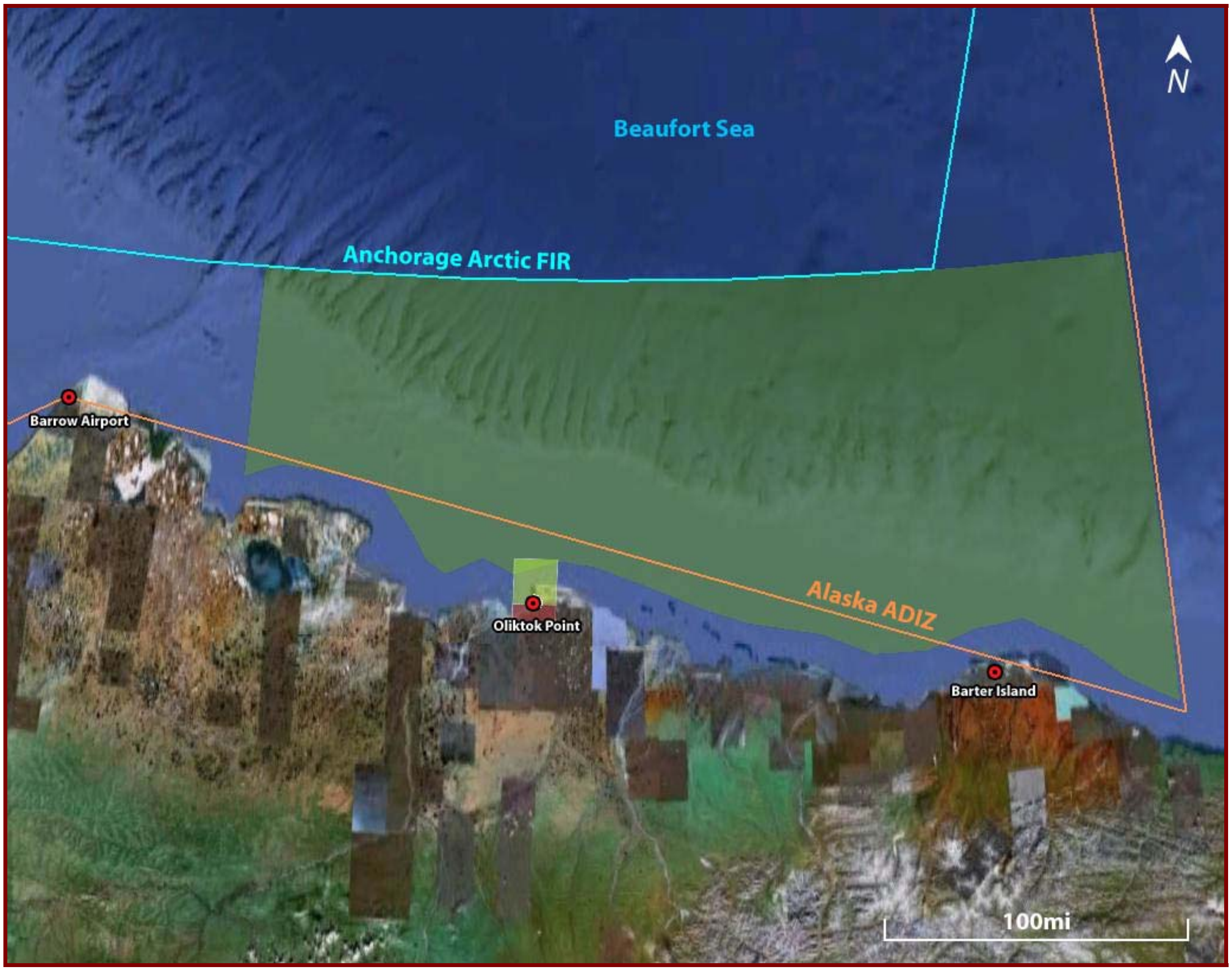

Figure 10. Beaufort Sea and Oliktok Point Corridor UA Operating Regions

In addition to the Class E and Class G airspace in the vicinity of Oliktok Point, there is a 4-nautical mile diameter region of restricted airspace[3] below 7,000 ft MSL under the Department

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[3] Restricted areas contain airspace identified by an area on the surface of the earth within which the flight of aircraft, while not wholly prohibited, is subject to restrictions. Restricted areas denote the existence of unusual, often invisible, hazards to aircraft such as artillery firing, aerial gunnery, or guided missiles. Penetration of restricted areas without authorization from the using or controlling agency may be extremely hazardous to the aircraft and its occupants. Restricted areas are published in the Federal Register and constitute 14 CFR Part 73.

of Energy at Oliktok Point, identified as Restricted Airspace Area 2204 (R-2204). Sandia National Laboratories manages the usage of R-2204. Table 4 summarizes the availability and times of use for the Oliktok Point restricted area complex R-2204. The restricted airspace at R-2204 is traditionally activated only by the Department of Energy when they operate a tethered airship at Oliktok Point. However, R-2204 could be activated for other uses. If R-2204 is activated during a time of UA operations, the availability for the UA will be unaltered, and there will be no other aircraft in the area due to the active restriction. The restricted area limitations are documented here in order to understand the manned aircraft flight patterns in the region.

Table 4. Department of Energy Restricted Area Complex at Oliktok Point

Restricted Area Identification (Altitude)	Restricted Area Operating Limitations	
	Times of Use	Availability
R-2204 Low (Surface to 1,500 ft MSL)	Variable – announced by NOTAM; 24 hours in advance	• Current: Not to exceed 30 days annually (inclusive of both low and high areas) • After 3 June 2010: Not to exceed 75 days annually (inclusive of both low and high areas) • Any activation regardless of schedule length will subtract in 24-hour increments from days allocated (i.e. 1 hour operating time = 1 allocated day of the 30 [75 after 3 June 2010] available annually)
R-2204 High (1,500 ft to 7,000 ft MSL)		

Table 5 summarizes the altitudes of Class E and Class G airspace in the Beaufort Sea operating region and Oliktok Point launch and recovery corridor. The southern boundary of the Anchorage Arctic FIR is at 72°N latitude and, therefore, is outside of the Beaufort Sea operating region.

Table 5. Altitude of the Class E and Class G Airspace in the Beaufort Sea and Oliktok Point Operating Region (10,000 ft and Below)

Description	Altitude	
	Class G Airspace	Class E Airspace
Over-land and within 12 nm of the coast	Surface to 1,200 ft to Anchorage Arctic FIR boundary at 72°N	1,200 ft to 18,000 ft MSL to Anchorage Arctic FIR boundary at 72°N
Beyond 12 nm from the coast (oceanic airspace)		

Figure 11 illustrates the airspace classes associated with the Oliktok Point corridor and Beaufort Sea oceanic operating area.

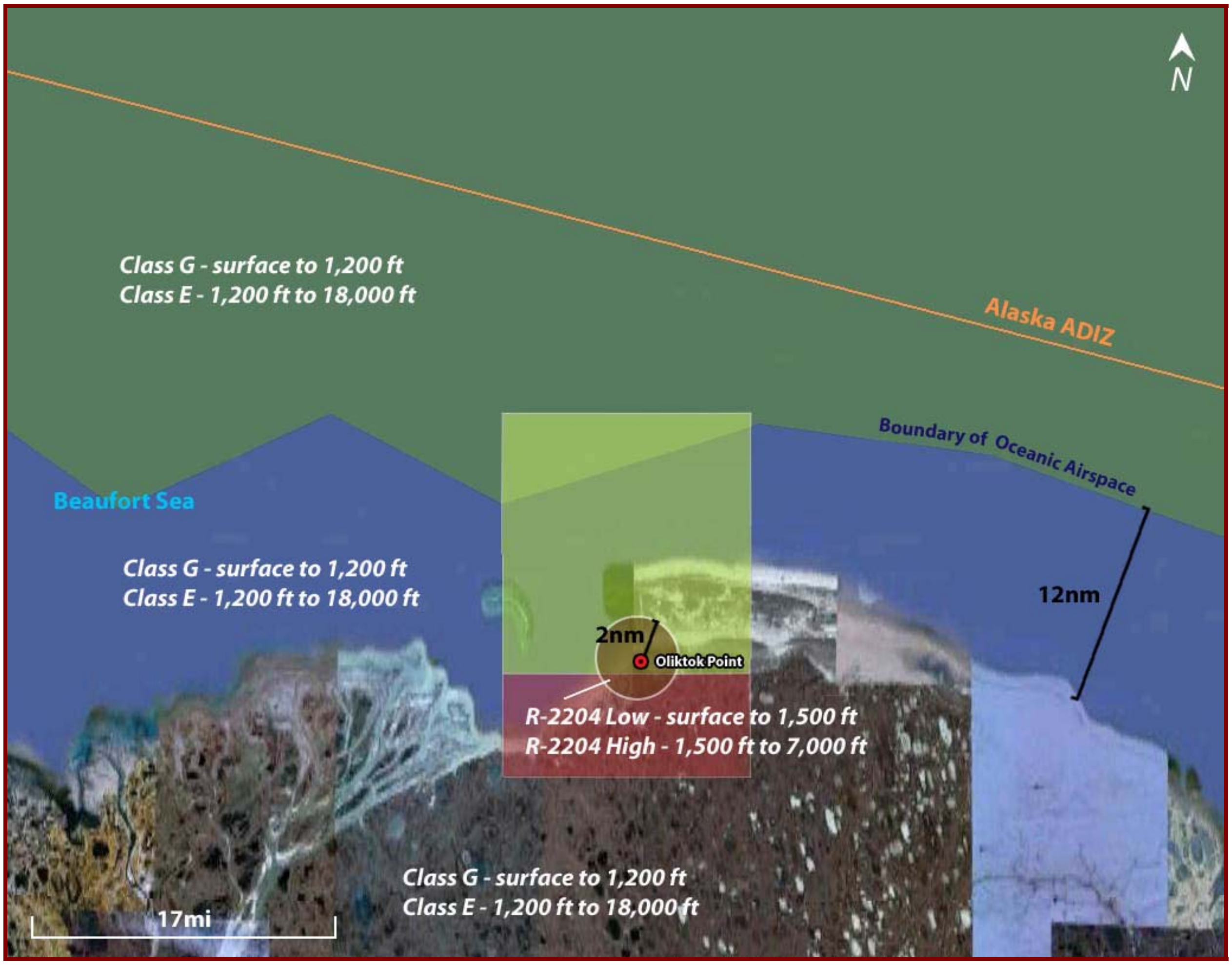

Figure 11. Oliktok Corridor and Classes of Airspace

There are several VFR flight routes used by scheduled commercial flights in and near the Beaufort Sea operating region as they fly into and out of Barrow (to the west of the operating area), Barter Island (near the eastern edge of the operating area), and Deadhorse/Prudhoe Bay (south of the operating area between Oliktok Point and Barter Island). Figure 12 illustrates the VFR flight routes (in blue) in the Beaufort Sea operating region, and Figure 13 shows the detail of the flight routes impinging on the Oliktok Point launch and recovery corridor.

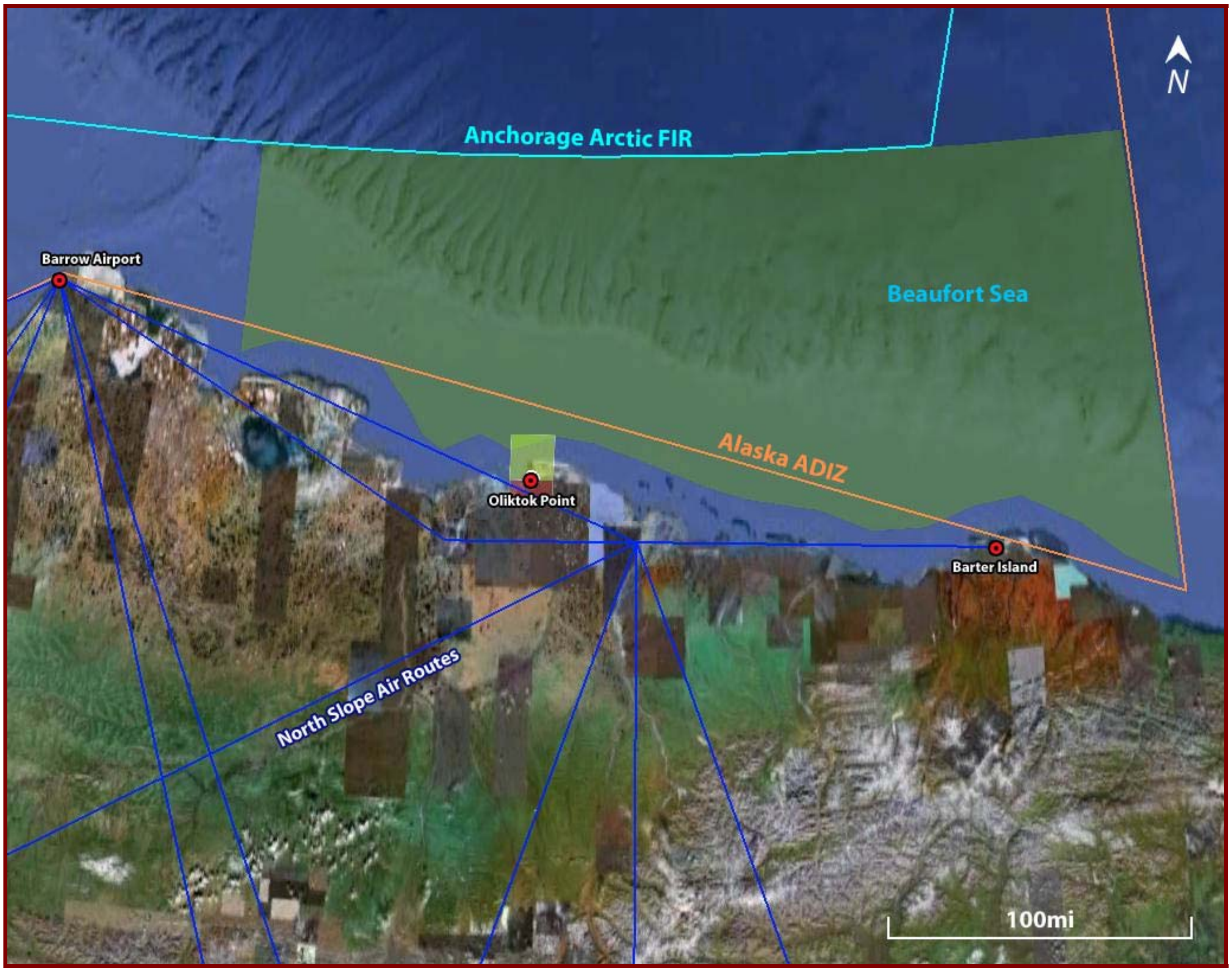

Figure 12. VFR Flight Routes in the Beaufort Sea Operating Region

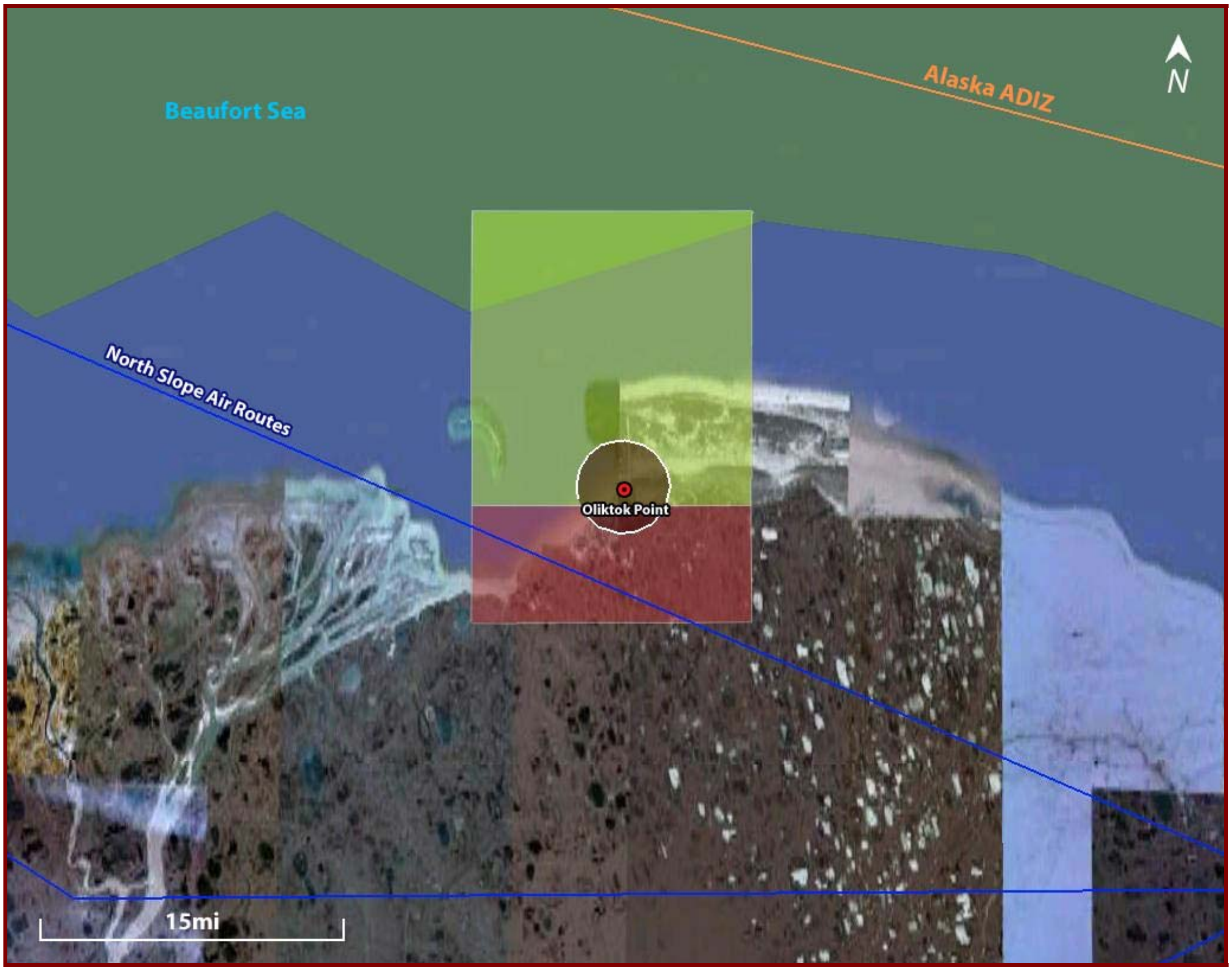

Figure 13. VFR Flight Routes near the Oliktok Point Launch and Recovery Corridor

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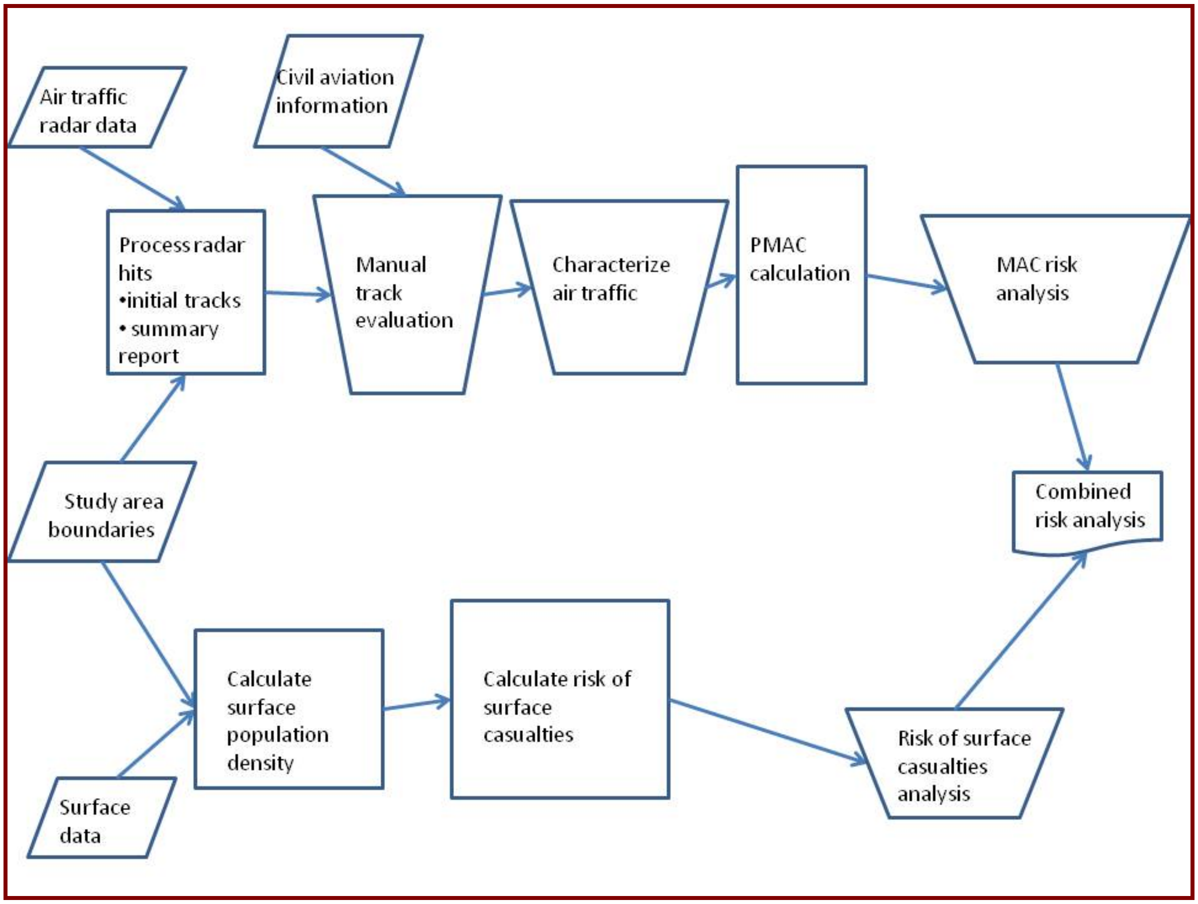
Methodology

General Approach

Figure 14 illustrates the overall approach that the study team used to complete the risk assessment, including airspace traffic characterization, calculation of the resultant region-specific probability of midair collisions, and the risk of surface casualties. Additional details regarding the airspace traffic characterization and midair collision risk approaches are located in Appendix B.



Legend: parallelogram = input; rectangle = automated computing process; trapezoid = manual analysis process; rectangle with curved bottom = output

Figure 14. Overview of General Approach

Data Sources

The study team obtained data from a wide variety of sources to complete the risk analysis for the operating areas and launch and recovery corridors. The main data source was primary radar data but an understanding of the air traffic within the study area was necessary as well. The data sources are listed in Table 6, along with a general description of the data from each source. Primary radar data does not rely on aircraft transponders but instead is recorded when an electromagnetic pulse is sent out from the radar and the signal is bounced off any aircraft in the coverage area, regardless of whether that aircraft has an active transmitting beacon. Secondary radar data ("beacon data") only records data provided by the aircraft beacon and, therefore, does not identify aircraft that do not have an active transmitting beacon.

Table 6. Data Sources and Descriptions

Data Source	Data Description	Security Restrictions
NORAD radar data	• Continuous data covering July 2008 through June 2009 (1 year) of unprocessed radar hits for the Beaufort Sea and Oliktok Point corridor • Continuous data covering July 2008 through May 2009 (11 months) of unprocessed radar hits for the Chukchi Sea and Wainwright corridor • Below 10,000 ft • Primary and secondary radar data from Cape Lisburne, Barrow, and Barter Island radars • Secondary (beacon only) radar data from Oliktok Point radar • Altitude, location, time, and transponder code	For Official Use Only (FOUO)
Civil aviation charts, including sectionals and high-altitude route charts	• Commercial VFR flight route information • Airspace classifications • Flight regulations for manned flight	None
Commercial passenger airline schedules	• Flight schedules and routes • Commonly used aircraft types	None
Aircraft tracking websites	• Verification of commercial airline schedules • Airport information • Additional (non-passenger) flight information	None
Marine mammal survey flight records	2008 aerial survey flight paths and times • Bowhead Whale Feeding Ecology Study (BOWFEST) • Chukchi Offshore Monitoring in Drilling Area (COMIDA) • Bowhead Whale Aerial Survey Projects (BWASP)	None
2000 US Census	Population density in the study area	None

Radar Data Limitations

There were two inherent limitations in the radar data used to conduct the risk analysis: incomplete radar coverage of the study area at all altitudes due to radar locations and capabilities as well as the prevalence of "ghost tracks." The presence of ghost tracks in the NORAD-provided radar data occurs as a result of multiple radar reflections due to the unique high-latitude atmospheric and surface conditions. The elimination of ghost tracks from the original data set was critical to accurately characterize the air traffic in the study areas. Failure to eliminate ghost tracks would result in assuming a higher density of air traffic than was actually present, as well as incorrectly representing flight paths in the study area. The process to eliminate ghost tracks is discussed in detail in Appendix B.

Figure 15 shows the overview of the maximum region covered by NORAD radars relative to the study areas. The four radars, from west to east, are Cape Lisburne, Barrow, Oliktok Point (beacon only), and Barter Island. Overall, 95 percent of the Chukchi Sea operating area was covered by radar coverage, with 100 percent of the southern boundary of the study area covered by radar from Barrow and Cape Lisburne. In the Beaufort Sea region, approximately 90 percent of the region had radar coverage, with 95 percent of the southern boundary covered by either the Barrow or Barter Island primary radar.

Figure 15. Radar Boundaries Relative to the Chukchi and Beaufort Sea Operating Areas

Airspace Traffic Characterization

The input data used for the airspace traffic characterization included:

- Study area boundaries, including latitude, longitude, and altitude
  - Chukchi Sea and Wainwright corridor
  - Beaufort Sea and Oliktok Point corridor
- Air traffic radar data from NORAD, unprocessed (raw)
- Civil aviation information, including published air routes and commercial flight schedules

The key components of the airspace traffic characterization process included:

- Process radar hits in Microsoft Access to identify initial set of tracks and produce a summary report for traffic within the study area
- Manual track evaluation to:
    - Eliminate duplicate tracks from overlapping radars
    - Consolidate tracks
    - Eliminate "ghost tracks"
- Characterize air traffic
    - Number of aircraft per day in the operating area
    - Aircraft altitude
    - Aircraft speed and size
    - Dwell time
    - Predictability
    - Operators

For each of the 12 months of available historical air traffic data, the study team used the metadata associated with each of the radar hits (e.g. time, position, and squawk code[4]) to eliminate ghost tracks and duplicate tracks from overlapping radars and to determine when aircraft were operating in the operating regions and the nature of those operations (i.e., military, civilian commuter, or scientific research flights (to include previous UA flights as described earlier). This allowed the study team to identify the number of flights, each representing one aircraft, in the operating regions as well as identifying frequently used air traffic routes. The study team then used the number of aircraft operating in the region as well as the dwell time of each flight (the amount of time an aircraft was observed in the region based on the start and stop time of each track) identified through the airspace characterization process to calculate the P(MAC). Further details regarding the airspace traffic characterization methodology, including the elimination of ghost tracks, are located in Appendix B.

Probability of Midair Collision

Based on the results of the airspace traffic characterization, the probability of midair collision calculation and risk analysis was performed for each operating area:

- P(MAC) calculation
    - Air traffic characterization, including number, size, and speed of aircraft potentially collocated with the UA
    - UA cylindrical operating volume
        - 48 nautical mile diameter (1 hour of flight time)
        - 10,000 ft altitude (maximum operating altitude for A-20 UA)
    - Assumptions
        - Aircraft are transiting the operating volume
        - UA may be anywhere in the operating volume
        - UA and aircraft maintain constant speeds

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[4] ATC assigns each aircraft a four-digit transponder code, commonly referred to as a "squawk" code.

- Risk analysis based on:
    - Calculated P(MAC) value(s)
    - Predictability of regional air traffic
    - FAA risk matrix

The methodology selected to calculate the expected P(MAC) in a defined volume of airspace assesses the likelihood that a UA operating in a given airspace will intersect with manned aircraft in the same airspace in a given timeframe, and P(MAC)is expressed as the probability of an incident occurring in one flight hour. That is, one incident per million flight hours is stated numerically as 1×10^{-6}. In this methodology, the risk of collision with the UA increases as the size and number of manned aircraft increases, and decreases with faster manned aircraft speeds (because they exit the operating volume sooner). Appendix B contains a detailed discussion of the calculations used to develop the P(MAC) reported in this study.

Figure 16 shows the severity and likelihood risk assessment matrix found in the FAA's System Safety Handbook, and used by the study team, to determine the overall rating of an expected incident. Red indicates high risk (to be avoided), yellow indicates medium risk (there are risks present that need to be mitigated), and green indicates low risk (operations are within the safety parameters). Each of the likelihood categories is bounded by minimum and maximum risk values; a "Remote" likelihood corresponds to a probability that falls between one incident per hundred thousand hours and one incident every ten million hours. Catastrophic severity, as defined by the FAA, does not apply to UA situations because there are no onboard operators or passengers. Therefore, for the purposes of this study, the hazardous column was used as there will never be loss of life from a UA-only incident, although there is potential risk to ground personnel if the UA incident occurs near populated surface areas (such an incident may fall within the "Hazardous" severity level). The blue arrow indicates the intended efforts of mitigation to decrease a calculated likelihood through the use of mitigation. The blue dotted line represents the commonly stated DoD threshold of one incident per million flight hours (1×10^{-6}) for reference, although the DoD is not a decision authority for the proposed UA operations.[5] Appendix A contains complete definitions of the FAA severity and likelihood categories.

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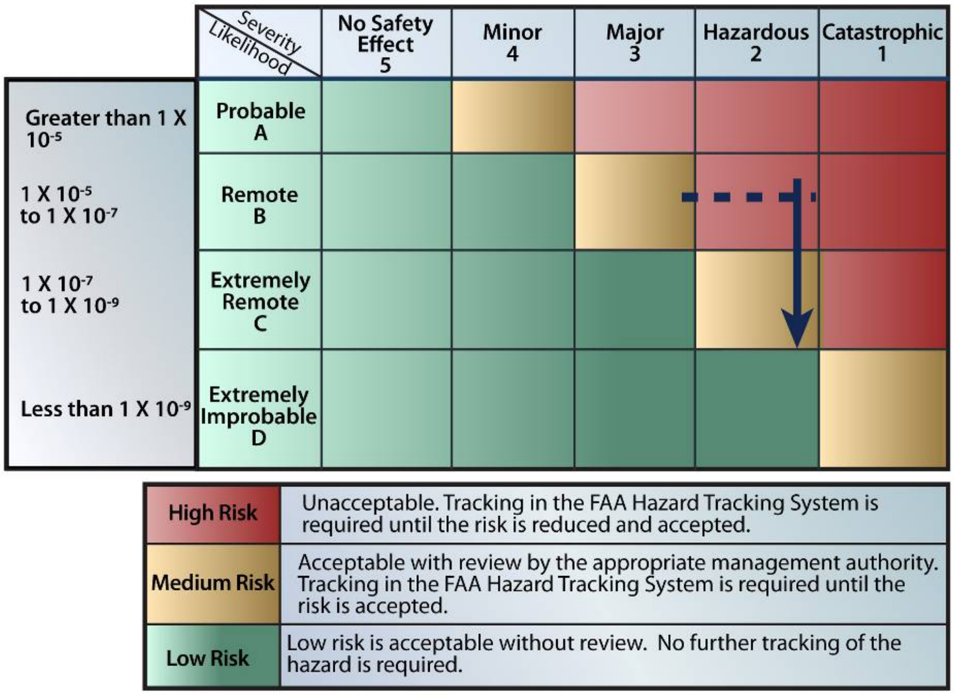
[5] DoD Range Commanders Council Document 323-99, "*Range Safety Criteria for Unmanned Air Vehicles*," December 1999



	Severity / Likelihood	No Safety Effect 5	Minor 4	Major 3	Hazardous 2	Catastrophic 1
Greater than 1 X 10^{-5}	Probable A	🟩	🟨	🟥	🟥	🟥
1 X 10^{-5} to 1 X 10^{-7}	Remote B	🟩	🟩	🟨	🟥	🟥
1 X 10^{-7} to 1 X 10^{-9}	Extremely Remote C	🟩	🟩	🟩	🟨	🟥
Less than 1 X 10^{-9}	Extremely Improbable D	🟩	🟩	🟩	🟩	🟨

🟥 High Risk	Unacceptable. Tracking in the FAA Hazard Tracking System is required until the risk is reduced and accepted.
🟨 Medium Risk	Acceptable with review by the appropriate management authority. Tracking in the FAA Hazard Tracking System is required until the risk is accepted.
🟩 Low Risk	Low risk is acceptable without review. No further tracking of the hazard is required.

Figure 16. FAA Risk Assessment Matrix

Risk of Surface Casualties

The input data used for the risk of surface casualties analysis included:

- Study area boundaries, including latitude and longitude
    - Chukchi Sea and Wainwright corridor
    - Beaufort Sea and Oliktok Point corridor
- Surface data including historical population density and building locations

The key components of the analysis of the risk of surface casualties included:

- Surface population density calculation based on:
    - The size of the area of interest
    - The total population in the area of interest
- Calculated risk of surface casualties based on:
    - Kinetic energy based on the size and speed of the UA
    - Population density
    - Estimated number of operating hours between UA failures
- Risk of surface casualties analysis based on:
    - Calculated risk of surface casualties value(s)
    - FAA risk matrix

The risk of surface casualties is the total risk to an exposed population from UA operations being conducted overhead (i.e., the likelihood of casualties in the event of a UA crash). Primary factors affecting this calculation are the density of population on the ground, the kinetic energy (based on weight and velocity), and size of the UA. In addition, the casualty expectation calculation relies heavily on an estimate of UA reliability; that is, how frequently a given UA is expected to experience a failure causing it to impact the surface in an uncontrolled manner. For the purposes of this study, the study team varied the probability of failure to generate a series of curves across a series of population densities. This allows the decision-making team to assess the risk of casualties on the surface for a number of regions without relying on potentially incomplete failure data for the UA system. The risk of surface casualties includes considerations of property damage and other ground features and is calculated separately from the P(MAC). For this study, the risk of surface casualties was calculated only for the two proposed over-land corridors as there is no static population in the waters within the operating region, and, therefore, the population density is effectively zero.

Combined Risk Analysis Report

The results for each of these three analyses (traffic characterization, risk analysis, and surface casualty risk analysis) were used by the study team to develop an overall risk assessment for each of the proposed operating regions. This study reports the overall risk assessments as well as suggested risk mitigation factors associated with each region.

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Results

The summarized results presented in this section were derived from the air traffic characterization, P(MAC), and risk of surface casualty calculation processes detailed in Appendix B. In order to facilitate land- or ship-based UA mission planning, the study team analyzed the oceanic operating regions and the potential launch and recovery corridors separately. Appendix C contains the detailed monthly air traffic characterization results for the Chukchi Sea and Wainwright corridor, and Appendix D contains the detailed monthly results for the Beaufort Sea and Oliktok Point corridor regions.

Based on climatology data collected by the US Air Force 14th Weather Squadron at Wainwright,[6] the study team determined that the North Slope of Alaska has variable weather patterns. However, the general trends indicate that summer (June, July, and August) and winter (December and January, February) generally represent the clearest weather in the area as determined by the likelihood of ceilings above 3,000 ft MSL and visibility greater than 5 statute miles. During spring (March, April, and May), warmer weather contributes to low ceilings and decreased visibility. During the fall and early winter (September, October, and November), storms are common which contribute to increased likelihood of low ceilings and low visibility, which can impact flight operations in the region.

Oceanic Operating Regions

After processing the radar data to eliminate confirmed ghost returns and consolidating radar hits into separate tracks, the study team calculated the number of monthly flights and total dwell time in the oceanic operating regions. Most flights in the region were flights observed for relatively short periods of time as they transited the operating areas. The science missions operated for longer periods of time in the oceanic operating regions, and the radar data corresponds to much longer dwell times in the regions. Almost all of the transiting flights observed in both the Chukchi Sea and Beaufort Sea oceanic operating areas correlated with regularly scheduled transiting commercial air traffic flying along the standard VFR routes. Appendix C contains the detailed monthly air traffic results for the Chukchi Sea, and Appendix D contains the detailed monthly air traffic results for the Beaufort Sea.

Chukchi Sea

Table 7 summarizes the observed air traffic operating below 10,000 ft MSL within the Chukchi Sea oceanic operating area. During the majority of the year, there were fewer than 60 flights observed each month within the Chukchi Sea, and the average dwell time was generally less than 20 minutes for each flight. There were 930 flights observed throughout the year in this region. However, after excluding the 64 science flights from the analysis as they are not transiting flights, the study team determined that there were 866 total transiting flights in the area. The large number and dwell time of flights observed in August is due to both marine mammal surveys and the larger quantity of commercial traffic related to the summer season on the North Slope. There was an average of only 2.53 transiting flights per day, each with an average dwell time of 0:10:54.

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[6] Data derived from the US Air Force 14th Weather Squadron Surface Observation Database

Table 7. *Chukchi Sea Monthly Air Traffic Summary*

Month	Overall		Transiting		
	Number of flights dwell time	Science flights dwell time	Transiting flights dwell time	Transiting flights with more than one radar hit average dwell time per transiting flight	Average transiting flights per day
July 2008	76 24:25:05	2 3:52:36	74 20:32:29	64 0:19:15	2.39
August 2008	280 106:45:15	59 81:25:07	221 25:20:08	136 0:11:11	7.13
September 2008	99 47:27:20	9 24:06:22	90 23:20:58	78 0:17:58	3.00
October 2008	65 25:15:51	13 21:14:42	52 4:01:09	38 0:06:21	1.68
November 2008	57 3:47:12	1 0:43:29	56 3:03:43	45 0:04:05	1.87
December 2008	53 1:36:46	0	53 1:36:46	38 0:02:33	1.71
January 2009	68 2:05:48	0	68 2:05:48	52 0:02:25	2.19
February 2009	52 1:42:10	0	52 1:42:10	35 0:02:55	1.86
March 2009	60 16:47:34	0	60 16:47:34	42 0:23:59	1.94
April 2009	63 13:09:28	0	63 13:09:28	56 0:14:06	2.10
May 2009	57 2:11:09	0	57 2:11:09	43 0:03:03	1.84
Total (11 months)	**930 245:13:28**	**64 131:22:06**	**866 113:51:22**	**627 00:10:54**	**2.53**

Figure 17 illustrates October 2008, a representative month of air traffic in the Chukchi Sea, both with and without the marine mammal flights. Note that the elimination of the marine mammal flights greatly reduced the observed footprint of the air traffic in the area.

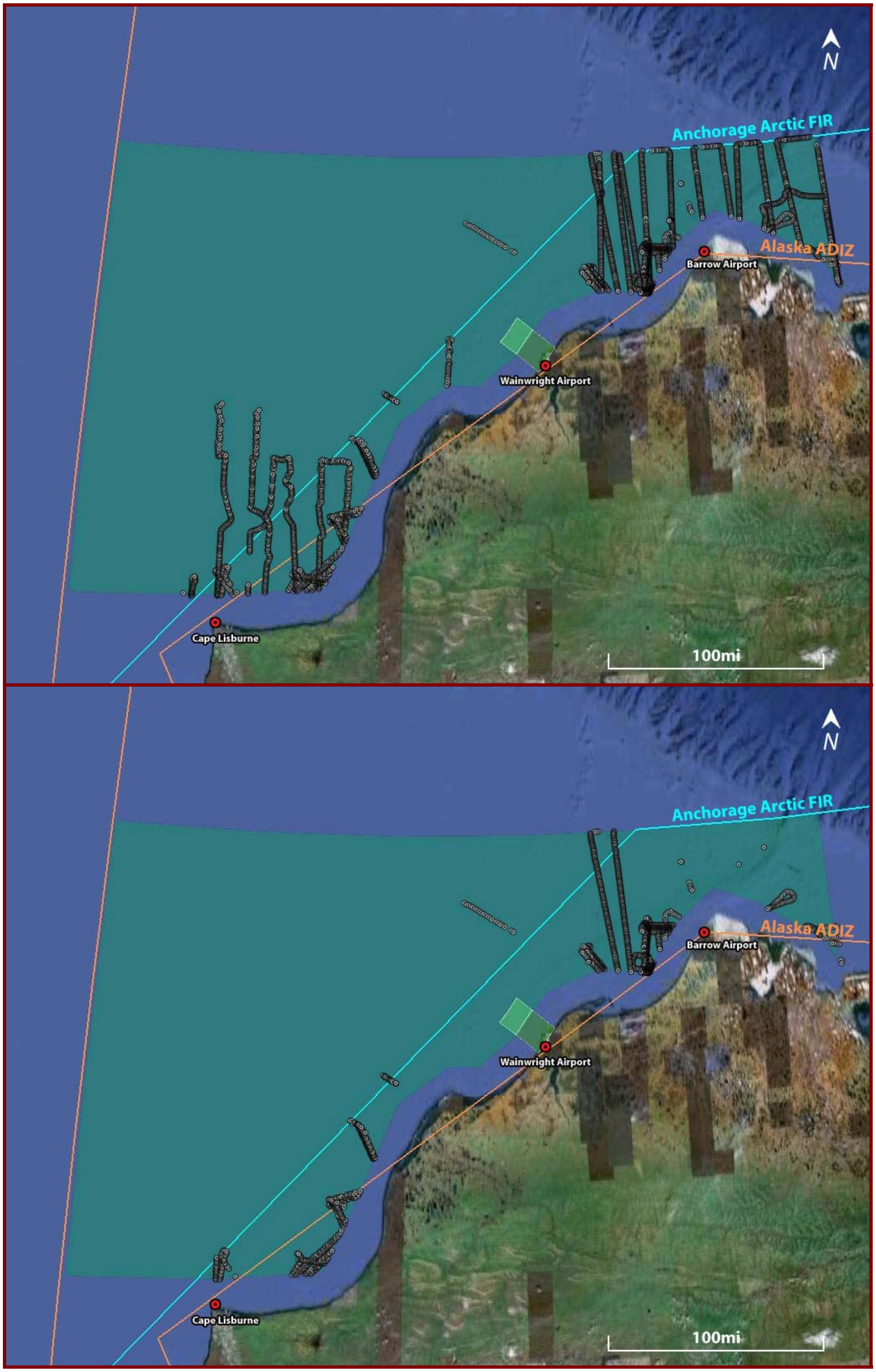


Figure 17. Chukchi Sea: (Top) All October 2008 Air Traffic (46 Flights), (Bottom) October 2008 Transiting Air Traffic Only (Science Flights Excluded)

Beaufort Sea

Table 8 summarizes the observed air traffic within the Beaufort Sea oceanic operating area. During the majority of the year, there were less than 40 flights observed each month within the Beaufort Sea, and the average dwell time was generally less than 30 minutes for each flight. There were 420 flights observed throughout the year in this region, 133 of which were identified as science flights. After excluding the non-transiting science flights from the analysis, the study team determined that there were 287 total transiting flights in the area. The relatively large number and dwell time of flights observed in August and September is likely due to the larger quantity of commercial traffic related to the summer season on the North Slope. Over the course of the year, there was an average of only 0.79 transiting flights per day, each with an average dwell time of 0:20:18.

Table 8. Beaufort Sea Monthly Air Traffic Summary

Month	Overall		Transiting		
	Number of Flights Dwell Time	Science Flights Dwell Time	Transiting Flights Dwell Time	Transiting Flights with more than1 Radar Hit Average Dwell Time per Transiting Flight	Average Transiting Flights per Day
July 2008	43 48:01:24	22 41:46:25	21 6:14:59	15 0:25:00	0.68
August 2008	61 43:28:15	23 33:14:40	38 10:13:35	29 0:21:09	1.23
September 2008	100 85:29:11	70 79:53:02	30 5:36:09	19 0:17:42	1.00
October 2008	33 30:39:02	18 29:17:56	15 1:21:06	10 0:08:07	0.48
November 2008	28 2:25:17	0	28 2:25:17	14 0:10:23	0.93
December 2008	2 1:49:23	0	2 1:49:23	2 0:54:41	0.06
January 2009	19 1:56:45	0	19 1:56:45	10 0:11:41	0.61
February 2009	15 1:46:41	0	15 1:46:41	12 0:08:53	0.54
March 2009*	49 16:31:09	0	49 16:31:09	43 0:23:03	1.58
April 2009	37 9:36:02	0	37 9:36:02	28 0:20:34	1.23
May 2009	26 12:45:12	0	26 12:45:12	25 0:30:36	0.84
June 2009	7 2:08:43	0	7 2:08:43	7 0:18:23	0.23
Yearly Total	**420** **256:37:04**	**133** **184:12:03**	**287** **72:25:01**	**214** **0:20:18**	**0.79**

* The 42 of the 43 March transiting flights are suspected to be ghost returns and may not represent actual flights. However, the study team was unable to confirm that the March flights were actually ghost returns due to limitations of the over-land radar data.

Figure 18 illustrates June 2009, showing transiting air traffic in the Beaufort Sea.

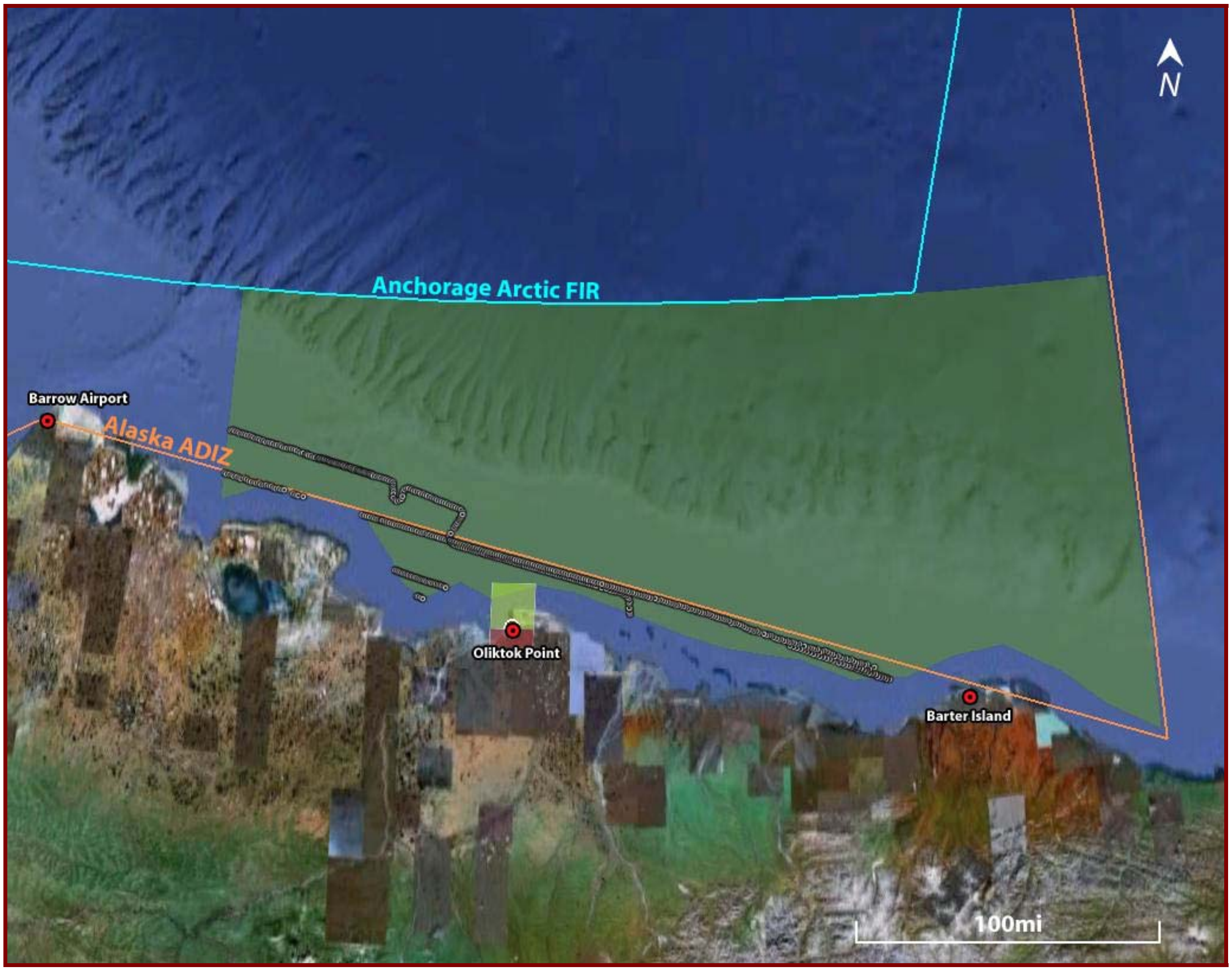


Figure 18. June 2009 Transiting Air Traffic in the Beaufort Sea

Oceanic Air Traffic Characterization

Based on the radar data analysis, the study team was able to determine where flights operated, what types of aircraft were common, how much of the time throughout the year had air traffic, and the frequency of multiple flights operating at the same time.

Locations

The vast majority of both oceanic operating regions fall within the Alaska ADIZ, ensuring that all civil aircraft operating in the region will have filed DVFR flight plans and be operating transponders, regardless of operating altitude. In addition, since most air traffic in both regions was transiting, the aircraft were operating in Class E controlled airspace above 1,200 ft MSL.

Figure 19 illustrates the commercial air routes in the Chukchi Sea (blue lines), along which much of the air traffic was observed to be operating.

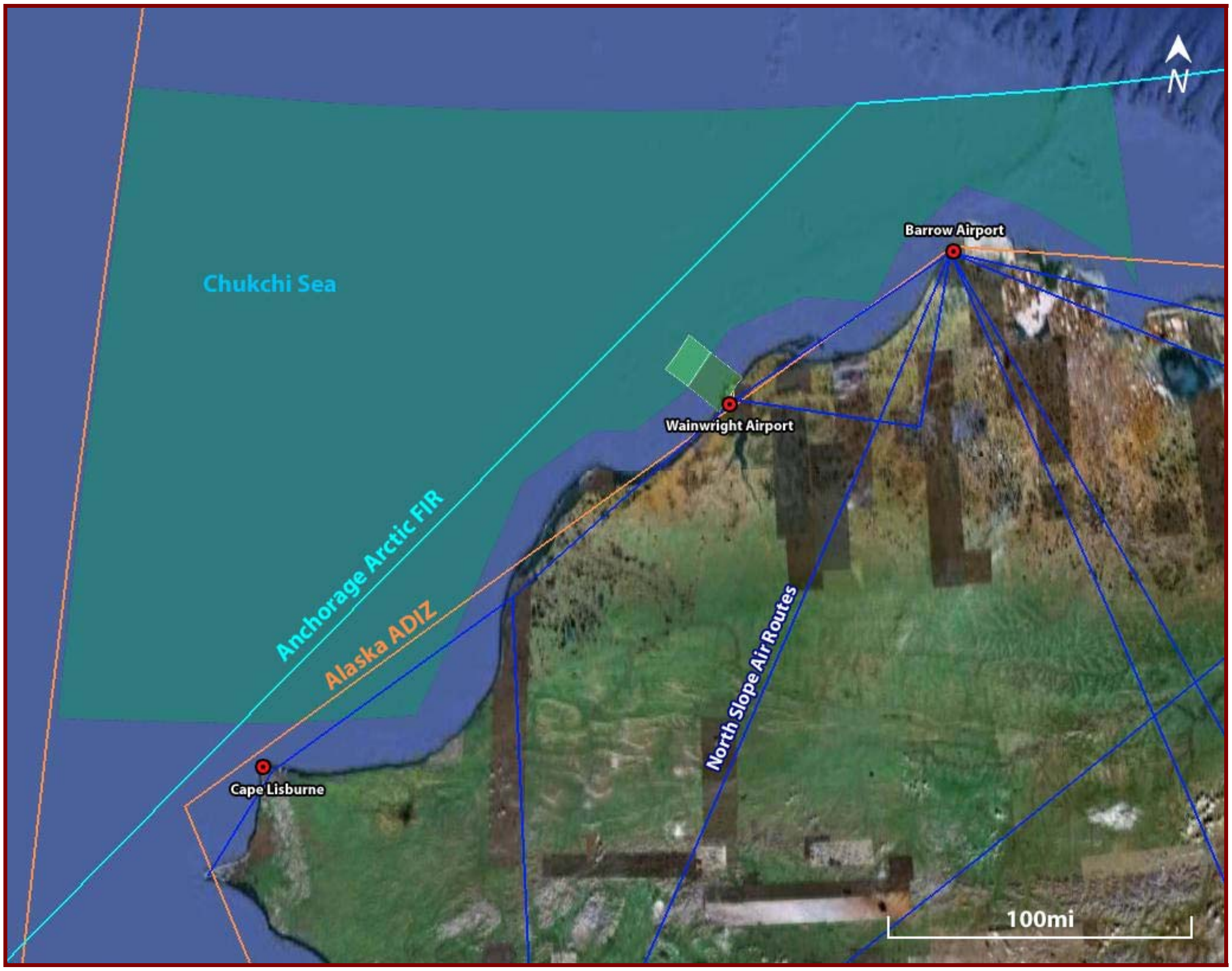


Figure 19. Commercial Air Routes in the Chukchi Sea

Figure 20 illustrates the commercial air routes in the Beaufort Sea. Commercial aviation information indicated that there are only occasional direct flights between Barter Island and Barrow that operate just south of the ADIZ border within the Beaufort Sea operating region. The transiting air traffic near the Beaufort Sea operating area was generally very predictable over the course of the year.

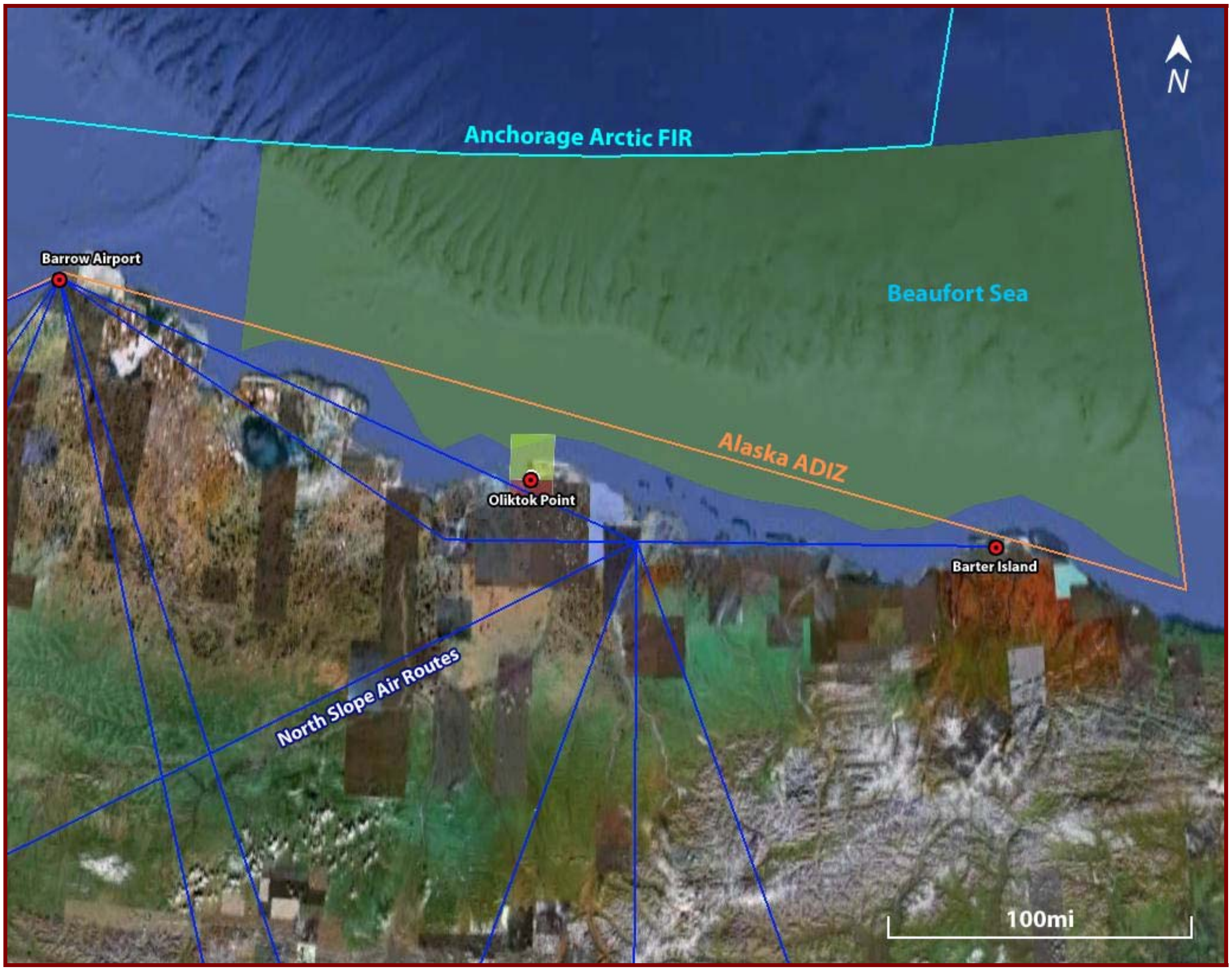


Figure 20. Commercial Air Routes in the Beaufort Sea

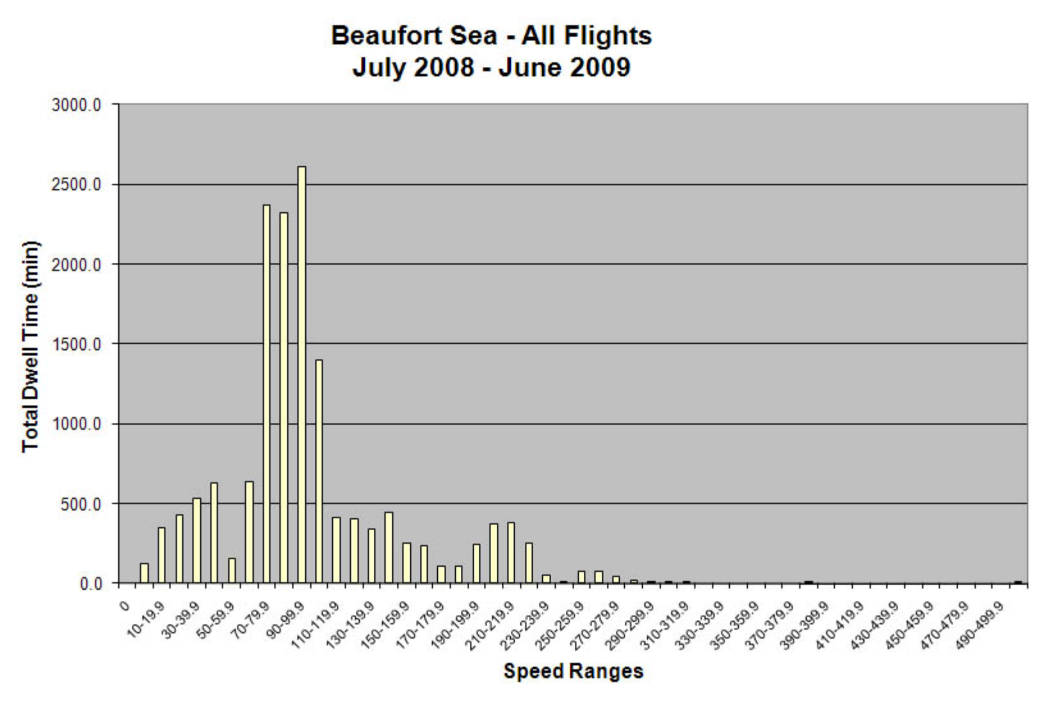
These observed transiting flight patterns found in this study are consistent with those patterns that have been flown in the North Slope region in past years by local aviators. Aircraft that were observed during this study period not following the commercial air routes were science mission flights, or on rare occasion a flight with a military squawk code. The science mission flights followed their pre-published transect flight paths. These types of flights were observed July through October 2008 in the Beaufort and July through November 2008 in the Chukchi. Over the course of the study period 11 military flights were observed (2 of these were tracks with only one hit) in the Beaufort Sea operating region with 40 observed in the Chukchi Sea operating region (12 of these were one-track hits). Radar data indicated that all aircraft operating within the region had transponders as there were no uncooperative aircraft radar hits (radar hits without an associated squawk code) in the study area In addition, there are no know parachutists or balloonists that operate within these regions.

Types of Aircraft

Study Period

Throughout both the Chukchi Sea and Beaufort Sea oceanic operating areas, the study team determined that the Twin Otter (230-knot cruise speed) was the main aircraft operated per flight hour throughout the region. In addition, the team identified slower aircraft as Cessnas (120-knot cruise speed), and faster aircraft as larger Boeing 737s (up to 500-knot cruise speeds). Airspeeds were determined based on the calculated distance and time between radar hits for each flight represented by more than one radar hit. For the purposes of classifying the type of aircraft used for each flight, the study team binned the calculated airspeeds of transiting aircraft. Flights that had calculated speeds from 0 to 120 knots were identified as Cessnas. Between 121 and 230 knots were classified as Twin Otters, and above 231 knots were classified as Boeing 737s. Within the Beaufort Sea, 58 percent of the flights fell between 121 and 230 knots and were, therefore, classified as Twin Otters. Another 36 percent of the flights had calculated speeds that fell below the Twin Otter range, and were therefore classified as Cessnas. Only 6 percent of the flights were calculated as faster than 230 knots and classified as Boeing 737s.

Figure 21 shows the calculated airspeeds of the transiting flights in the Beaufort Sea relative to the dwell time at each speed. There was significantly more variation in speeds observed in the Chukchi Sea (Figure 22) because of the landings and takeoffs at Barrow, which occurred at speeds lower than the optimum cruising speeds for each of the aircraft types.



Min = minute

Figure 21. Air Speed Distribution of Transiting Flights in the Beaufort Sea Operating Region (Total Dwell Time at each Calculated Speed)

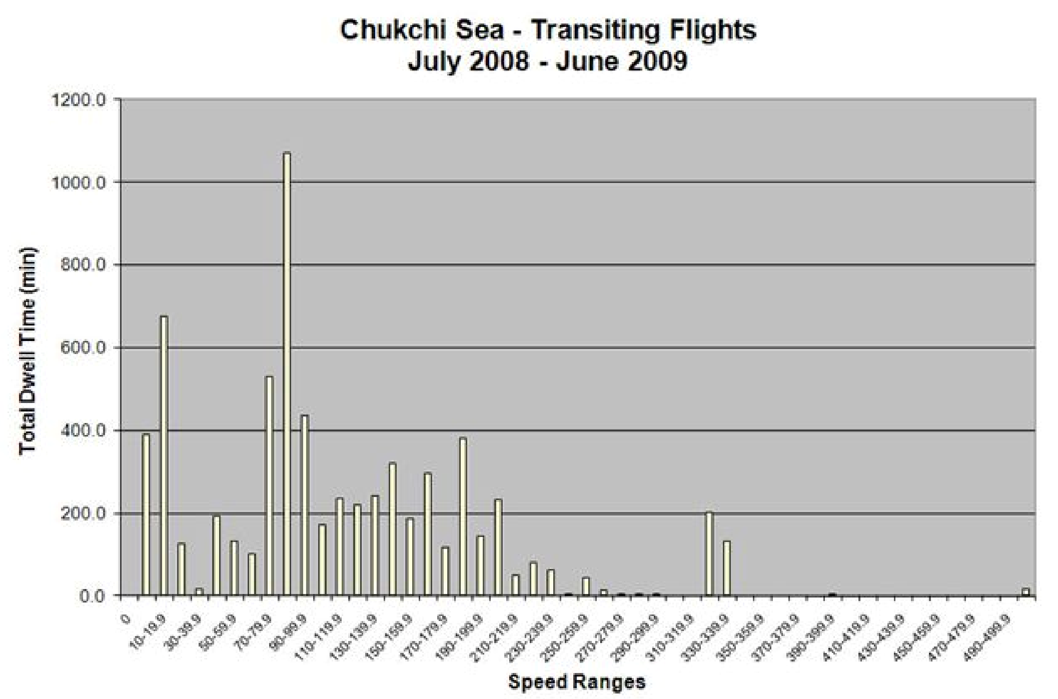


Figure 22. Air Speed Distribution of Transiting Flights in the Chukchi Sea Operating Region (Total Dwell Time at each Calculated Speed)

Current

While the Cessna, Twin Otter, and Boeing 737 were the aircraft types identified to be operating during the study period, the team noted that commercial aviators operating on the North Slope have expanded the types of aircraft being flown. Commercial aviators such as Alaska Airlines continue to fly Boeing 737s, while Frontier Flying Services are currently operating Beechcraft 1900 Ds that have a cruise speed between 260 to 288 knots. These faster transiting aircraft create a similar volume as they transect the airspace but their increased speed lowers the risk of a mid-air collision. Science mission flights are still being conducted with Twin Otters and now include turbo props such as the Rockwell Jet Commander with science missions typically being conducted at cruise speeds of 110 knots.

Time

The average of the percentage of time with observed flights over 11 months in the Chukchi Sea was 1.3 percent, and the highest percentage of time with transiting aircraft observed was 3.52 percent in the month of August (25:20:08 out of 720 total hours). Similarly, the yearly average of time with flights observed in the Beaufort Sea was 0.83 percent, and the highest percentage of time was 2.22 percent in the month of March (16:31:09 out of 744 total hours). Table 9 summarizes the monthly dwell times and percentage of time the airspace was occupied for both oceanic regions.

Table 9. Percentage of Time Airspace was Occupied in the Chukchi Sea and Beaufort Sea Operating Regions

Month (Total hours)	Chukchi Sea		Beaufort Sea	
	Transiting Flights Dwell Time	% of Hours with Aircraft	Transiting Flights Dwell Time	% of Hours with Aircraft
July 2008 (744)	20:32:29	2.76	6:14:59	0.84
August 2008 (744)	25:20:08	3.52	10:13:35	1.42
September 2008 (720)	23:20:58	3.24	5:36:09	0.78
October 2008 (744)	2:45:18	0.37	1:21:06	0.18
November 2008 (720)	3:03:43	0.43	2:25:17	0.34
December 2008 (744)	1:36:46	0.22	1:49:23	0.25
January 2009 (744)	2:05:48	0.28	1:56:45	0.26
February 2009 (672)	1:42:10	0.25	1:46:41	0.26
March 2009 (744)	16:47:34	2.26	16:31:09	2.22
April 2009 (720)	13:09:28	1.83	9:36:02	1.33
May 2009 (744)	2:11:09	0.29	12:45:12	1.71
June 2008 (720)			2:08:43	0.30
Yearly Total (8760)	113:51:27	1.30	**72:25:01**	**0.83**

Simultaneous Flights

The study team determined that there was more than one transiting flight operating at a time in the Chukchi Sea only 35 times throughout the 11 months of data. The largest number of aircraft observed operating at any given time was three, and that only occurred 4 times throughout the year. There were 36 instances of two aircraft operating at a time, half of which were in August 2008. Table 10 summarizes the number of aircraft operating at the same time in the Chukchi Sea operating area. The locations and altitudes were not considerations in determining these counts. However, future analysis of the simultaneous radar tracks could be completed to provide this information.

Table 10. Number of Transiting Aircraft Operating at One Time in the Chukchi Sea

Month	Total Flights	Number of Times each Month there were Simultaneous Flights Operating	
		2 Aircraft	3 Aircraft
July 2008	74	4	0
August 2008	241	9	0
September 2008	90	2	1
October 2008	52	1	0
November 2008	56	0	0
December 2008	53	0	0
January 2009	68	1	0
February 2009	52	1	0
March 2009	60	4	1
April 2009	63	3	1
May 2009	57	0	0
Total	**866**	**25 (50 flights)**	**3 (9 flights)**

The study team determined that there were more than one transiting flight operating at a time in the Beaufort Sea only 31 times throughout the year. The largest number of aircraft observed operating at any given time was three, and that only occurred once during the year, in September. There were 14 instances of two aircraft operating at a time, almost half of which were in March 2009. Table 11 summarizes the number of aircraft operating at the same time in the Beaufort Sea operating area.

Table 11. Number of Transiting Aircraft Operating at One Time in the Beaufort Sea

Month	Total Flights	Number of Times each Month there were Simultaneous Flights Operating	
		2 Aircraft	3 Aircraft
July 2008	21	0	0
August 2008	38	0	0
September 2008	30	0	0
October 2008	15	1	0
November 2008	28	0	0
December 2008	2	0	0
January 2009	19	1	0
February 2009	15	0	0
March 2009	49	6	0
April 2009	37	1	0
May 2009	26	2	0
June 2009	7	0	0
Total	**287**	**11 (22 flights)**	**0 (0 flights)**

Launch and Recovery Corridors

Due to the presence of an active airport in the Wainwright launch and recovery corridor, there were many low altitude flights observed which correlated with the regularly scheduled landings and takeoffs from regional commercial air traffic. There were also some higher altitude flights which correlated with transiting air traffic between Barrow and airports in western Alaska such as Point Lay, west of Cape Lisburne. Appendix C contains the detailed monthly air traffic routes for the Wainwright corridor.

Almost all of the flights observed in the Oliktok Point corridor correlated with regularly scheduled transiting commercial air traffic flying along the standard VFR routes between Deadhorse/Prudhoe Bay, Barter Island, and Barrow. The few flights which were not commercial air traffic were mostly the documented marine mammal surveys. For the purposes of evaluating the risks of land-based launch and recovery, the study team did not eliminate the science flights from the Oliktok Point corridor because they served to define the commonly used overland flight routes in the area. Appendix D contains the detailed monthly air traffic results for Oliktok Point.

Wainwright corridor

Table 12 summarizes the observed air traffic below 10,000 ft MSL within the Wainwright corridor. During the majority of the 11 months (July 2008 through May 2009) for which the study team received data, there were fewer than 20 flights observed each month within the Wainwright corridor, and the average dwell time was less than 2 minutes for each flight. The average number of flights per day over the course of the 11 months was 0.40. The total dwell time for observed flights in this launch and recovery corridor during the 11 months of radar data analyzed was 3:39:30. The large number of flights observed in August was due to both marine mammal surveys and the larger quantity of commercial traffic related to the summer season on the North Slope.

Table 12. Wainwright Corridor Monthly Air Traffic Summary

Month	Flights Dwell Time	Flights with more than 1 Radar Hit Average Dwell Time per Flight	Average Flights per Day
July 2008	10 0:10:23	6 0:01:44	0.19
August 2008	71 1:39:20	58 0:01:43	1.87
September 2008	15 0:25:25	14 0:01:49	0.47
October 2008	8 0:13:14	7 0:01:53	0.23
November 2008	2 0:01:36	2 0:00:48	0.07
December 2008	27 0:20:58	18 0:01:10	0.58
January 2009	22 0:38:58	17 0:02:18	0.55
February 2009	8 0:04:59	4 0:01:15	0.14
March 2009	4 0:01:49	3 0:00:36	0.10
April 2009	4 0:02:48	4 0:00:42	0.13
May 2009	1 0:00:00	0 0:00:00	0
11 Month Total	**172** **03:39:30**	**133** **00:01:24**	**0.40**

Figure 23 illustrates December 2008, a representative month of air traffic in the Wainwright corridor. Due to the limitations of the software used to graphically display this data, it is not possible to display the flights as lines. Each dot therefore represents a single radar hit that the study team evaluated.

Figure 23. December 2008 Air Traffic in the Wainwright Corridor

Oliktok Point corridor

Table 13 summarizes the observed air traffic below 10,000 ft MSL within the Oliktok Point corridor. During the majority of the year, there were less than 30 flights observed each month within the Oliktok Point corridor, and the average dwell time was approximately 7 minutes for each flight. The average number of flights per day was 0.68. The total dwell time for observed flights in this launch and recovery corridor during the 12 month study period was 29:26:11. The large number of flights observed in August and September is due to both marine mammal surveys and the larger quantity of commercial traffic related to the summer season on the North Slope.

Table 13. Oliktok Point Corridor Monthly Air Traffic Summary

Month	Flights Dwell Time	Flights with more than 1 Radar Hit Average Dwell Time per Flight	Average Flights per Day
July 2008	24 1:09:12	24 0:07:07	0.77
August 2008	61 8:18:29	58 0:02:53	1.87
September 2008	58 13:55:05	56 0:08:36	0.87
October 2008	28 2:32:08	27 0:05:38	0.87
November 2008	8 0:09:55	8 0:01:14	0.27
December 2008	9 0:39:52	9 0:04:26	0.29
January 2009	7 0:14:03	7 0:02:00	0.23
February 2009	2 0:00:36	2 0:00:18	0.07
March 2009	7 0:12:01	7 0:01:43	0.23
April 2009	10 0:52:06	10 0:05:13	0.33
May 2009	23 0:48:13	23 0:02:06	0.74
June 2009	17 0:34:31	17 0:02:02	0.57
Yearly Total	**255 29:26:11**	**248 0:07:07**	**0.68**

Figure 24 illustrates the September 2008 air traffic in the Oliktok Point corridor. Although there are a large number of flights in this area during this month, note that all of them avoid the 2 nm radius circle of potentially restricted airspace which surrounds the Oliktok Point launch area. There were only two observed instances, one in July 2008 and the other in May 2009, where flights transited through the potential 2 nm radius circle restricted area.

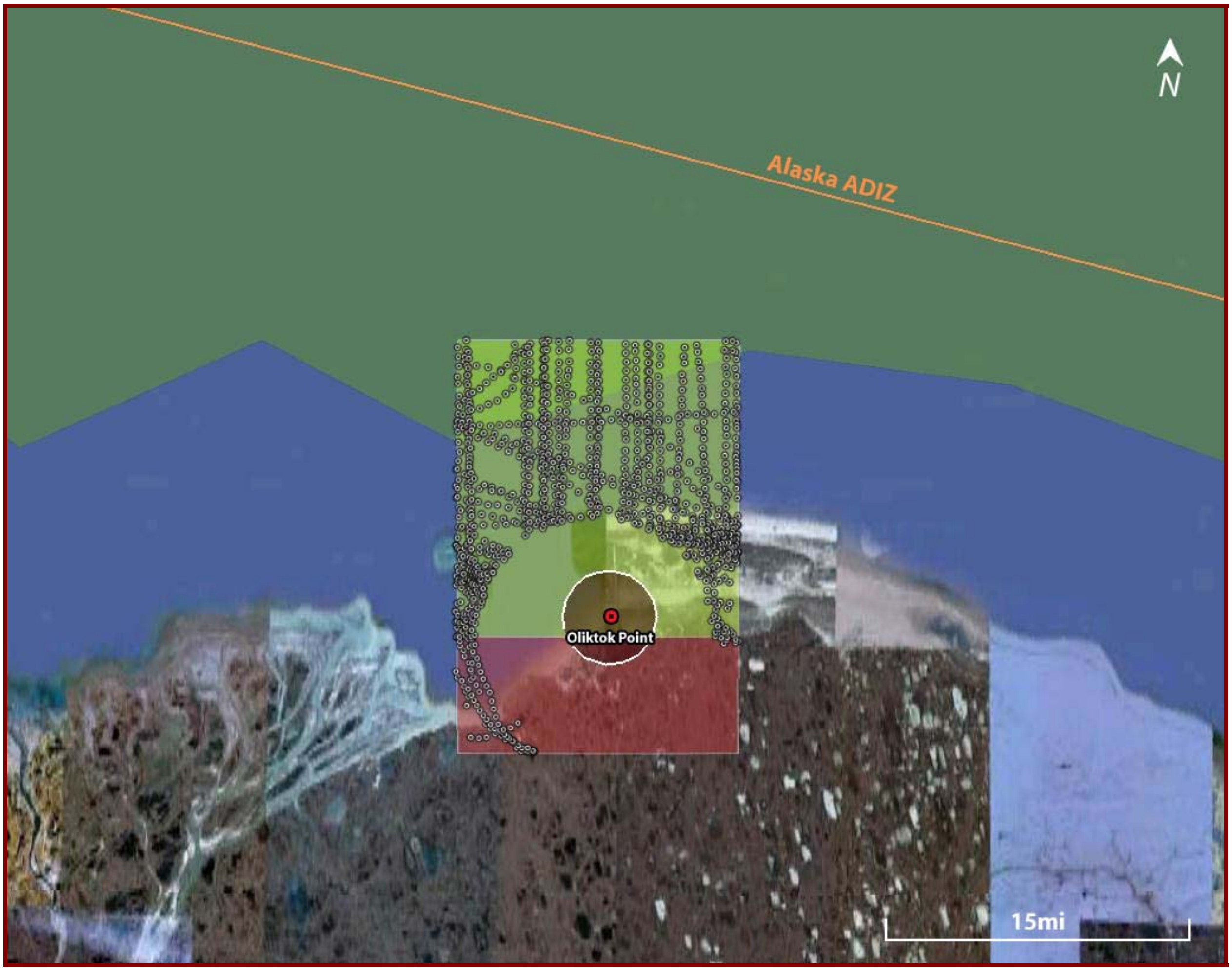


Figure 24. September 2008 Air Traffic in the Oliktok Point Corridor

Corridor Air Traffic Characterization

Based on the radar data analysis, the study team was able to determine where flights operated, what types of aircraft were common, and how much of the time throughout the year had air traffic.

Locations

The study team found that there are gaps in low-level radar coverage directly over the air field at Wainwright which prevented the radar data from containing low altitude information on the approaches and landings. However, as of the completion of this study, the commercial aircraft schedules indicated that there are only four incoming and four outgoing flights each day to the Wainwright airfield, and that they are each on the ground at Wainwright for less than 20 minutes.

The air traffic into and out of Wainwright airfield was very predictable over the course of the year, as was the larger pattern of transiting aircraft.

The entire Wainwright launch and recovery corridor fall within the Alaska ADIZ, ensuring that all civil aircraft operating in the region will have filed DVFR flight plans and be operating transponders, regardless of operating altitude. In addition, since most air traffic in both regions was transiting, many of the aircraft were operating in Class E controlled airspace above 1,200 ft MSL. Figure 25 illustrates the commercial air routes in the Wainwright corridor (blue lines), along which much of the air traffic was observed to be operating.

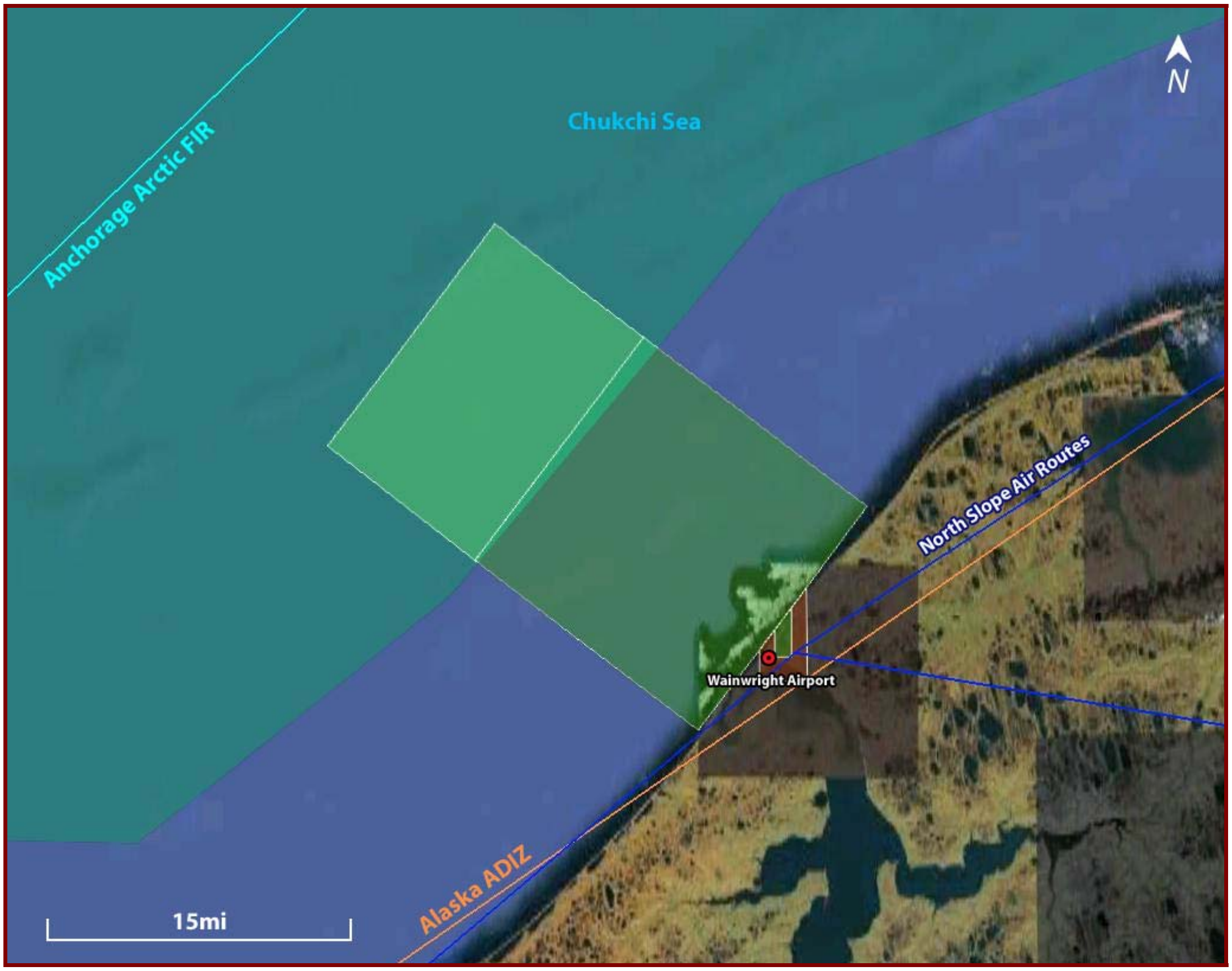


Figure 25. Commercial Air Routes near the Wainwright Launch and Recovery Corridor

There are no regularly scheduled operations at the Oliktok Point launch site. Unlike the Wainwright corridor, the Oliktok Point corridor does not fall within the ADIZ. However, the majority of civil air traffic operate in Class E controlled airspace above 1,200 ft MSL and avoids the identified restricted area centered over the air strip, even though it is rarely active. Figure 26 illustrates the commercial air routes in the Oliktok Point launch and recovery corridor.

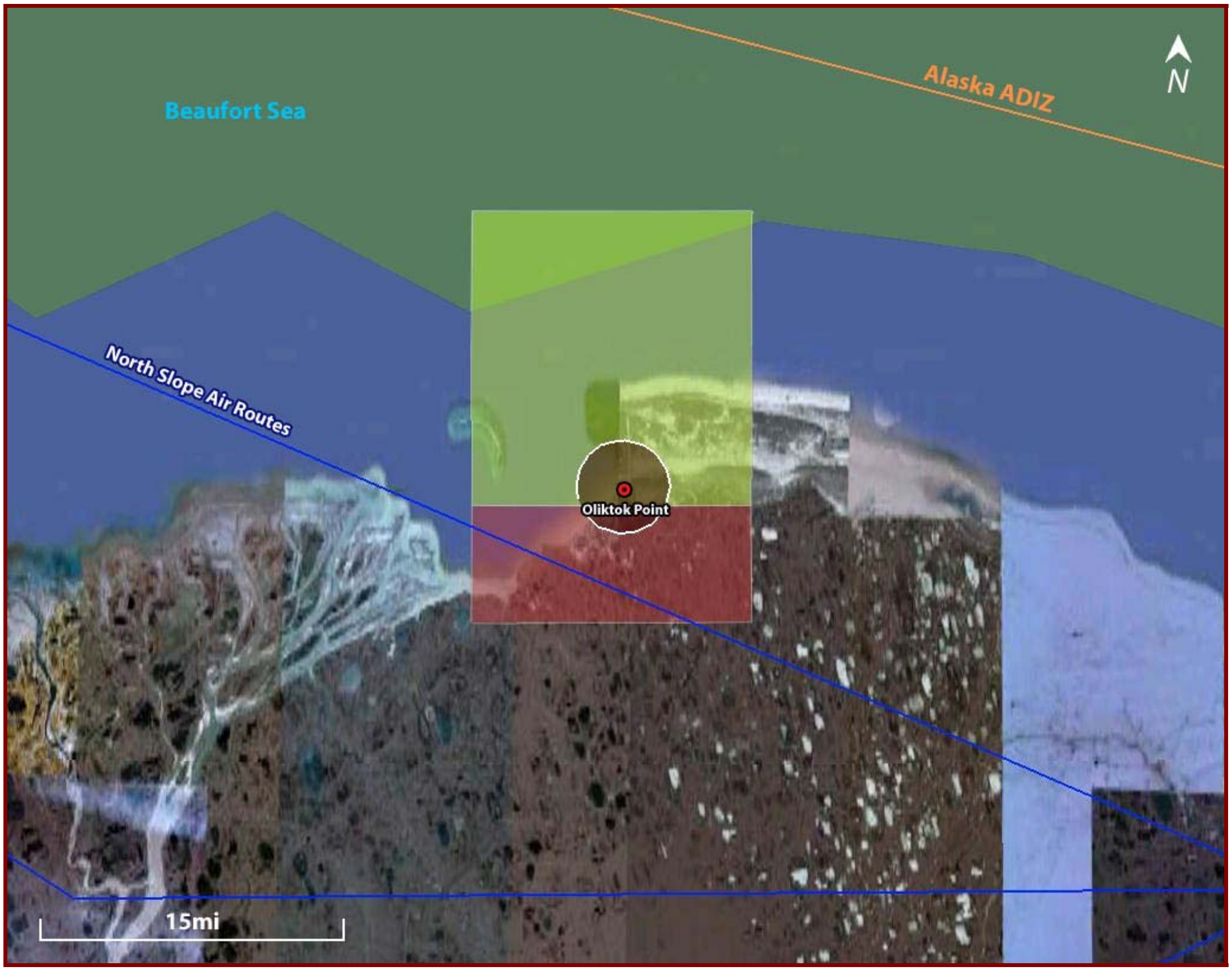


Figure 26. Commercial Air Routes near the Oliktok Point Corridor

Types of Aircraft

The aircraft operating in both the Wainwright and Oliktok Point launch and recovery corridors are interpreted to be the same as those identified in the larger oceanic operating areas. That is, the majority of air traffic is likely Twin Otters, followed by Cessnas, and only a few Boeing 737s.

Time

The average of the percentage of time with observed flights over 11 months in the Wainwright launch and recovery corridor was 0.04 percent, and the highest percentage of time with transiting aircraft observed was 0.23 percent in the month of August 2008 (1:39:20 out of 720 total hours). Similarly, the yearly average of time with flights observed in the Oliktok Point corridor was 0.34 percent, and the highest percentage of time was 1.93 percent in the month of September (13:55:05 out of 720 total hours). Table 14 summarizes the monthly dwell times and percentage of time the airspace was occupied for both corridors.

Table 14. Percentage of Time Airspace was Occupied in the Wainwright and Oliktok Point Corridors

Month (Total Hours)	Wainwright Corridor		Oliktok Point Corridor	
	Flights Dwell Time	% of Hours with Aircraft	Flights Dwell Time	% of Hours with Aircraft
July 2008 (744)	0:10:23	0.02	1:09:12	0.16
August 2008 (744)	1:39:20	0.23	8:18:29	1.15
September 2008 (720)	0:25:25	0.06	13:55:05	1.93
October 2008 (744)	0:13:14	0.03	2:32:08	0.34
November 2008 (720)	0:01:36	0.00	0:09:55	0.02
December 2008 (744)	0:20:58	0.05	0:39:52	0.09
January 2009 (744)	0:38:58	0.09	0:14:03	0.03
February 2009 (672)	0:04:59	0.01	0:00:36	0.00
March 2009 (744)	0:01:49	0.00	0:12:01	0.03
April 2009 (720)	0:02:48	0.01	0:52:06	0.12
May 2009 (744)	0:00:00	0.00	0:48:13	0.11
June 2008 (720)	No data	No data	0:34:31	0.08
Yearly Total (8760)	**03:39:30**	**0.04**	**29:26:11**	**0.34**

Risk Analysis

The combined risk analysis is based on the calculated P(MAC) between the unmanned aircraft and manned aircraft within the oceanic operating areas as well as the launch and recovery areas. It also includes the risk of surface casualties in the event of a catastrophic UA failure within the launch and recovery corridors.

The following risk analyses are specific to the A-20 UA as both the P(MAC) and probability of surface casualty calculations are specifically tied to the size and cruise speed of the UA. If a different UA is proposed, these analyses can be updated for any other UA by applying the methodology and airspace characterization results found within this study. This methodology can also be applied to include any aircraft that is currently or will be operating within the North Slope region as well.

Oceanic Operating Regions

For the vast majority of the year for which the study team analyzed the air traffic information, there were no aircraft operating in the oceanic operating areas. However, during most of the 2.2 percent of the year with aircraft in the Chukchi Sea, and the 2.9 percent of the time in the Beaufort Sea, there was only one aircraft operating at a time. In general, most of the aircraft in the area were interpreted to be Twin Otters, based upon the commercial air traffic information and speed distribution. If a UA was operating near a Twin Otter (within 48 nm of each other and below 10,000 ft MSL) during the small percentage of the year in which there was air traffic observed, the P(MAC) was calculated to be 2.2×10^{-7}, or 2.2 collisions per ten million UA operating hours. This falls within the “Remote” likelihood rating of the FAA risk assessment matrix.

The worst case P(MAC) calculated for the operating areas occurred when there were three Twin Otters operating simultaneously in the region. In this rare instance, which would likely occur only if the UA was operating near the Barrow approach or takeoff path, the P(MAC) was calculated to be 6.6 x 10^{-7}, or 6.6 collisions per ten million operating hours. This also falls within the "Remote" likelihood rating of the FAA risk assessment matrix.

Based upon the airspace occupation analysis that provided the percentage of each month during which aircraft were operating, the study team also calculated the average P(MAC) for each month within the Beaufort and Chukchi Seas. Approximately 60 percent of the overall flights in either region were classified as Twin Otters, so this monthly P(MAC) calculation is based on the presence of one Twin Otter. Table 15 summarizes the P(MAC) in the oceanic operating regions. The yellow and green shading correlate with the FAA risk matrix colors representing "Remote" and "Extremely Remote" likelihoods of a Hazardous severity event, respectively.

Table 15. Monthly P(MAC) in the Chukchi Sea and Beaufort Sea Operating Regions

Month (Total Hours)	Chukchi Sea		Beaufort Sea	
	% of Hours with Aircraft	Average P(MAC) (1 Twin Otter)	% of Hours with Aircraft	Average P(MAC) (1 Twin Otter)
July 2008 (744)	2.76	6.09 x 10^{-9}	0.84	1.85 x 10^{-9}
August 2008 (744)	3.52	7.77 x 10^{-9}	1.42	3.13 x 10^{-9}
September 2008 (720)	3.24	7.15 x 10^{-9}	0.78	1.72 x 10^{-9}
October 2008 (744)	0.37	8.17 x 10^{-10}	0.18	3.97 x 10^{-10}
November 2008 (720)	0.43	9.49 x 10^{-10}	0.34	7.51 x 10^{-10}
December 2008 (744)	0.22	4.86 x 10^{-10}	0.25	5.52 x 10^{-10}
January 2009 (744)	0.28	6.18 x 10^{-10}	0.26	5.74 x 10^{-10}
February 2009 (672)	0.25	5.52 x 10^{-10}	0.26	5.74 x 10^{-10}
March 2009 (744)	2.26	4.99 x 10^{-9}	2.22	4.90 x 10^{-9}
April 2009 (720)	1.83	4.04 x 10^{-9}	1.33	2.94 x 10^{-9}
May 2009 (744)	0.29	6.40 x 10^{-9}	1.71	3.77 x 10^{-9}
June 2008 (720)			0.30	6.62 x 10^{-10}
Yearly Total (8760)	1.30	2.87 x 10^{-9}	**0.83**	**1.43 x 10^{-9}**

Because there is no population located within the boundaries of the Chukchi and Beaufort Sea operating regions, the risk of surface casualties is effectively zero.

Launch and Recovery Corridors

For the vast majority of the year for which the study team analyzed the air traffic information, there were no aircraft operating in either corridor. However, during most of the 0.04 percent of the year with aircraft in the Wainwright corridor, and the 0.34 percent of the time in the Oliktok Point corridor, there was only one aircraft operating at a time. As in the larger oceanic operating areas, most of the aircraft in the area were interpreted to be Twin Otters, based upon the commercial air traffic information and speed distribution. If a UA was operating near a Twin Otter (within 48 nm of each other and below 10,000 ft MSL) during the small percentage of the year in which there was air traffic observed, the P(MAC) was calculated to be 2.21 x 10^{-7}, or 2.21 collisions per ten million UA operating hours. This falls within the “Remote” likelihood rating of the FAA risk assessment matrix.

Based upon the airspace occupation analysis that provided the percentage of each month during which aircraft were operating, the study team also calculated the average P(MAC) for each month within the Beaufort and Chukchi Seas. Approximately 60 percent of the overall flights in either region were classified as Twin Otters, so this monthly P(MAC) calculation is based on the presence of 1 Twin Otter. Table 16 summarizes the P(MAC) in the corridors. The yellow and green shading correlate with the FAA risk matrix colors representing “Remote” and “Extremely Remote” likelihoods of a Hazardous severity event.

Table 16. Monthly P(MAC) in the Wainwright and Oliktok Point Launch and Recovery Corridors

Month (Total hours)	**Wainwright corridor**		**Oliktok Point corridor**	
	% of hours with aircraft	**Average P(MAC) (1 Twin Otter)**	**% of hours with aircraft**	**Average P(MAC) (1 Twin Otter)**
July 2008 (744)	0.02	4.41 x 10^{-11}	0.16	3.53 x 10^{-10}
August 2008 (744)	0.23	5.08 x 10^{-10}	1.15	2.54 x 10^{-9}
September 2008 (720)	0.06	1.32 x 10^{-10}	1.93	4.26 x 10^{-9}
October 2008 (744)	0.03	6.62 x 10^{-11}	0.34	7.51 x 10^{-10}
November 2008 (720)	0.00	0	0.02	4.41 x 10^{-11}
December 2008 (744)	0.05	1.10 x 10^{-10}	0.09	1.99 x 10^{-10}
January 2009 (744)	0.09	1.99 x 10^{-10}	0.03	6.62 x 10^{-11}
February 2009 (672)	0.01	2.21 x 10^{-11}	0.00	0
March 2009 (744)	0.00	0	0.03	6.62 x 10^{-11}
April 2009 (720)	0.01	2.21 x 10^{-11}	0.12	2.65 x 10^{-10}
May 2009 (744)	0.00	0	0.11	2.43 x 10^{-10}
June 2008 (720)	No data	No data	0.08	1.77 x 10^{-10}
Yearly Total (8760)	**0.04**	**8.83 x 10^{-11}**	**0.34**	**7.51 x 10^{-10}**

The only concern regarding the potential risk of surface casualties in either corridor was determined to be during launch and recovery near the town of Wainwright. Based upon the most recent information available, the town of Wainwright has a very low population density of approximately 31 people per square mile. Based upon the size of the A-20 UA, and an arbitrary estimation of 75 operating hours between catastrophic failures resulting in a crash, the resulting risk of surface casualties was calculated at 3 x 10^{-13}, or 3 casualties per 10 trillion operating hours. This is many order of magnitude smaller than the calculated P(MAC), so the study team determined that the risk of surface casualties was so small as to be negligible. In addition, the boundaries of the launch and recovery corridor were chosen to avoid the settled area of the town of Wainwright, further decreasing the potential risk of surface casualties. There are no permanent settlements near Oliktok Point, so the effective risk of surface casualties there is zero.

Conclusions

Based on a year's worth of credible radar data collected by NORAD, the study team determined that the percentage of time throughout the year in which there were transiting aircraft operating in the Beaufort and Chukchi Seas was less than 3 percent. Based on the conservative midair collision risk analysis methodology used during this study, the study team determined the risk of midair collision between a UA and a manned transiting aircraft. Throughout the operating regions, the calculated P(MAC) fell within the Remote probability category of the FAA risk matrix if both the UA and manned aircraft were collocated for an entire hour. Based on the percentage of time that aircraft were observed in the operating regions, average P(MAC) values were calculated that ranged from 7.7 collisions in one billion UA operating hours to as low as 2.21 in 100 billion operating hours. These P(MAC) values assume that both the UA and aircraft operators are unaware of the presence of the other craft and there is no mitigation strategy in place by the UA operating team. The probability of midair collision in the real world may be reduced below the calculated values through the use of mitigation strategies. Standard UA operating procedures provide risk mitigation. In addition, based upon the overall analysis of the air traffic history, P(MAC), and risk of surface casualties, the study team identified a number of simple risk mitigation strategies that, if employed during UA flights, would reduce the remaining risks of the UA operations. There are risk mitigation strategies specific to each operating region, as well as overall strategies that could be applied to every UA mission.

Current Procedures

Several standard UA operating procedures serve to mitigate the identified risks of operating an UA in civil airspace, including:

- Lost link planning (the UA loses contact with its ground station), recovery planning and standard operating procedures are documented in the CoA.
- During recovery of the UA (whether land- or ship-based), if the initial Skyhook capture opportunity fails, procedures are in place for a UA fly around for multiple attempts. This procedure is part of recovery planning and is documented in the CoA.
- To support low-altitude launch and recovery operations, the UA mission planners verify that the communications link between the UA and one or more ground stations is sufficient to guarantee control during the low altitude launch and recovery process (electronic line of sight).

Additional Risk Mitigation Strategies

In addition to the standard UA operating procedures already in common usage that serve to mitigate UA operating risk, the study team identified additional risk mitigation strategies. These fell into three categories; general strategies that can be used regardless of the operating region, strategies specific to the oceanic operating areas, and strategies specific to the land-based launch and recovery corridors.

General Findings

The general mitigation strategies identified by the study team, regardless of region of operation, are:

- UA flight planning procedures must ensure coordination with Barrow-based ATC personnel before, during, and after flights.
    - Notify ATC of the planned operating area, times, and other NOTAM information.
    - If UA operations will take place in the ADIZ, information on DVFR flights in the region should be requested by the UA flight planners and operators.
    - During the flight, there must be one operator at the UA ground station who maintains the line of communication with Barrow ATC.
- UA flight planning procedures must also ensure coordination with any manned marine mammal surveys such as COMIDA, BWASP, or BOWFEST operating in the region to ensure deconfliction and communication procedures.
- UA flight planning procedures should include verification of commercial flight routes in the area as well as the specific schedules for those flights to provide separation in time from transiting aircraft.
- When available, land- or ship-based air search radar should be utilized to provide additional situational awareness within the UA operating region, especially if using the land-based corridors for launch and recovery.
- UA flights should operate below 1,200 ft to operate solely within Class G airspace and to provide vertical separation below transiting aircraft.
- UA flights should avoid commonly used air traffic routes if possible to provide lateral separation from transiting aircraft.

Oceanic Findings

In addition to the general risk mitigation strategies recommended above, the study team identified several additional risk mitigation strategies applicable within the Chukchi Sea and Beaufort Sea operating regions.

- Within the larger Chukchi Sea operating area (outside of the Wainwright corridor), UA mission planning should ensure that UA operating areas are planned to avoid the common paths of transiting aircraft through the region to provide lateral, as well as vertical, separation from the civil aircraft operating in the region. These areas are circled in Figure 27:
    - The northern approach to the Barrow airport
    - The area between Barrow and Wainwright where a straight line path between the two airports passes through the operating region
    - The area between Wainwright and Cape Lisburne where the flight route passes through the operating region

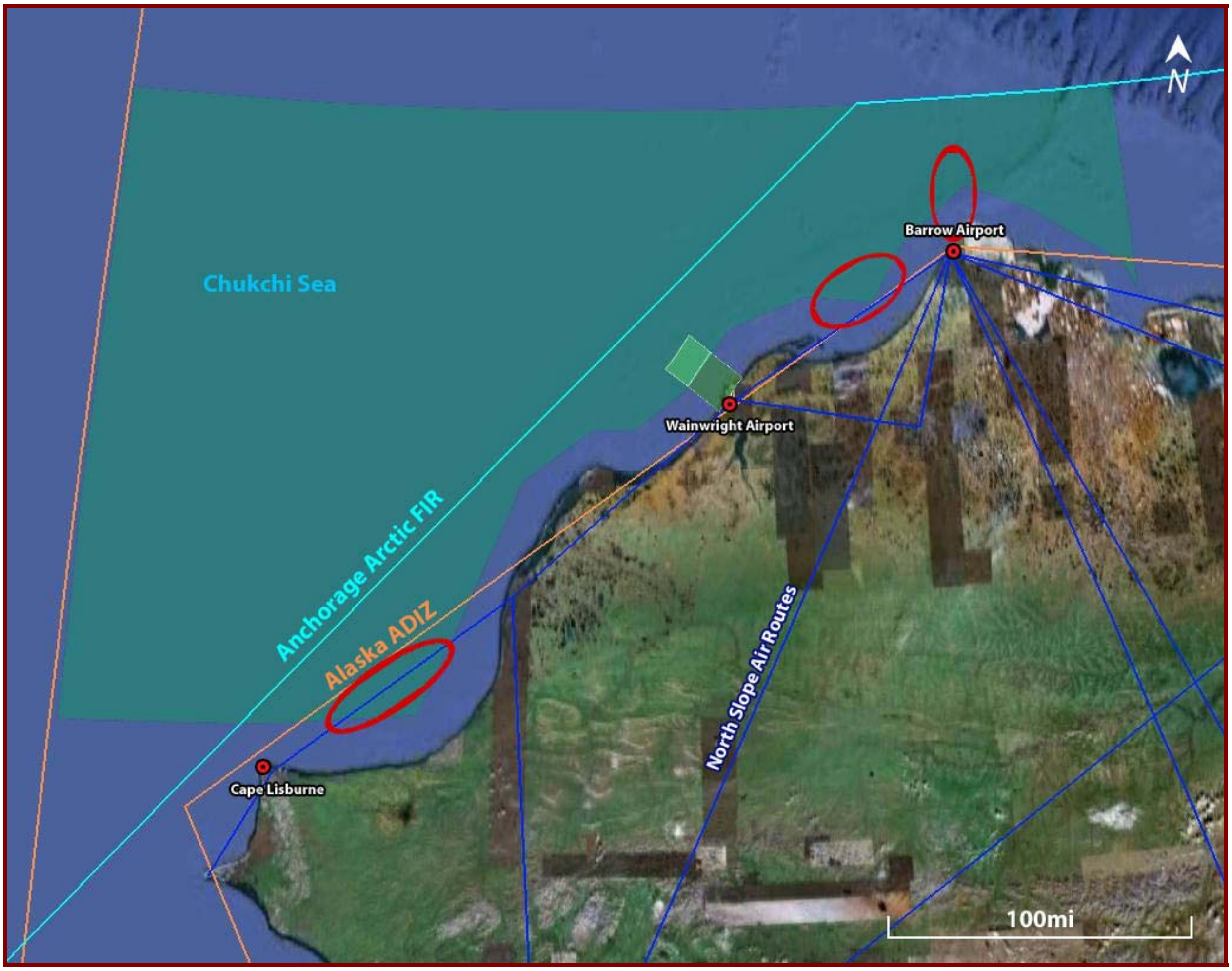


Figure 27. Chukchi Sea Areas to be Avoided for Risk Mitigation

Within the Beaufort Sea operating area, UA mission planning should ensure that UA operating areas are planned to avoid the common paths of transiting aircraft through the region to provide lateral, as well as vertical, separation from the civil aircraft operating in the region. The area circled in red , Figure 28 shows a direct flight route used between Barter Island and Barrow just south of the ADIZ boundary that is not indicated by North Slope Air Routes and thus should be avoided.

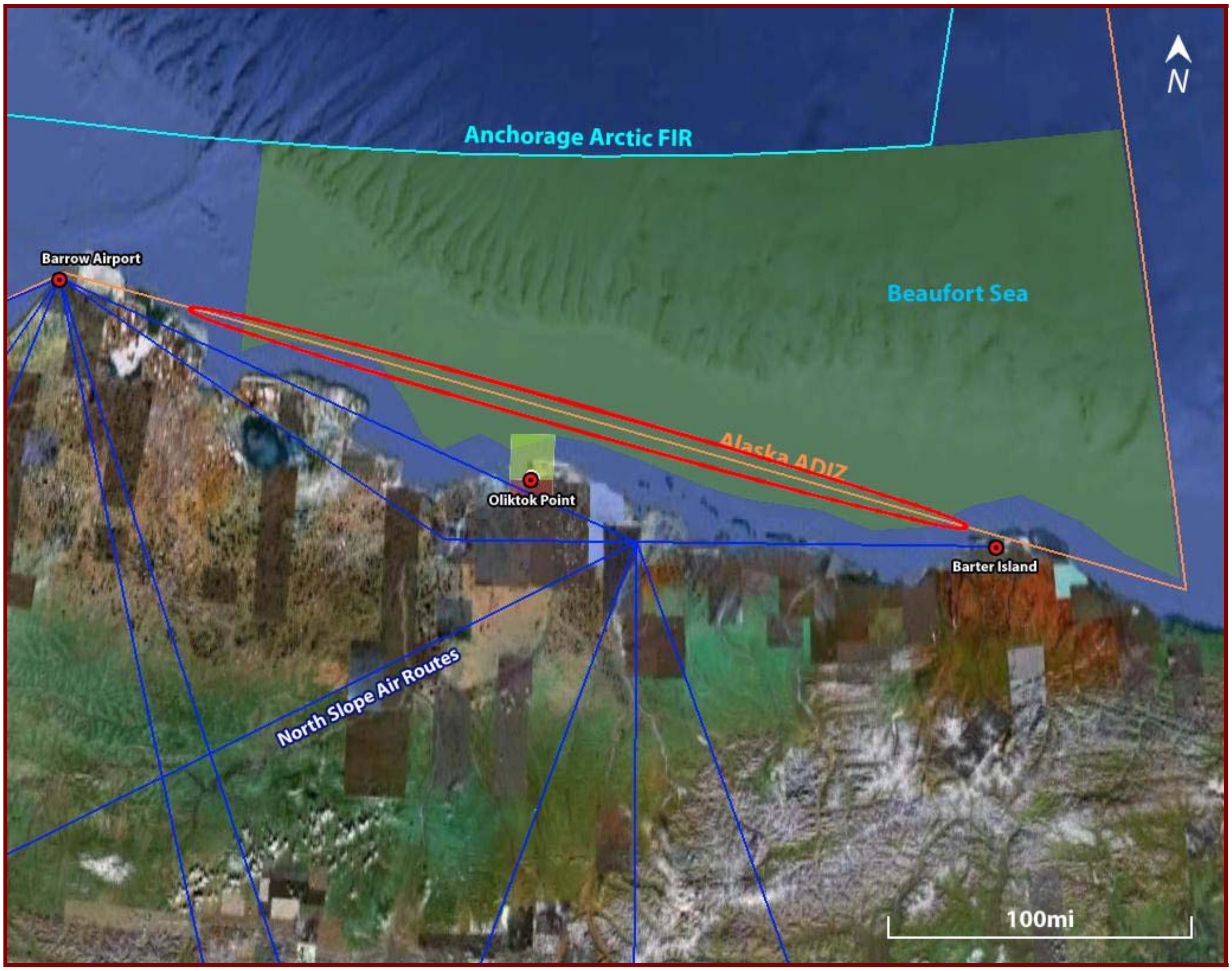


Figure 28. Beaufort Sea Areas to be Avoided for Risk Mitigation

Launch and Recovery Corridor Findings

In addition to the general risk mitigation strategies recommended above, the study team identified several additional risk mitigation strategies applicable within the Beaufort Sea and Oliktok Point corridor operating regions.

- When the UA is launched from within the identified corridors and flies out to sea to be controlled by a ship-based ground station, it is recommended that the UA should transit to oceanic airspace no higher than 200 ft MSL until the 12 nautical mile oceanic airspace boundary is reached to provide vertical separation below all civil aircraft potentially operating in the region. The same altitude should be used for land-based recovery. Low altitudes provide additional flexibility in maintaining visual flight rules under cloud cover for launch and recovery processes.
- Prior to finalizing UA mission plans, the UA operating team should verify the Wainwright airport commercial flight schedule (to and from Barrow and Cape Lisburne) flying into and out of Wainwright. As of the completion of this study, the commercial aircraft schedules indicated that there are 4 incoming and 4 outgoing flights each day, and that they are each on the ground at Wainwright for less than 20 minutes. UA planning, including launch, recovery,

and contingency planning, should take into account these flight schedules so as to minimize the impact of UA operations on the regional civil air traffic.

- If available, ground-based portable radar coverage (such as that provided by the University of Alaska which is discussed further in Appendix E) should be employed to provide supplemental air radar coverage for launch and recovery on the runway at Wainwright or from the airstrip at Oliktok Point.
- At Wainwright, the UA flight path for launch and recovery should avoid flying over populated areas including buildings, and should be restricted to a narrow 2 nautical mile wide flight corridor. The notional Wainwright corridor area used for this air traffic study would satisfy this risk mitigation strategy.
- At Oliktok Point, UA flight planning procedures must ensure coordination with the DOE Oliktok Point airspace manager to ensure deconfliction and communication procedures regarding DOE use of the restricted airspace at Oliktok Point.

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Appendix A: References

Acronyms

ADIZ	Air Defense Identification Zone
ATC	air traffic control
BOWFEST	Bowhead Whale Feeding Ecology Study
BWASP	Bowhead Whale Aerial Survey Project
CFR	Code of Federal Regulations
CoA	certificate of authorization
COMIDA	Chukchi Sea Offshore Monitoring in Drilling Area
DoD	Department of Defense
DVFR	defense visual flight rules
FAA	Federal Aviation Administration
FIR	flight information region
ft	feet
ICAO	International Civil Aviation Organization
IFR	instrument flight rules
LA	lethal area
MSL	mean sea level
N	north
nm	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NORAD	North American Aerospace Defense Command
NOTAM	Notice to Airmen
P(MAC)	probability of a midair collision
SAIC	Science Applications International Corporation
SMS	Safety Management System
UA	unmanned aircraft
US	United States
VFR	visual flight rule
W	west
km	kilometer
R-2204	Restricted Airspace Area 2204
Min	minute
RADES	

Terms

Acceptable Risk: (1) The portion of identified risk that is allowed to persist without further controls. It is accepted by the appropriate decision maker.[7] (2) A predetermined criterion or standard for a maximum risk ceiling that permits the evaluation of cost, national priority interests, and number of tests to be conducted.[8]

Restricted Area: From the FAA Aeronautical Information Manual, Section 4: Special Use Airspace: Restricted areas contain airspace identified by an area on the surface of the earth within which the flight of aircraft, while not wholly prohibited, is subject to restrictions. Activities within these areas must be confined because of their nature or limitations imposed upon aircraft operations that are not a part of those activities or both. Restricted areas denote the existence of unusual, often invisible, hazards to aircraft such as artillery firing, aerial gunnery, or guided missiles. Penetration of restricted areas without authorization from the using or controlling agency may be extremely hazardous to the aircraft and its occupants. Restricted areas are published in the Federal Register and constitute 14 Code of Federal Regulation (CFR) Part 73.

Risk of Surface Casualties: Sometimes referred to as "Casualty Expectation." The collective risk to an exposed population; that is, the total number of individuals who may become fatalities in the case of a crash. This approach to estimating casualty expectation uses the vehicle crash rate, vehicle size, and local population density. Casualty expectation is a cumulative calculation; therefore, it must be calculated for each segment of the flight path and summed over the entire flight. The general equations that are used to calculate casualty expectation are included in the Definitions section of this appendix.

Unmanned Aircraft: UA refers to the aircraft itself and in all cases wherein the term aircraft might apply.

Unmanned Aircraft System: UA system refers to the entire system comprised of the ground and/or shipboard elements and aircraft.

Definitions

ICAO Oceanic Airspace Characterization

Oceanic airspace is defined as airspace over the oceans of the world, considered international airspace, where oceanic separation and procedures per the ICAO are applied.[9] Responsibility for the provisions of ATC service in this airspace is delegated to various countries, based generally upon geographic proximity and the availability of the required resources. The majority of the world's oceanic airspace has been divided into several dozen flight information regions, each assigned to a country, to facilitate air traffic management in oceanic airspace.

- Any operation that is conducted in international oceanic airspace on an IFR flight plan, a VFR controlled flight plan, or at night, and is continued beyond the published range of

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[7] Air Force Pamphlet 91-214

[8] Range Commanders Council Standard 321-00

[9] A: ICAO DOC 4444, Section 15.2 Special Procedures for In-Flight Contingencies in Oceanic Airspace
B: FAA Airspace Docket No. 00-AWA-3 RIN 2130-AA66 Designation of Oceanic Airspace
C: FAA Oceanic and Offshore Services, http://www.faa.gov/aua/oceanicatc/index.cfm

normal airways navigation facilities (non-directional beacon, very high frequency omni-directional radio range/distance measuring equipment), is considered to be a long-range Class II navigation operation. Long-range Class II navigation in controlled airspace requires the aircraft to be navigated within the degree of accuracy required for ATC, meaning that the aircraft must follow the centerline of the assigned route and maintain the assigned altitude and the speed filed or assigned. Accurate navigational performance is required to support the separation minima that ATC units apply.

- 14 CFR Part 91.1(b) requires that civil aircraft must comply with ICAO Annex 2 when operating over the high seas. Annex 2 requires that “aircraft shall be equipped with suitable instruments and with navigation equipment appropriate to the route being flown.” In addition, ICAO, Annex 6, Part II stipulates that an airplane operated in international airspace be provided with navigation equipment, which will enable it to proceed in accordance with the flight plan and with the requirements of air traffic services. This means that the navigation equipment, installed and approved, should be capable of providing the pilot with the ability to navigate the aircraft with sufficient accuracy.
- ICAO establishes standards and recommended practices governing international air traffic services. Recognizing the requirement for consistency between various nations’ ATC service requirements, each nation exercises its own prerogative in establishing times, geographic limits, and altitudes regarding the management of the FIR(s) it has been delegated responsibility thereof.

FAA Severity and Likelihood Definitions

Definitions approved by the FAA System Engineering Council for severity and likelihood of occurrence for all events throughout the lifecycle of the technology are shown in Tables A-1 and A-2.

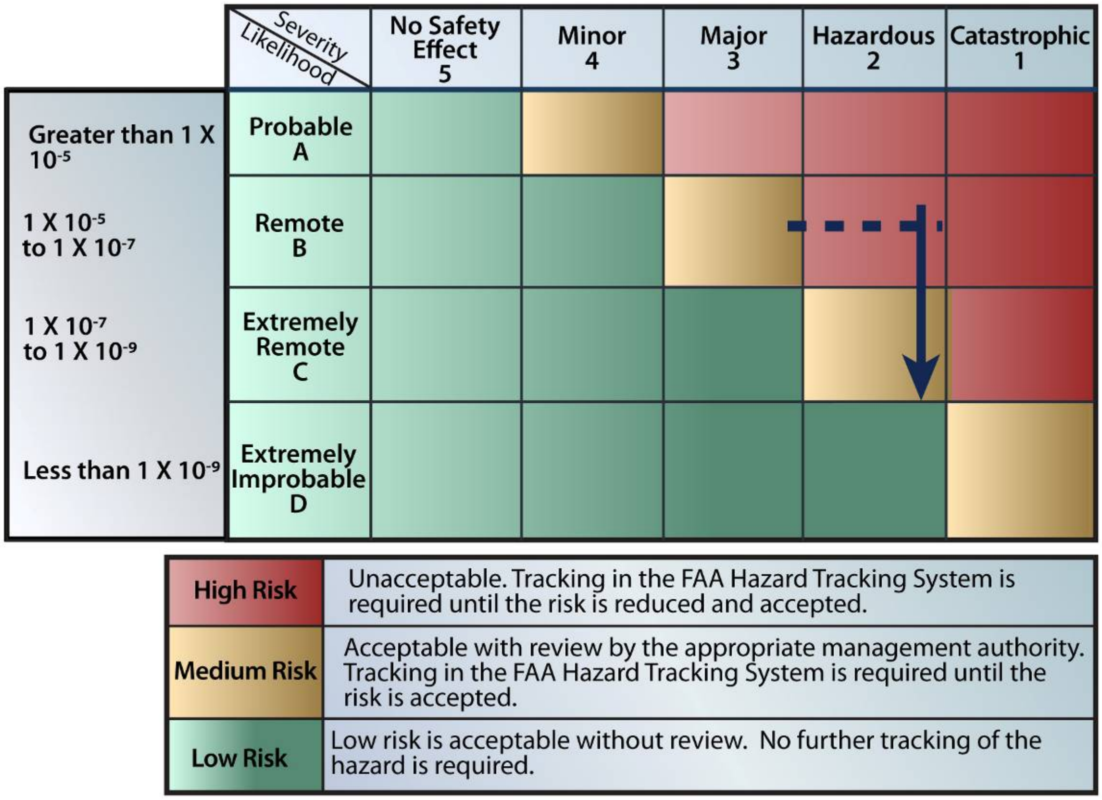
Table A-1. Severity Definitions

Level of Severity	Definition
No Safety Effect	Has no effect on safety
Minor	Does not significantly reduce system safety. Actions required by operators are well within their abilities. Conditions may include the following: • Slight reduction in safety margin or functional capabilities • Slight increase in workload, such as routing flight plan changes • Some physical discomfort to occupants of aircraft (except operators) Minor occupational illness and/or minor environmental damage and/or minor property damage
Major	Reduces the capability of the system or the operator's ability to cope with adverse operating conditions to the extent that the following would occur: • Significant reduction in safety margin or functional capability • Significant increase in operator workload • Conditions impairing operator efficiency or creating significant discomfort • Physical distress to occupants of aircraft (except operator), including injuries • Major occupational illness and/or major environmental damage and/or major property damage
Hazardous	Reduces the capability of the system or the operator's ability to cope with adverse operating conditions to the extent that the following would occur: • Large reduction in safety margin or functional capability • Crew physical distress/excessive workload, such that operators cannot be relied upon to perform required tasks accurately or completely • Serious or fatal injury to small number of occupants of aircraft (except operators) • Fatal injury to ground personnel and/or general public
Catastrophic	Results in multiple fatalities and/or loss of the system

Table A-2. Likelihood of Occurrence Definitions

Level of Likelihood	Definition
Probable	Qualitative: Anticipated to occur one or more times during the entire system/operational life of an item Quantitative: Probability of occurrence per operational hour is greater than 1×10^{-5}
Remote	Qualitative: Unlikely to occur to each item during its total life. May occur several times in the life of an entire system or fleet Quantitative: Probability of occurrence per operational hour is less than 1×10^{-5} but greater than 1×10^{-7}
Extremely Remote	Qualitative: 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 Quantitative: Probability of occurrence per operational hour is less than 1×10^{-7} but greater than 1×10^{-9}
Extremely Improbable	Qualitative: So unlikely that it is not anticipated to occur during the entire operational life of an entire system or fleet Quantitative: Probability of occurrence per operational hour is less than 1×10^{-9}

Figure A-1 shows the severity and likelihood chart developed by the FAA and used by the study team to determine the overall rating of an expected incident. Red indicates high risk (to be avoided), yellow indicates medium risk (there are risks present that need to be mitigated), and green indicates low risk (operations are within the safety parameters). Catastrophic severity does not apply to UA situations because there are no onboard operators or passengers. Therefore, for the purposes of this study, the hazardous column was used as there will never be loss of life from a UA-only incident, although there is risk to ground personnel if the UA incident occurs near populated surface areas. The blue arrow indicates the intended efforts of mitigation to decrease a calculated likelihood through the use of mitigation. The blue dotted line represents the stated DoD threshold of one incident per million flight hours (1×10^{-6}).



	Severity / Likelihood	No Safety Effect 5	Minor 4	Major 3	Hazardous 2	Catastrophic 1
Greater than 1 X 10^{-5}	Probable A	🟩	🟨	🟥	🟥	🟥
1 X 10^{-5} to 1 X 10^{-7}	Remote B	🟩	🟩	🟨	🟥	🟥
1 X 10^{-7} to 1 X 10^{-9}	Extremely Remote C	🟩	🟩	🟩	🟨	🟥
Less than 1 X 10^{-9}	Extremely Improbable D	🟩	🟩	🟩	🟩	🟨

🟥 High Risk	Unacceptable. Tracking in the FAA Hazard Tracking System is required until the risk is reduced and accepted.
🟨 Medium Risk	Acceptable with review by the appropriate management authority. Tracking in the FAA Hazard Tracking System is required until the risk is accepted.
🟩 Low Risk	Low risk is acceptable without review. No further tracking of the hazard is required.

Figure A-1. FAA Risk Assessment Matrix

Documents Referenced

- 2009 (Draft dated March 2009), Unmanned Aerial Surveys (Chapter 8), in Joint Monitoring Program in Chukchi and Beaufort Seas, Open Water Season, 2006 – 2008, Prepared by LGL Ltd., Greeneridge Sciences, and Jasco Research for the National Marine Fisheries Service and US Fish and Wildlife Service.
- The Supplement to Range Commanders Council Standard 321-00, "Common Risk Criteria for National Test Ranges: Inert Debris,"
- Air Force Pamphlet 91-214
- Range Commanders Council Standard 321-00
- A: ICAO DOC 4444, Section 15.2 Special Procedures for In-Flight Contingencies in Oceanic Airspace
- B: FAA Airspace Docket No. 00-AWA-3 RIN 2130-AA66 Designation of Oceanic Airspace
- C: FAA Oceanic and Offshore Services, http://www.faa.gov/aua/oceanicatc/index.cfm
- FAA System Safety Handbook, May 2008

1. One or multiple primary surveillance radar sites,
2. Transponder equipped aircraft collected through a modified TCAS unit residing on the ground,
3. Automatic Dependent Surveillance – Broadcast (ADS-B) equipped aircraft,
4. Published data feeds from local air traffic control, and
5. Custom messages from cooperative aircraft including unmanned aircraft cursor-on-target messages.

In addition to stationary installation, the system can also be installed on a moving platform such as a ship or truck. An integrated attitude GPS system is designed that will allow the system to keep the data aligned regardless of the platform's location and orientation, thus maintaining geographical alignment on the moving platform.

On the display, the target information is portrayed on a background generated from a web-based map server. The web-based map server can reside online for maximum flexibility in providing background imagery or it can be on a local server at the operational site, allowing for operations when Internet connectivity is not available. Built into the display are operator choices on how to show the information from the various sources to help minimize operational confusion.

3.1 Primary Radar

The Portable Search and Target Acquisition Radar (PSTAR), manufactured by Lockheed Martin, is an early warning radar that provides directional orientation to aid air defense weapons systems in acquiring and engaging hostile aircraft. The military nomenclature for this radar is AN/PPQ-2. The units owned, operated, and tested by the University of Alaska are Generation 1 units. The system was designed for a wide range of environments and has detection capability for both fixed and rotary-wing targets. In product acceptance testing, the US Army verified the Lockheed Martin claims that the system successfully demonstrated effective operations in electronic-jamming environments. The unit is man-portable, tripod mounted surveillance and target acquisition radar. The radar is Pulse-Doppler and classifies based on Doppler returns to a maximum range of 20 km.

Figure 1. An AN/PPQ-2 PSTAR (Portable Search and Target Acquisition Radar) Generation 1 at Poker Flat Research Range Fairbanks Alaska

The AN/PPQ-2 PSTAR system is made up of five components:

1. **Transceiver.** The transceiver is monostatic with an integrated processor. Transceiver properties are described in Table 1. There is no specified limit to the number of targets

that the radar can track simultaneously however in testing it has successfully managed over 10 targets simultaneously with no noticeable effects.

Table 1. AN/PPQ-2 P-STAR Transceiver and Processor Properties.

Operating Frequency Range	L-Band (1.2 to 1.4 GHz)
Selectable Channels	19 channels in selectable 10 MHz increments
Peak Power	1 kW
Pulse Repetition Frequency (PRF)	5.55 to 6.25 kHz
Duty Factor	4.44% low PRF and 5.0% high PRF
Maximum Resolvable Range	20 km (10.8 nmi) for a moving target (skin track detection) 8 km (4.3 nmi) for a hovering helicopter (blade flash detection alone)
Minimum Resolvable Range (blanked area near the transceiver)	1.2 km (0.65 nmi)
Range Resolution	1.5 km (0.81 nmi)
Range accuracy	200 m (0.1 nmi)
Tunable Target Velocity Range	20 to 550 m/s (39 to 1,070 knots)
Resolvable Target Size	1 m^2 at 20 km range 0.5 m^2 at 17 km range
Detectable Altitude Range	Surface to 3,000 m (9,800 ft) specified Surface to 4,300 m (14,000 ft) successfully tested in Alaska
Operating Frequency Range	L-Band (1.2 to 1.4 GHz)
Selectable Channels	19 channels in selectable 10 MHz increments
Peak Power	1 kW
Pulse Repetition Frequency (PRF)	5.55 to 6.25 kHz
Duty Factor	4.44% low PRF and 5.0% high PRF
Ground Safety Hazard Area	10 ft radius around rotating antenna

2. **Antenna.** Properties are described in Table 2.

Table 2. AN/PPQ-2 P-STAR Antenna Properties.

Fiberglass radome	65 cm tall by 150 cm wide
3 dB beam pattern	28° vertical and 10.8° horizontal
Peak gain	19.5 dBi at 1.3 GHz
Sidelobe rejection	-35 dB average azimuth sidelobe

3. **Tripod.** The tripod houses leveling legs and is designed to support the antenna and transceiver. The tripod has an integrated rotary coupler that allows the antenna to rotate 360° and brings the RF signals down into the fixed reference frame for processing. The scan rate is 10 rpm (6 seconds per rotation) and has a built-in absolute encoder that is resolved in 3.8° increments.
4. **Control Interface Unit (CIU).** The CIU is the standard user interface for the AN/PPQ-2. It includes a display, a keypad for user input, and connections to both the transceiver for power and data and an output for data transmission to other equipment. Figure 2. shows the CIU with the data port connected into a laptop computer. The University of Alaska built an embedded system that taps the data port, converts the format, time codes the messages, and then

Figure 2. The CIU With Data Port Being Tapped By The Laptop Computer

transmits them to the server.

5. **Power Supply.** The AN/PPQ-2 operates off a 24 VDC 1.5 kW power supply. The University of Alaska has built an 110V AC power module that acts as an uninterruptable power supply (UPS) capable of running the radar unit for over 5 hours if AC power is lost.

3.2 Secondary Radar (Transponder Detection) System

A secondary radar or transponder detection system capable of interrogating transponder-equipped aircraft is an integral part of this ground based surveillance solution. This unit interrogates aircraft Mode A, C, and S transponders on 1030 MHz and listens to their response on 1090 MHz. This element provides greater surveillance range; out to 74 Km (40 nmi) (for Mode S replies) than the primary radar alone and increases overall system reliability by redundantly detecting transponder-equipped threats. The University of Alaska selected a "state-of-the-art" TCAS system from Aviation Communication and Surveillance Systems, LLC (ACSS) for this secondary target detection system.

The transponder detection system uses the ACSS TCAS 3000 processor as the transponder detector. The solid-state unit provides range, barometric altitude, and bearing for each tracked Mode C or Mode S transponder reply received. Mode A replies are also tracked for range and bearing.

Mounted externally, as if it were on an aircraft, is an aircraft TCAS directional antenna. Figure 3 shows this antenna and the directional pattern used in its azimuth detection algorithms. This antenna should be mounted to a circular ground plane on top of a building or tower at least 25 feet above the ground for best line-of-sight for traffic.

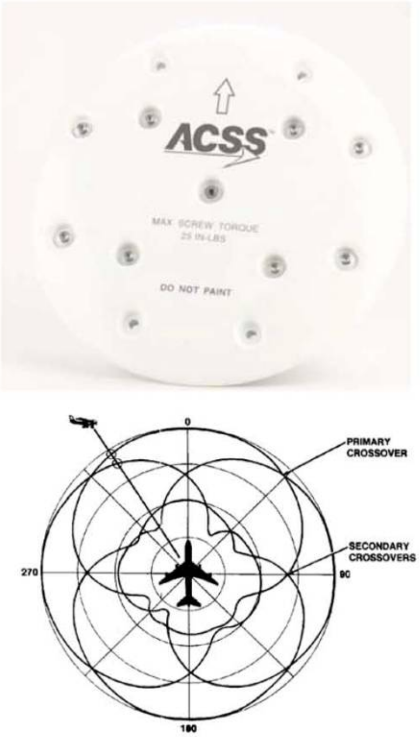


Figure 3. TCAS 3000 Antenna and Antenna Pattern

As with the primary radar, traffic data from the transponder detection system is reformatted and stored on the surveillance systems server.

Capabilities of the transponder detection system include:

- Track up to 70 aircraft simultaneously without any degradation in performance.
- Track aircraft at speeds up to 1,200 knots and 10,000 feet per minute vertical rate.
- Maximum range for Mode S traffic replies with nominal effective radiated transponder power exceeds 40 nmi.

- Bearing accuracy is greater than +/- 10 degrees for line of sight traffic with no significant multipath or diffraction effects.
- At the maximum detection range (20 nmi) for Mode C and Mode A transponders the link margins are 10 db.
- Slant range quantization and accuracy is better than 0.1 nmi under typical non-multipath conditions.
- Line of sight traffic are tracked on all 360° of azimuth. Because the antenna is vertically polarized there is a varying cone of silence directly overhead. Throughout this overhead cone any aircraft transponder emission that exceeds the link margin is detected.
- Relative altitude for each tracked airplane is the difference between the traffic reply barometric altitude, and the barometric altitude setup in the detection system. Absolute accuracy of the barometric altitude information is determined by the equipped traffic aircraft altimetry system.
- EMI with other L-Band equipment is minimized by limiting inactive state output power to -72 dBm.

3.3 Server and Display System

The server and display elements of the airspace surveillance system provide common information management, display, and further data analysis.

On the display, the target information is portrayed on a background generated from a web-based map server. The web-based map server can reside online for maximum flexibility in providing background imagery or it can be on a local server at the operational site, allowing for operations when Internet connectivity is not available. Built into the display are operator choices on how to show the information from the various sources.

The display of the data is independent of the source type as well as the source location. The display is based on a web-hosted graphical user interface (GUI) that can be displayed on any computer that can connect to the server and runs a web browser, either on a private network or the Internet as desired for the application. Any target detected is tracked automatically with a moving target indicator (MTI) symbology that shows the target location and the targets path history and projected direction of travel. The operator can configure the display to specify what map overlay (if any) to use from various web map server options including topographic maps, aviation charts, satellite imagery, or airborne

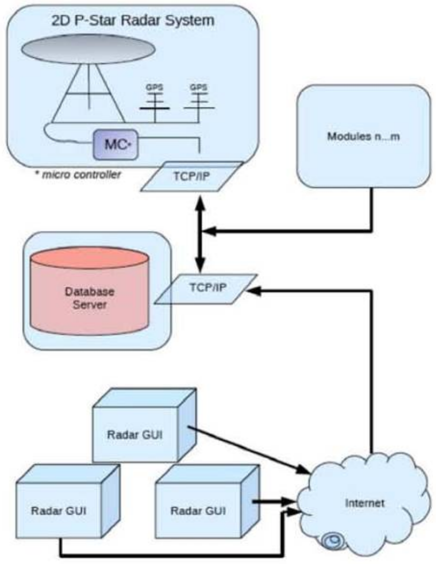


Figure 4. The Surveillance System Conceptual Design

imagery. The operator also configures what active discrete detection systems to monitor and what data feeds to display. Data feeds may include historical and real-time information from any of the collection sources. Figure 5 shows an initial conceptual display from early 2009. This image was generated to prototype the display client and shows the notional user interface and how the information from multiple sources could be overlaid on a single display. Figure 6 shows a screen shot of revision 1.0 of this display populated with the historical data collected while testing at NASA Ames Research Center on November 4, 2009.

4.4 Future Development

Planned further development of the airspace surveillance system includes the incorporation of:

- Available FAA data feeds. This is scheduled to begin in late spring 2010 following formal agreements with the FAA being completed.
- Transponder detection TCAS. The TCAS unit was ordered in December 2009 and is due in April 2010.
- The Cursor-on-Target message from an unmanned aircraft into the server.

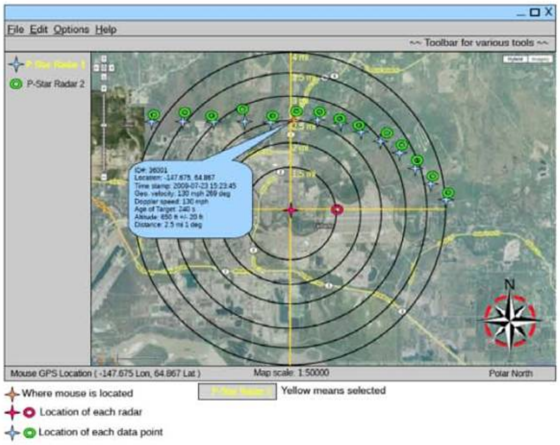


Figure 5. This image was generated to prototype the display client and shows the notional user interface and how the information from multiple sources could be overlaid on a single display.

Figure 6. Data collected on November 4, at NASA Ames. This image shows the display with two hours of data displayed simultaneously on an aerial image of the San Jose California area. This display is intended for studying traffic patterns whereas a real-time display showing less traffic would be selected for airspace monitoring.

4.0 System Testing Results

Testing at the University of Alaska Poker Flat Research Range began in March 2009. This testing consisted of (1) observing targets of opportunity and (2) flying various aircraft in defined patterns carrying a GPS receiver. Altitudes for the control tests were between 500 feet above the local terrain to up to 14,000 feet AGL. These flights included single engine aircraft; such as the Cessna 182 and a twin engine Piper Navaho. Smaller targets are needed to fully test the radar sensitivity. Targets of opportunity have included an even smaller aircraft, a Piper SuperCub. The

SuperCub was seen on the radar as any other aircraft and when it passed overhead it was verified by visual observations. Initial testing against the ScanEagle A-20 UAS has also occurred that indicates targets as small and as slow as a ScanEagle UAS can be detected, see Figure 7. The ScanEagle testing have shown the quantization limitations of the PSTAR radar and the effective ability to track aircraft that are flying very tight turns of less than 100 meters in radius. Figure 8 shows the full 20 km PSTAR detection area to put these tight maneuvers into perspective. Accuracy, when compared to GPS tracks for all control tests have been better than specifications for the radar.

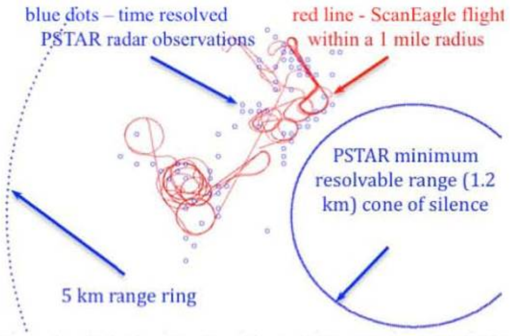


Figure 7. Detecting the ScanEagle UAS with the AN/PPQ-2 primary radar. The ScanEagle was flying at 500 to 600 feet above the radar installation at speeds between 48 and 60 knots (25 to 31 m/s).

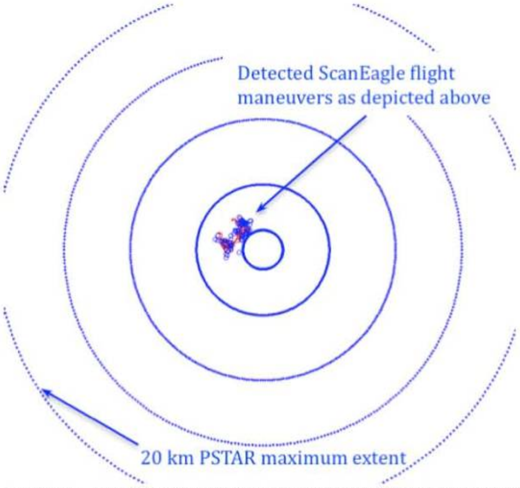


Figure 8. These ScanEagle maneuvers as viewed on the full AN/PPQ-2 radar coverage area.

Testing conducted at NASA Ames Research Center included placing the display alongside the terminal radar display used in their airports control tower. With the two displays aircraft were tracked enroute coming and going form San Jose International, NASA Ames, San Francisco International, and the Palo Alto regional airport. The NASA controller evaluating the system claims to have seen nothing on the certified FAA display scope that was not present on the University display within the limitation of the PSTAR range. In Figure 6 above shows that the 20 km range gate on the AN/PPQ-2 radar is a hard limit of the system regardless of the targets size as the resulting display shows a 20 km geographical circle around the site the radar was installed. As a result of this testing the NASA Wallops Flight Safety Office approved the use of the AN/PPQ-2 for airspace surveillance necessary for suborbital rocket launch operations within the National Airspace System (NAS). Changes in the display based on the air traffic controller's comments were incorporated and were evaluated by FAA researchers in March 2010 at Atlantic City.

Both the on-line web-based map server and the local server at the operational site have been tested and are operational.

Data collection for an airspace use study at the Atlantic City NJ airport, where the FAA's Science and Technology office is located began on March 25, 2010. In this effort 30 days of air traffic is being logged to look at use patterns and density in an effort to develop a safety case for operating unmanned aircraft in that airspace.

Testing of the transponder detection system is ongoing at ACSS and will begin in Alaska after it is integrated into the display system starting in April 2010.

5.0 Supporting Arctic Unmanned Aircraft Operations

Deploying the University of Alaska's portable ground based airspace surveillance system near the Alaskan Arctic coast would have several benefits to unmanned aircraft operation. Since today unmanned aircraft do not have on-board sense and avoid capability and there is a potential for civil aircraft to be present in the airspace, the unmanned aircraft operator needs to know where the civil aircraft are for airspace deconfliction. One possible mitigation solution would be to employ this ground based airspace surveillance system to provide that deconfliction. For operations over the ocean if setup on the shore the primary radar component would provide observations of any aircraft, with a reflective surface greater than 1 square meter surface area, that would be operating in the area out to 10.8 nmi (20 km maximum AN/PPQ-2 range). Combining this with the transponder detection component the system would have detection capability beyond the 12 nautical mile sovereign airspace boundary. Additionally, along the Arctic coastline in Alaska there is the North American Air Defense Identification Zone (ADIZ). In that area all aircraft operating must be transponder equipped. In situations where the ADIZ lies beyond 10.8 nm, the range of the primary radar component, a second ship-based primary radar could augment the surveillance system. To show how this varies along the North Slope three low population density sites that could support unmanned aircraft operations on the North Slope of Alaska are shown in Figure 9. Each of these sites poses a different situation for the airspace

Figure 9. Cape Lisburne, Wainwright, and Oliktok Point Alaska. Three potential low population density sites for unmanned aircraft operations off the North Slope of Alaska.

Figure 10. The ADIZ is approximately 6 nmi off the coast at Cape Lisburne Alaska.

Figure 11. The ADIZ is inland at Wainwright Alaska.

surveillance system. For example, at Cape Lisburne, Figure 10, the ADIZ lies approximately 6 miles from shore, within range of the primary radar AN/PPQ-2, at Wainwright, Figure 11, the ADIZ boundary actually lies inland, suggesting that only the transponder detection system would be required to see all aircraft. At Oliktok Point, Figure 12, the ADIZ is approximately 23 miles out to sea and would therefore require additional ship based assets to adequately cover the range to the sovereign airspace boundary.

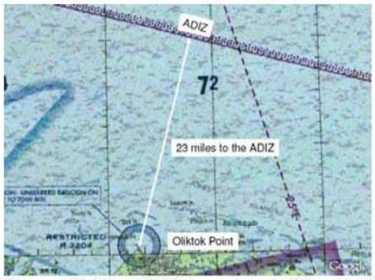


Figure 12. The ADIZ boundary is 23 nmi off the coast at Oliktok Point, Alaska

Placement of the primary radar near the unmanned aircraft operation is beneficial for several reasons. Although the radar cannot see targets in its cone of silence, seeing the unmanned aircraft near its launch and recovery point is not the purpose of the surveillance system. The interest is in detecting any threat approaching from outside the cone of silence, rather than detecting aircraft originating locally which will be managed with other means. Co-locating the airspace surveillance system and display for the surveillance system with the unmanned aircraft system is desirable for coordination between the pilot-in-command of the unmanned aircraft and the observer managing the surveillance system.

Operational use of the frequencies in the airspace surveillance system should not be impacted by operations over water for two reasons. First, the frequencies are sufficiently separated from the resonant frequencies of water (2.4 GHz), and secondly the incident angle for the transmissions is above the horizon and will consequently have little energy transmitted towards the water to create reflection. A significant benefit of observing over water is the absence of clutter or false targets that arise from moving features or complex reflective targets that are seen with operations over land topography.

Obtaining frequency authorization for AN/PPWQ-2 PSTAR radar units requires a frequency request authorization to be processed by the user of the radar with the FCC. The AN/PPQ-2 PSTAR has a DoD spectrum certification on-file (JF12/06990). This spectrum certification simplifies the application process as it provides assurance that the transmitter performs as specified. The transponder detection system on the other hand does not require site-specific frequency authorization. It was built FCC-compliant for the use and the spectrum where it transmits.

6.0 References

1. US Code
    - CFAR 99.13 Pertains To Air Defense Identification Zone (ADIZ) rules of operation.
    - CFAR 91.113 Pertains To An Aircraft Pilots Responsibility to See and Avoid
2. US Army Technical Manuals for AN/PPQ-2
   (National Stock Number, NSN, 1430-01-347-7673)
    - TM 9-1430-775-10 (Operator's Technical Manual, September 1993
    - TM 9-1430-775-20&P (Unit Maintenance Manual), September 1993

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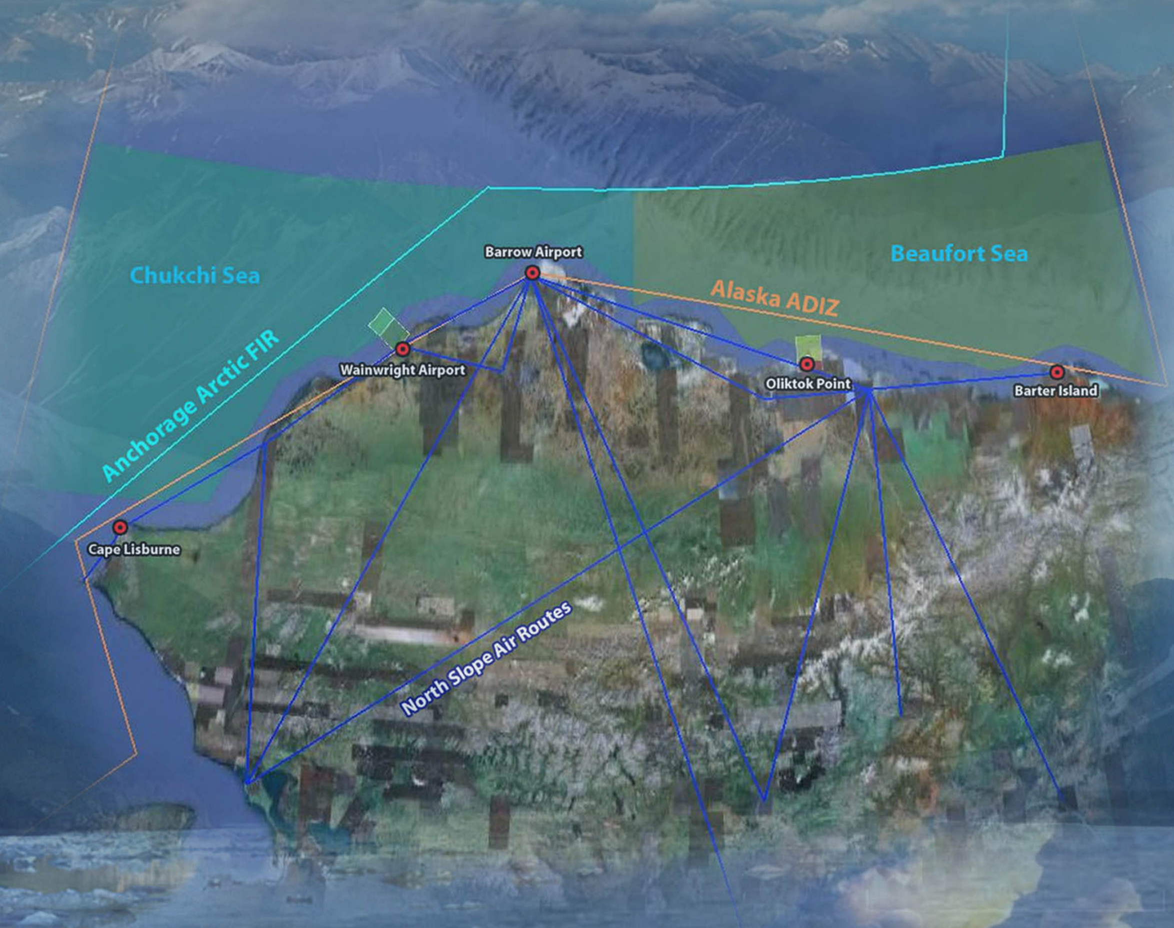
Chukchi Sea
Beaufort Sea
Barrow Airport
Alaska ADIZ
Anchorage Arctic FIR
Wainwright Airport
Oliktok Point
Barter Island
Cape Lisburne
North Slope Air Routes