RECORD OF ENVIRONMENTAL CONSIDERATION

PROJECT NAME: Operation Ice Bridge

1. Date and/or Duration of project: March 2010 - 2015

2. It has been determined that the above action (choose one)

_____ a. Is adequately covered in an existing EA or EIS.
Title: ____
Date: ________________________

__XX__ b. Qualifies for Categorical Exclusion and has no special circumstances which would suggest a need for an Environmental Assessment.
Categorical Exclusion: 14 CFR 1216.305 (d)(2) – Research and Development activities in space and terrestrial applications

_____ c. Is exempt from NEPA requirements under the provisions of:
____

_____ d. Has no significant environmental impacts as indicated by the results of an environmental checklist and/or detailed environmental analysis. (Attach checklist or analysis as applicable)

_____ e. Will require the preparation of an Environmental Assessment.

_____ f. Will require the preparation of an Environmental Impact Statement.

3. Description and location of proposed action:

Operation Ice Bridge is a data gap filler project between ICESat-1 (Ice, Cloud and Land Elevation Satellite 1) and ICESat-2 (Ice, Cloud and Land Elevation Satellite 2) that will not be launched until the 2015 time frame. The goals of Operation Ice Bridge are to study and monitor the changing areas of the Cryosphere including the Earth's ice sheets, sea ice and glaciers. Operation Ice Bridge will use airborne platforms to maintain altimetry time series and monitor important areas of land ice and sea ice until the launch of NASA's next satellite-lidar mission. Operation Ice Bridge will monitor the sea ice extent, snow cover on sea ice, ice sheet elevation, ice sheet near surface firn (snow which has persisted through one melt season), ice sheet mass balance and the bed topography of the ice sheet. The Ice Bridge science objective will be met by conducting two airborne campaigns per year, one over the Greenland ice sheet and surrounding areas and the second over the Antarctic Ice Sheet and surrounding areas.

Antarctica Campaign

The Antarctic DC-8 Ice Bridge Campaign will occur from approximately October 15 to November 30, 2010 with additional flights through 2015. The NASA DC-8 aircraft will be loaded with a complete instrument package to reach the science objectives for flights over the Greenland Ice Sheet and outlet glaciers. The instrument package will include laser altimeters, (the Airborne Topographic Mapper (ATM) and the Laser Vegetation Imaging System (LVIS) altimetry instruments), a suite of near surface and depth sounding radars (the University of Kansas' Center for Remote Sensing of Ice Sheets (CReSIS) radar suite that includes the snow radar, accumulation radar, Ku altimeter and the Multichannel Radar Depth Sounder (MCORDS) radar), a visible imaging system (the Digital Mapping System (DMS)) and a gravimeter (the AIRGrav system supplied by Lamont Doherty Earth Observatory (LDEO) of Columbia University). The NASA DC-8 aircraft will be based out of Punta Arenas, Chile.

Greenland Campaign

The Greenland 2010 Operation Ice Bridge campaign will consist of two phases. Phase 1 will occur from approximately March 22 to April 23, 2010. During phase 1 the NASA DC-8 aircraft will be loaded with a complete instrument package to reach the science objectives for flights over sea ice and the northern Greenland Ice Sheet. The instrument package will include 2 altimeters, (the Laser Vegetation Imaging Sensor (LVIS) and Airborne Topographic Mapper (ATM) altimetry instruments), a suite of near surface and depth sounding radars (the University of Kansas' Center for Remote Sensing of Ice Sheets (CReSIS) radar suite that includes the snow radar, accumulation radar, Ku altimeter and the Multichannel Radar Depth Sounder (MCORDS) radar), a visible imaging system (the digital mapping system (DMS)) and a gravimeter (the AIRGrav system supplied by Lamont Doherty Earth Observatory (LDEO)). During phase 1 the NASA DC-8 aircraft will be based out of Thule, Greenland, Fairbanks, Alaska and Keflavik, Iceland.

Phase 2 of the Operation Ice Bridge Greenland 2010 campaign will occur from approximately May 3 to May 28, 2010. During phase 2 the NASA P-3 aircraft will be loaded with a complete instrument package to reach the science objectives for flights over the Greenland Ice Sheet and outlet glaciers. The instrument package will include an altimeter, (the Airborne Topographic Mapper (ATM) altimetry instrument), a suite of near surface and depth sounding radars (the University of Kansas' Center for Remote Sensing of Ice Sheets (CReSIS) radar suite that includes the snow radar, accumulation radar, Ku altimeter and the Multichannel Radar Depth Sounder (MCORDS) radar), a visible imaging system (the Digital Mapping System (DMS)) and a gravimeter (the AIRGrav system supplied by Lamont Doherty Earth Observatory (LDEO) of Columbia University). During phase 2 the NASA P-3 aircraft will be based out of Kangerlussuaq and Thule, Greenland.

The campaigns will continue through 2015 timeframe until the launch of ICESat-2. Different aircraft platforms, such as the Global Hawk, and different instrument packages may be used for some of these campaigns.

The campaigns will implement measures to mitigate impacts from aircraft/laser operations, such as change and timing of flight paths, increase in flight altitudes over certain sensitive areas, laser operation restrictions, and FAA letter of non-objection or foreign equivalent, as needed.

Numerous environmental evaluations have been performed for the airborne science activities. These are hereby incorporated by reference into this document. They include:

(1) WFF Record of Environmental Consideration (REC) for the Laser Vegetation Imaging Sensor (LVIS) 2009 Greenland Ice Cloud and Land Elevation Satellite (ICESat) Gap Filler Field Campaign, March 20, 2009
(2) ARC Environmental Document and Finding of No Significant Impact and Not More than Minor or Transitory Environmental Impact, October 5,2009
(3) DFRC Record of Environmental Consideration DC-8 Operation Ice Bridge, Chile to Antarctica, September 8, 2009
(4) WFF Record of Environmental Consideration Arctic Campaign, April 19, 2007

Operation Ice Bridge has been evaluated in accordance with NASA's NEPA regulations and procedural requirements. Based on this review it is concluded that environmental impacts of Operation Ice Bridge would be minor and transient and would not be significant. As such the project qualifies as a Categorical Exclusion in accordance with 14 CFR 1216.305 (d)(2) – Research and Development activities in space and terrestrial applications. For the purposes of review under EO 12114, Environmental Effects Abroad of Major Federal Actions, Operation Ice Bridge is considered an action not having a significant effect on the environment outside the United States.

Beth Montgomery GSFC NEPA Program Manager, Code 250	4/20/2010 Date
Dan Morgan DFRC NEPA Program Manager, Code SH	4-20-10 Date
Kent Shiffer ARC Earth Science Project Office	4/20/10 Date

DFRC Record of Environmental Consideration	DFRC CONTROL NUMBER 09-12

INSTRUCTIONS: Section I to be completed by Proponent. Sections II and III to be completed by the Safety, Health & Environmental Office. Continue on page 2 or attach additional sheets as necessary and reference appropriate item number(s).

SECTION I - PROPONENT INFORMATION Start Date: 8/1/2009

1. TO:	2. FROM: (Proponent organization and functional address symbol)	2a. TELEPHONE NO.
Safety, Health, & Environmental Office Code SH	Code P	X3715

3. TITLE OF PROPOSED ACTION/START DATE
DC-8 Operation IceBridge, Chile to Antarctica

4. PURPOSE AND NEED FOR ACTION (Describe why you need to take this action.)
The purpose of the IceBridge mission is to collect airborne laser altimetry data of Earth Science observations over key targets on Antarctica and the surrounding waters. This data collection is needed to insure continuity of the cryospheric data set that is currently being acquired by the IceSAT satellite. Specific science objectives for the IceBridge mission are described in a white paper prepared by the NASA Airborne Science program (see attachment). The white paper discusses a variety of proposed missions in the Arctic and Antarctic with various aircraft; (continued on pg. 2)

5. DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES (DOPAA)(Provide sufficient details for evaluation of the total action.)
The DC-8 IceBridge mission would involve integration of a suite of science instruments, local checkout flights, and deployment to Chile for a series of science collection flights in the Antarctic. The primary instruments would include two laser topology mapping systems, several radar sounders, a gravimeter, and an instrument to measure in-situ carbon dioxide. The science payload would include lasers, compressed gases, and other various materials standard for a DC -8 science payload. These hazardous materials would be tracked (continued on pg. 2)

6. PROPONENT		6b. DATE
Robert Curry	[signature]	10/8/09

SECTION II - PRELIMINARY ENVIRONMENTAL ANALYSIS (Check appropriate box and describe potential environmental effects and mitigations.) (+ = positive effect; 0 = no effect; - = adverse effect; U = Unknown effect)	+	0	-	U
7. NOISE/LAND USE ZONE (Noise, accident potential, land use, etc.)			X	
8. AIR QUALITY (Emmissions, attainment status, conformity, etc.)			X	
9. WATER RESOURCES (Quality, quanity, source, etc.)		X		
10. SAFETY & OCCUPATIONAL HEALTH (Asbestos/radiation/chemical exposure, explosives, safe quantity-distance, etc			X	
11. HAZARDOUS MATERIALS/WASTE (Use/storage/generation/solid waste, etc.)			X	
12. BIOLOGICAL RESOURCES (Floodplains, flora, fauna, etc.)			X	
13. CULTURAL RESOURCES (Architectural ,historical, etc.)		X		
14. GEOLOGY & SOILS (Topography, Superfund Program, seismicity, etc.)		X		
15. SOCIOECONOMIC (Employment/population projections, school and local fiscal impacts, etc.)	X			
16. OTHER (Potential impacts not addressed above.)				

SECTION III - ENVIRONMENTAL ANALYSIS DETERMINATAION

17 [X] PROPOSED ACTION QUALIFIES FOR CATEGORICAL EXCLUSION (CATEX) Local Flights: 4.2.1.a.(3) ; OR
[X] PROPOSED ACTION DOES NOT QUALIFY FOR A CATEX; FURTHER ENVIRONMENTAL ANALYSIS IS REQUIRED.

18. SHE OFFICE CERTIFICATION	18a. SIGNATURE	18b. DATE
Dan Morgan	[signature]	10/8/09

DFRC 39 (Mar 02)

(continued from Section 4) Pg. 2 of 2, DFRC #09-12

however, the current mission specifically addresses the Antarctic mission requirements proposed for the DC-8.

(continued from Section 5)

and mitigated through standard project processes. Local checkout flights would be conducted from the Dryden Aircraft Operations Facility to locations just off the Pacific Coast. Checkout flights would begin in mid-August. The aircraft would deploy to Punta Arenas, Chile 13 October 2009. Science flights would then be conducted over the Antarctic continent. Specific targets of interest are discussed in the attached white paper. Flight activity is expected to include approximately 35 hours of local checkout flights and transits to and from Chile; and approximately 150 hours of science flights from Chile to the Antarctic (a total of about 25 take-off and landing cycles). Final determinations regarding flight times and flight paths would be dependent on funding limitations and other factors such as weather at the target and deployment sites. Three high-altitude land ice flights would be flown over Antarctica at altitudes of approximately 30,000 feet (ft.) above ground level (AGL). The other 12 flights would be at an altitude of approximately 1,500 ft. AGL, which is below the 2,000 ft. AGL considered to be the minimum altitude to avoid impact to penguin and seal colonies. However, since the instruments planned to be used would not be capable of collecting the needed data if flown above 1,500 ft. AGL, the project would take flight planning and mitigation maneuvers to minimize impacts to native bird and mammal species. . The environmental impacts associated with flying into the Antarctic region is included in the attached "Environmental Document and Finding of No Significant Impact and Not More Than Minor or Transitory Environmental Impact". The National Science Foundation (NSF) and one of the NSF environmental contractors assisted Ames Research Center in developing the intended flight paths to avoid the known breeding colonies. Upon observation of unforeseen breeding colonies, the aircraft altitude would be brought up to 3,281 ft. AGL (from 1,500 ft. AGL) until the colony is passed.

Alternative Considered: There would be no flights below 2,000 ft. AGL. This alternative was not suitable since the main science objectives would not be met.

IMPACT ANALYSIS AND PROJECT REQUIREMENTS:

The following impacts and mitigation measures are for the local flights:

NOISE: An increase in short-term, local noise levels produced by project activities (at ground level) would occur with varying intensity and duration. Noise impacts from this project would not be significant.

AIR QUALITY: A short-term degradation of air quality may occur during the proposed project. These emissions will be minor and are well below the de minimis thresholds for non-attainment areas; therefore, a formal conformity determination is not required. Vehicle emissions from additional personnel required for temporary duty are exempt under 40 CFR 51.853(c)(2)(vii) & (x) and were not evaluated. Air quality impacts from this project would not be significant. Equipment with an internal combustion engine over 50 bhp shall be registered with the California Statewide Portable Equipment Registration Program (PERP). Contact Jennifer Martin at extension 2909 if mission activities would require equipment other than items currently in the Dryden PERP inventory.

SAFETY AND OCCUPATIONAL HEALTH: All applicable laws, regulations, and standard procedures shall be followed for project activities. Hazard risk reduction actions contained in the Project Hazard Reports shall be implemented. Lasers shall be operated in accordance with the Laser Safety Plan as approved by the Dryden Laser Safety Officer (LSO). The LSO shall stipulate appropriate requirements. If sealed ionizing radiation sources are used they shall be handled in accordance with the Radiation Protection Plan, as approved by the Dryden Laser Safety Officer. If toxic gases are used they shall be handled in accordance with applicable guidelines contained in the Toxic Gas Installation and Ground Operations Safety Action Plan as approved by Code SH. For assistance contact John Platt of Code SH at extension 7576. Major noise sources on the flightline are from aircraft and helicopter operations, engine testing, and the operation of powered aircraft ground equipment (AGE). As such, workers along the flightline may be exposed to increased noise levels that may be above acceptable levels established by OSHA regulations. The contractor/proponent shall be responsible for implementing OSHA hearing protection measures for their employees.

HAZARDOUS MATERIALS/WASTE: Hazardous materials/waste shall be handled in accordance with applicable regulations. All hazardous materials used at Dryden shall be included in the DFRC Chemical Management System. For more detailed information contact Steve Fedor of Code SH at extension 7403. All spills or releases of hazardous materials or waste that occur during this project (regardless of quantity or location of spill) must be reported immediately to Steve Fedor, extension 7403 or Dale McCoy, extension 3630.

SOCIOECONOMIC: A minor positive impact to the local economy from the temporary stay of scientists and researchers would result from this project. CUMULATIVE IMPACT: This is a one-time project using aircraft and ground support operations within the existing mission of Dryden Flight Research Center. No specific follow-on actions have been determined at this time and no cumulative environmental impact is expected.

The impacts and mitigation measures for the flights between Chile and Antarctica are included in the attached "Environmental Document and Finding of No Significant Impact and Not More Than Minor or Transitory Environmental Impact".

CONCLUSION: Based on the above environmental impact analysis it is concluded that this is a categorically excluded action [NASA NPR 8580.1, paragraph 4.2.1.a.(3), Research and development activities in aeronautics and space technology and energy technology applications, other than experimental projects that have the potential for substantial environmental impacts] that does not substantially impact the human environment; therefore, neither an EA nor an EIS is required.

National Aeronautics and Space Administration
Earth Science Project Office
Ames Research Center (ARC)
Moffett Federal Airfield, Mountain View, California

**ENVIRONMENTAL DOCUMENT AND
FINDING OF NO SIGNIFICANT AND NOT MORE THAN
MINOR OR TRANSITORY ENVIRONMENTAL IMPACT**

Aircraft Over-flights of the Antarctic Sea Ice of the Weddell, Bellinghausen and Amundsen Seas and Land-Ice of the Antarctic Peninsula and the Thwaites, Pine Island and Abbot Glaciers

I. Finding

The National Aeronautics and Space Administration (NASA) has prepared an Initial Environmental Evaluation (IEE) and an Environmental Assessment (EA) as a combined environmental document for the Operation Ice Bridge (OIB) campaign over the Weddell, Bellingshausen and Amundsen Seas and the Thwaites, Pine Island and Abbot glaciers. Based on the analyses in the environmental document (IEE/EA), the NASA Office of the Earth Observing System/Earth Science Enterprise has determined that the implementation of OIB is not a major federal action that would have significant effect on the Antarctic marine environment, within the meaning of the National Environmental Policy Act (NEPA) of 1969. The action is also not one that would have more than a minor or transitory effect on the Antarctic environment, within the meaning of NASA's implementing regulation for the Protocol on Environmental Protection to the Antarctic Treaty. Therefore, an environmental impact statement and/or a comprehensive environmental evaluation will not be prepared.

The selected Alternative B provides for the means to achieve the scientific goal of OIB while protecting the well being of native birds and marine mammals as well as the state of the Antarctic environment.

Thomas Wagner
Cryosphere Program Manager
NASA Headquarters

10/05/2009
Date

II. Purpose and Need for the Proposed Action

The Ice, Cloud and land Elevation Satellite (ICESat I) was launched on January 12th, 2003, for a 3-5 year mission, by the Cryospheric Sciences Branch at Goddard Space Flight Center (GSFC). The satellite is the benchmark Earth Observing System (EOS) mission for measuring ice sheet mass balance, cloud and aerosol heights as well as land topography and vegetation characteristics. ICESat I is currently past its mission lifespan, running on extremely low power and may soon expire. ICESat II is scheduled for launch in the 2014-2015 time frame. The time gap between the end of ICESat I and the launch of ICESat II creates a critical data gap in laser observations of the changes of ice sheets, glaciers and sea ice, which will be filled in part by the Operation Ice Bridge (OIB) Mission described below. For the ice sheets and glaciers, the ICESat I laser acquires critical ice thickness data that allows determination of the properties of the rapidly changing ice streams. For the sea ice, the laser measures ice freeboard, from which ice thickness can be inferred.

OIB will employ aircraft resources, with a suite of instruments, to acquire essential data that will allow for continuous monitoring of ice thicknesses in the most sensitive and critical areas of the sea ice, ice sheets and glaciers. The most sensitive and critical areas include coastal Antarctica, the Antarctic Peninsula and sub-glacial lakes and certain fast moving glaciers in Antarctica's interior. The aircraft resource to be used for the Western Antarctica segment of OIB is a NASA DC-8. The suite of instruments includes OIB's highest priority instrument, the NASA Airborne Topographic Mapper (ATM), the NASA Laser Vegetation Imaging Sensor (LVIS), The University of Kansas' (KU) Center for Remote Sensing of Ice Sheets (CReSIS) Multichannel Coherent Radar Depth Sounder/Imager (MCoRDS II), Snow Radar and Ku-band radar, Columbia University's Lamont-Doherty Earth Observatory Gravimeter, the NASA Atmospheric Vertical Observations of CO_2 in the Earth's Troposphere (AVOCET), the NASA Diode Laser Hygrometer (DHL), the NASA Differential Absorption CO Measurement (DACOM) and the University of California, Irvine, Whole Air Sampler (WAS). All of these systems gather their data through passive means and, as such, have no direct impact on the environment. The ATM acquires data through the use of a scanning Light Detection and Ranging (LIDAR), Global Positioning System (GPS) receivers and Inertial Navigation System (INS) sensors. The LVIS is a scanning laser altimeter that also includes data from integrated GPS and INS systems. The MCoRDS II is a system that measures radar reflectivity through ice and determines ice thickness, ice internal layer maps and underlying bed maps. The Snow Radar measures snow thickness over sea and land ice. The Ku-band radar measures altitude, surface backscatter and depth profiles in snow and ice. The Gravimeter measures spatial changes in the gravity field.

A total of 15 flights over Antarctica, from October 15, 2009 through November 21, are currently scheduled. The flights are organized into three categories: High altitude land ice, low altitude land and sea ice. Each flight will depart from Punta Arenas, Chile, fly pre-defined flight lines over Antarctica, then return to Punta Arenas. The pre-defined flight lines consist predominantly of flight lines that are coincident with either ICESat tracks or flight lines that have been flown previously with the ATM instrument. It is essential that these ICESat tracks and previously flown ATM flight lines be duplicated. The ATM data is used to determine changes, from previous measurements, in ice thickness. If the ATM is not flown over tracks and flight lines for which previous data exists the continuity of the ice thickness measurements in the most sensitive and critical parts of Antarctica will be lost. Once over Antarctica, flights will occur over the Thwaites, Pine Island and Abbot glaciers to acquire land-ice data and over the Weddell, Bellingshausen and Amundsen Seas, to acquire sea-ice data. Flights will also occur over Recovery, Foundation, Willans/Mercer and MacAyeal Lakes. The 15 flights are each currently scheduled for 11-hour durations. The beginning of the typical flight profile calls for transit from Punta Arenas to near the Antarctic Peninsula at a speed of 440 knots and an altitude of 30,000 ft Above Ground Level (AGL). The three high-altitude land ice flights are designed specifically for LVIS data acquisition and will be flown over the Antarctica continent at altitudes of approximately 30,000 ft AGL. The other 12 are designed specifically for ATM and Ku-Band radar data acquisition and will be flown at altitudes of approximately 1,500 ft AGL over both land and sea ice. The transition from transit to data acquisition flight will require the aircraft to slow to a speed of approximately 250 knots and descend to an altitude of 1,500 ft AGL. The aircraft will fly at 1,500 ft AGL for the duration of the data acquisition. This flight altitude is below that set forth in "Resolution 2 (2004) – ATCM ATCM XXVII – CEP VII, Capetown", which states: "Penguin, albatross and other bird colonies are not to be over-flown below 2000ft (~ 610 m) Above Ground Level, except when operationally necessary for scientific purposes." The 1,500 ft AGL altitude is operationally necessary for OIB's highest priority instrument, the ATM and Ku-Band radar. The ATM lasers have insufficient power to acquire data, of the required accuracy, at higher altitudes and thus must be used at an altitude of 1500' AGL. The Ku-Band radar has been optimized for operation at an altitude of 1500' AGL for this mission so it can acquire the highest accuracy data possible at the optimum ATM operating altitude.

The issue that this document concerns is the environmental impact on the native birds and mammals that these flights may have. October is the beginning of the formation of breeding colonies of Antarctic birds. The impact of low flying aircraft on the fauna of the region has been a major concern, especially during the last few decades in which the operation frequency of such aircraft has been on the rise. Of primary concern is the apparent impact to penguin and seal colonies. Such low altitude flights over colonies are known to cause panic, disrupt breeding and cause the loss of penguin eggs.

III. Alternatives

Alternative A: No flights below 2000 feet (~ 610m)

Alternative A would involve no flights lower than 2000 feet. As a result, the main science objectives of OIB would not be met.

Alternative B: Inclusion of carefully planned low altitude flights.

The science requirements for the sea-ice and land-ice data require flights at 1500 feet (~ 457m) AGL. As the next section describes, the impact to native birds and mammals will be minimized by flight planning and mitigating maneuvers.

IV. Environmental Effects and Mitigating Measures

A. There would be no environmental effect on birds and mammals with Alternative A.

B. The environmental effects on birds and mammals with Alternative B will be minimized through the following measures:

Flight Planning
With assistance from the National Science Foundation and one of their contractors, Environmental Research and Assessment, intended flight lines have been drawn and superimposed with the locations of known breeding wildlife colonies (See Map 1, Appendix A). In addition the project has acquired the "Wildlife Awareness Manual, Antarctic Peninsula, South Shetland Islands, South Orkney Islands". The flight lines and their proximity to the known breeding wildlife colonies will be reviewed by the flight crew prior to take-off as will the Wildlife Awareness Manual. Flight lines for high altitude land ice flights will have no impact on breeding colonies as the aircraft will be at approximately 30,000 feet AGL. Flight lines for low altitude sea and land ice flights that pass over locations of known colonies will observe the minimum 3281 feet (1000m) buffer, as prescribed by the SCAR Bird Biology Sub-group recommendation for four engine aircraft separation distances from bird colonies. This altitude change from the data acquisition altitude of 1500 feet AGL to 3281 feet AGL will be incorporated into the flight lines that traverse the known breeding colony locations. Currently there are only two areas of potential conflict; Madder Cliffs on Joinville Island and Eden Glacier on the Antarctic Peninsula (See Maps 2 and 3, Appendix A).

Aircraft Observations and Mitigating Maneuvers
After the aircraft is in the air and as Antarctica is approached and over-flown, the flight crew will maintain a look-out for birds and mammals on the ground. Upon observation of unforeseen breeding colonies the aircraft altitude will be brought up to 3281 until the colony is passed. Realizing that the flight crew's primary responsibility is the safety of the aircraft and that flying a four engine aircraft the size of the DC-8 at 1500 ft. AGL demands a high degree of attentiveness the flight crew will assume this extra duty and carry it out to the best of their ability. This flight protocol for Operation Ice Bridge project will satisfy the guidelines of The Antarctic Conservation Act of 1978.

C. Neither Alternative A nor Alternative B is expected to cause long term or cumulative effects. Alternative B has been designed to avoid any harmful interference to native birds and mammals while still satisfying the science requirements of OIB.

V. Consultation With Others

Polly Penhale ppenhale@nsf.org 703-292-7420
National Science Foundation
Environmental Officer
Office of Polar Programs

Colin Harris colin.harris@era.gs 44(0)1223 277 842
Environmental Research & Assessment
5 Wellbrook Court
Girton Road
Cambridge
United Kingdom CB3 0NA

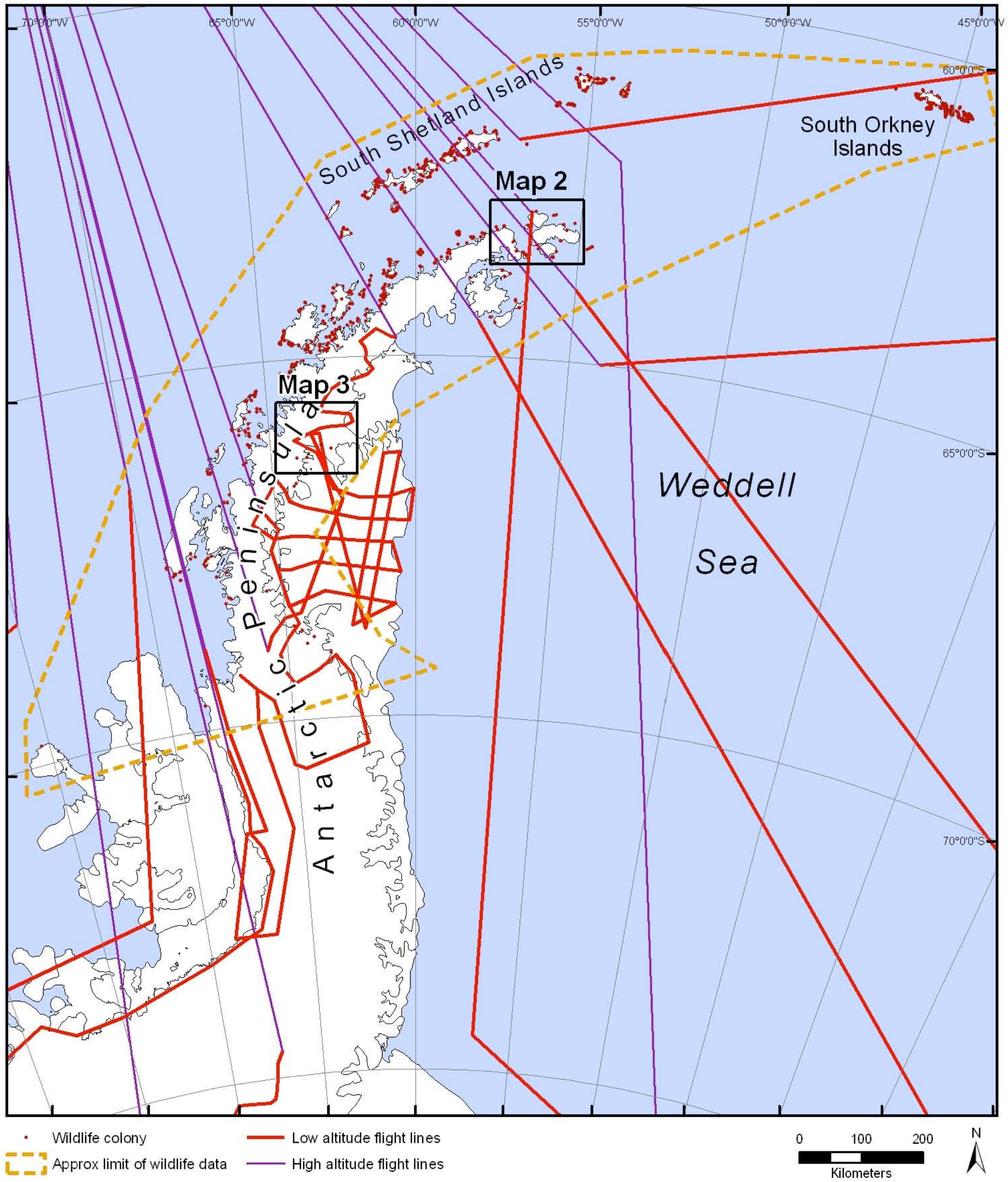
VI. References

Antarctic Conservation Act of 1978 as amended by the Antarctic Science, Tourism, and Conservation Act of 1996 (Public Law 104-227)

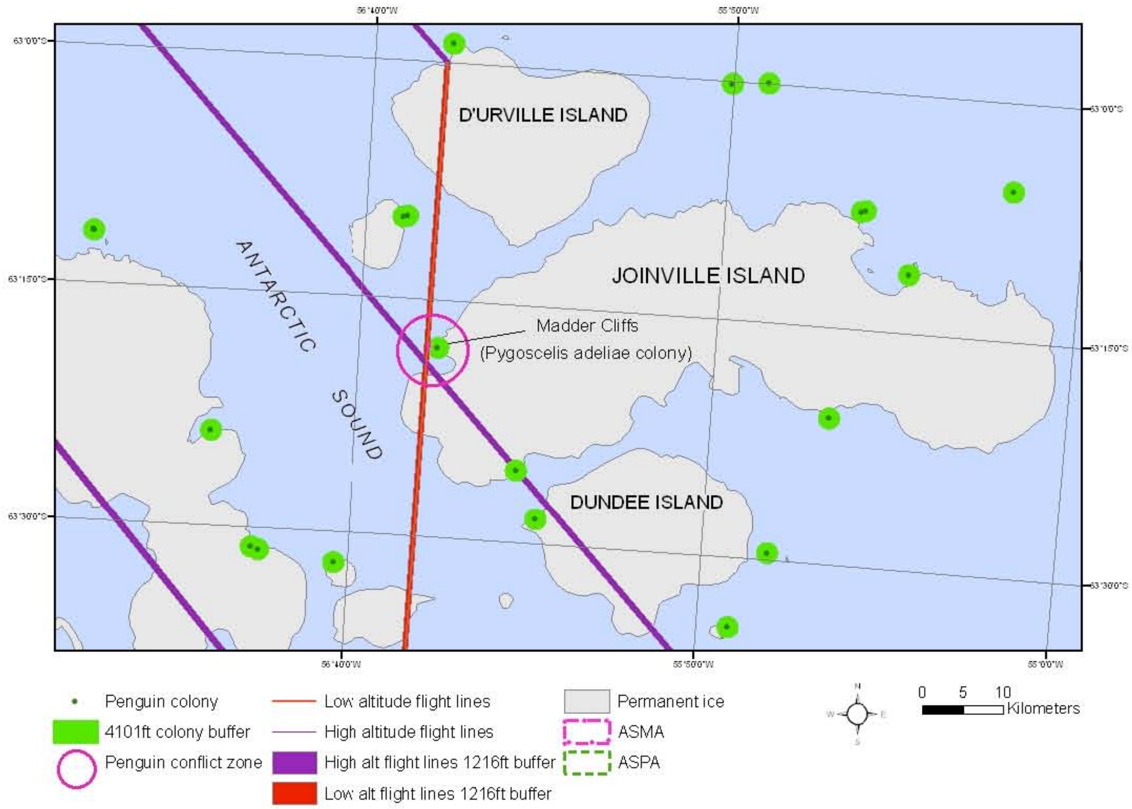
Harris, Colin M. Guidelines for the operation of aircraft near concentration of birds, Information Paper IP-39, CEP IV, St Petersburg, Russia, 10 pp., 2001.

Appendix A

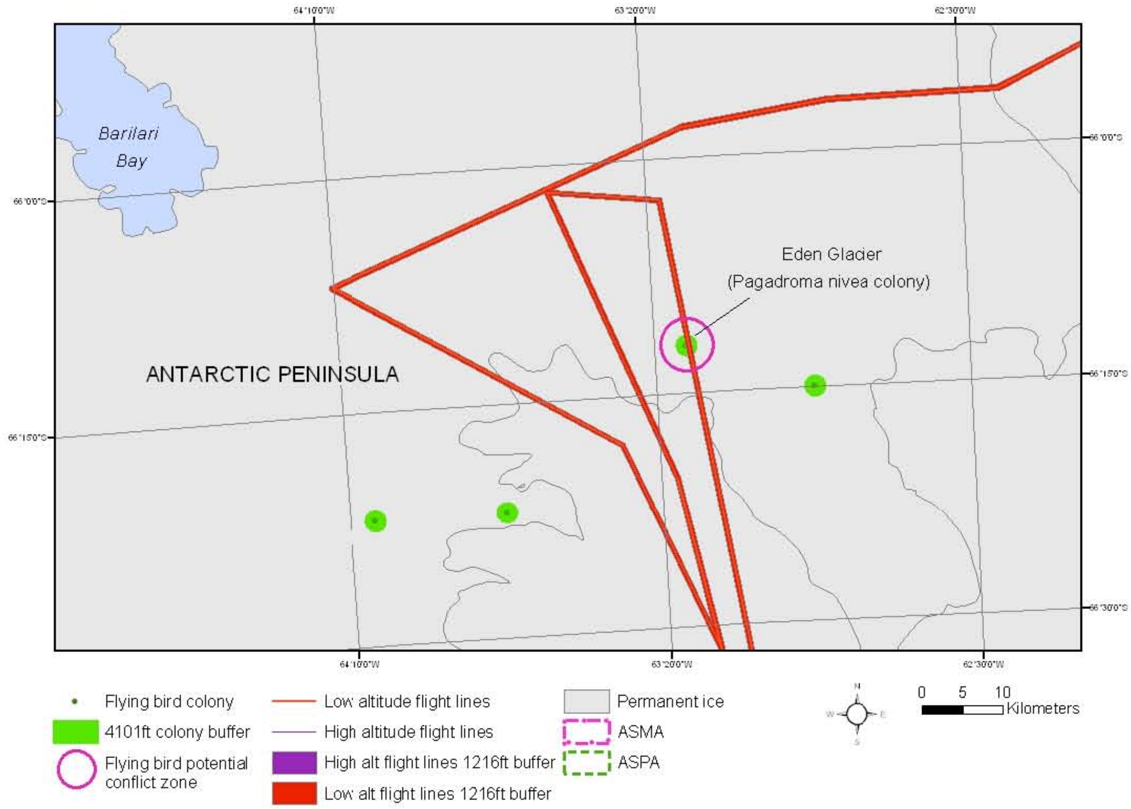
Map 1: Overview of OIB flight lines and breeding wildlife colonies in the Antarctic Peninsula region.



Map 2: Potential conflict zone: Low altitude flight lines over penguin breeding colony



Map 3: Potential conflict zone: Low altitude flight lines over flying bird breeding colony



A summary and analysis of options for collecting ICESat-like data from aircraft through 2014

1. Introduction

This report provides options for providing laser altimetry and when possible, radar altimetry measurements from aircraft, over priority regions of the Arctic and Antarctic, in order to provide initial " rough order-of- magnitude" estimates to NASA management on providing ICESat-like data from aircraft until launch of ICESat 2.

This report is intended to be a first step in providing a series of flexible options that take place over 2 phases: Spring 2009 – Fall 2011 (herein referred to as Phase I), and Spring 2012 – Fall 2014 (Phase II) and enable the weighing of the cost, schedule, and science return of different options. Phase 1 is composed primarily of near term, high TRL instruments, that can be easily modified to provide greater coverage, while Phase 2 includes a number of new platforms and instruments that are expected to become available in the near future.

Given the quick turnaround requested for this report, there were a number of general assumptions made that should be stated outright in addition to the assumptions that are listed for each of the mission concepts proposed. The first assumption is that it is not likely to be feasible for aircraft and payloads to cover all of the areas that ICESat covered, especially twice per year. The ICESat science team provided priority areas where time series information was especially important and this information guided planning and estimation. Because of the challenges of covering even these select areas located in very remote regions and across entire continents, we assumed that there would need to be a budget to cover aircraft as well as instrument upgrades and in some cases procurements. These costs are specifically called out and rolled up into each estimate. The last major assumption is that the existing ICESat DAAC maintained at the National Snow and Ice Data Center would be responsible for all data archiving and that participating scientists would agree to an open data policy with a similar timetable to that of the GLAS science products. While this report does not speak to archiving, we do include estimates of science team operations and data processing.

1.1 ICESat description and instrument specifications

The NASA ICESat Geoscience Laser Altimeter System (GLAS), launched in January 2003, was designed to provide precise and accurate altimetry of land and sea ice globally using a series of three diode pumped Q-switched Nd:YAG lasers operating in the near infrared (1064 nanometers). Observations took place from a polar orbit with a 183 day repeat pattern and measured ice elevation to within 10cm vertical accuracy across a 70m beam swath. After early failures of lasers 1 and 2,, the remaining laser has been used for 33 days at a time, 2 times each year in March and October (see figure 1 below)

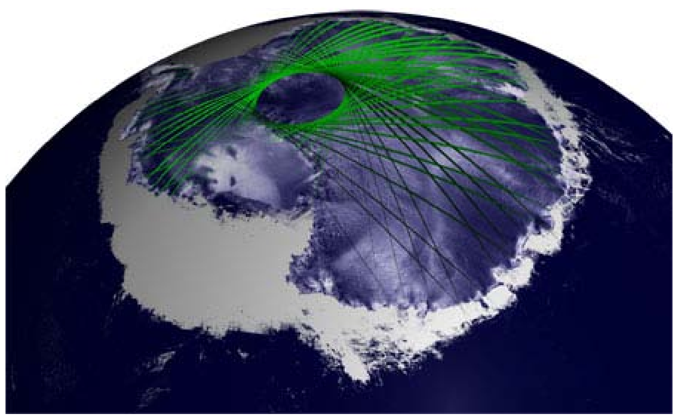


Figure 1: The footprint of GLAS beams in Antarctica over a x day period courtesy Jay Zwally.

With the follow-on mission, ICESat II not scheduled for launch until 2014, this leaves the gap in coverage of this key earth system science parameter, while the rapid rate of change seen recently in Greenland ice sheets, the Arctic sea ice, and the Antarctic shelves are a source of concern both to scientists and policy-makers. The situation requires balancing several options for providing a gap-filler datasets that will enable meaningful continuity and calibration between ICESat I and ICESat II and maintain this important time series over areas of scientific interest.

1.2 A summary of science requirements and regions of interest

While the primary goal of this analysis is to provide airborne laser altimetry data to complement ICESat data, the ICESat Science team requested that ice-penetrating radar measurements be considered as secondary payloads to provide soundings of ice depth, and to assist in resolving uncertainties related to surface snow. Minimum repeat time for measurements is the spring and fall 33-day GLAS operations schedule. In addition, the Science team requested seasonal measurements of Arctic and Antarctic sea ice.

The NASA ICESat science team provided information on priorities for extending ICESat-like measurements. The team assumed that not all of the orbits could be covered so they focused on 5 regions that are sensitive to climate change and are showing rapid change. These regions are Greenland glacial outlets, Arctic and Antarctic Sea Ice, Inland Antarctica, and SE Alaskan glacial outlets and they are described briefly below.

1.2.1 Greenland

The glacial outlets of Greenland are of most interest to the science community. Measurements of the interior, largely used to close ice mass balance estimates, can now be derived from GRACE. The regions of interest for coverage in Greenland are shown as polygons in figure x below.

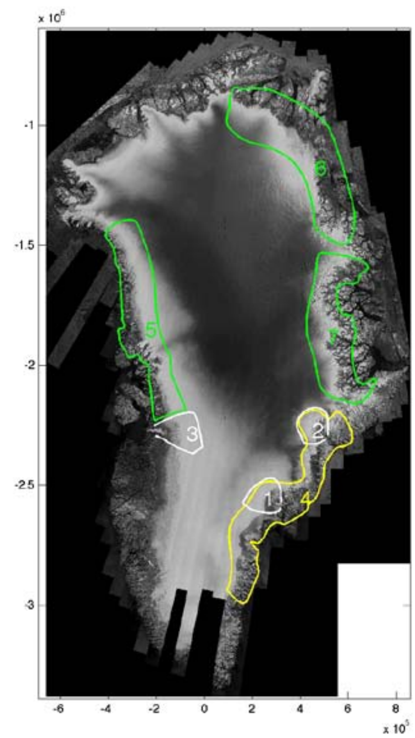


Figure 2: Priority areas for ICESat data continuity in Greenland in order of importance :. Helheim glacier; 2. Kangerdlugssuaq glacier; 3. Jakobshavn glacier 4. Southeast Greenland outlets 5. Northwest coast, 6. Northeast coast; 7. East-central coast.

These regions are best served from either Thule or Iceland, and cost estimates were based upon mission experience from both locations. The NASA SMD ESD Cryosphere Science Program is funding P-3 flights of Bill Krabill's Airborne Topographic Mapper in Spring of 2009. A payload of that similar to the Arctic 2007 campaign with ATM, the Land Vegetation Imaging Sensor (LVIS), and the Global Ice Sheet Mapping Observer (GISMO) would provide continuity with existing time series in the region, while enabling larger area collects of laser altimetry. Since GISMO has already been integrated on the P-3, this would enable rapid response coverage in 2009 and then there could be a more formal selection process for payloads in subsequent seasons.

1.2.2 Arctic and Antarctic Sea Ice

ICESat data over sea ice have successfully been used to retrieve sea ice thickness and to study regional and inter-annual variability. Those results have contributed to a better understanding of the sea ice mass balance and its relation to the changes in the polar climate. It is critical that the laser altimeter time series established by ICESat-1 be interrupted as little as possible.

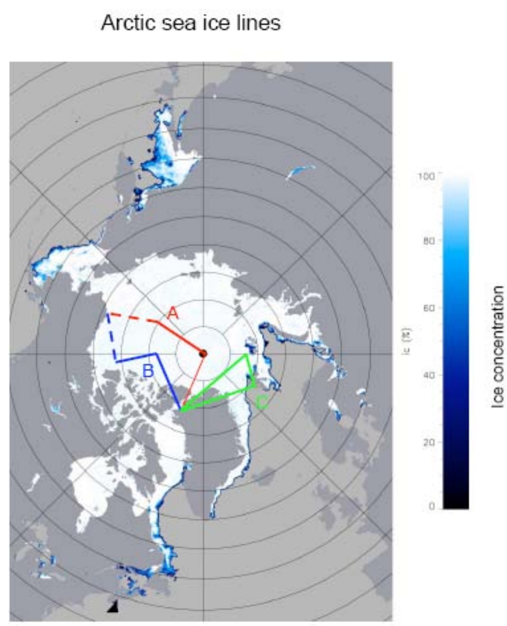


Figure 3 : Spatial coverage requested for Arctic Sea ice. Assumes flights would leave from Thule with a stop-over in Barrow. Flight lines are only conceptual and actual track-lines may differ depending on ice conditions and decisions made to fly, in part, along ICESat or CryoSat ground-tracks.

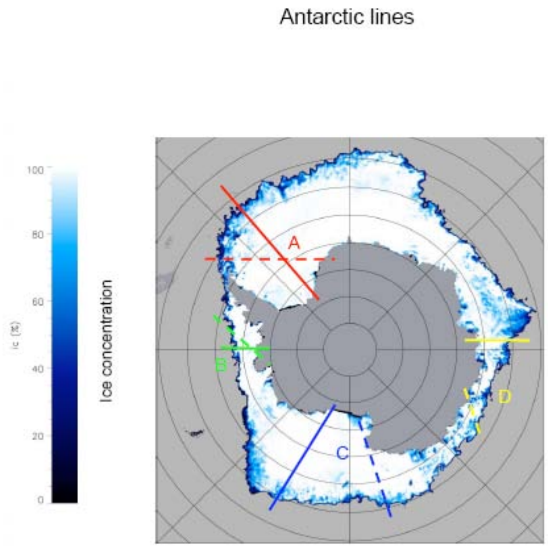


Figure 4 : Spatial coverage requested for Antarctic Sea ice. Solid lines denote ideal flight lines, while dashed indicate flight lines that could be modified in conjunction with coastal and interior flights.

Four radial spoke-like track-lines, A, B ,C and D, are proposed for the Southern Ocean that cover the main Antarctic areas. If sea ice flights are connected with ice sheets flights out of Chile and Australia/New Zealand those lines can be modified. The transects with the highest priority are line A (only the Weddell Sea has large amounts of 2nd-year ice) and line B (the areas east and west of the Antarctic peninsula is currently observing the greatest changes)

Temporal coverage: Seasonally (November/February/May/August)

1.2.3 Coastal Antarctica

The coastal glacial outlets are of increased interest as temperatures in the region warm more quickly than the rest of the planet. There is also great concern that increased movement of these glacier will cause instabilities in the larger interior shelves. Coupled with newly discovered sub-glacial lakes, coastal observations are required at least once per year.

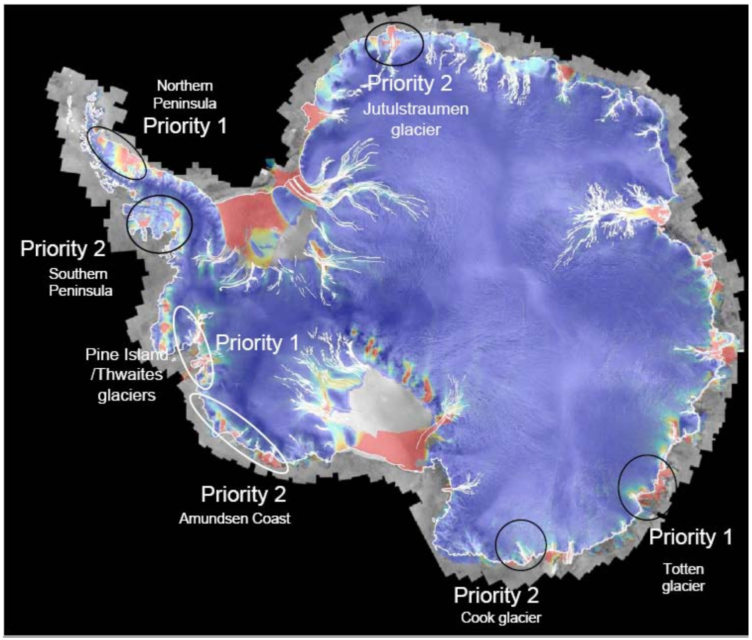


Figure 5: Antarctic glacier priority coverage regions.

1.2.4 Antarctic sub-Glacial Lakes

The under-ice lakes are important because they lubricate the glacier flow. They also express their change in volume by changes in surface elevation (~10-m). These should be surveyed at intervals of twice/year: in spring and in fall, at intervals of approximately 6-months. For comparison with ICESat observations, these profiles should be run along ICESat lines. The exact location of these lines will have to be worked out with the investigators. The priority regions are found in figure 6 below.

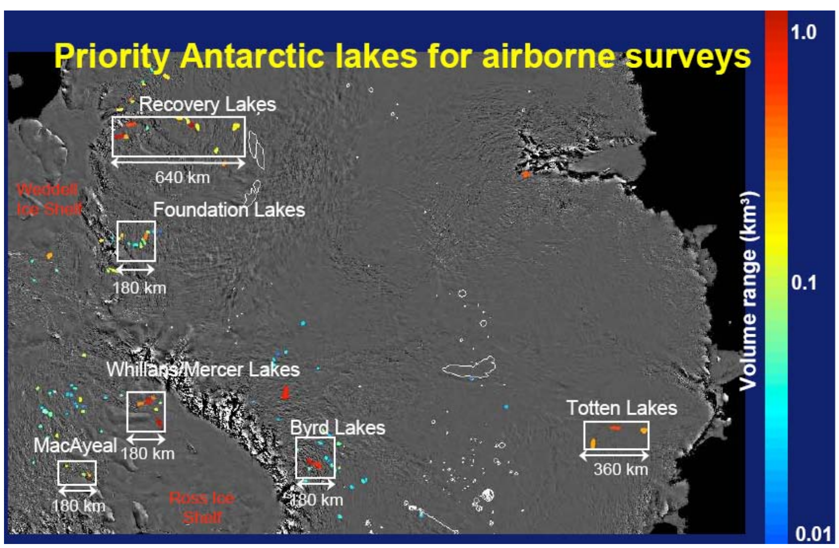


Figure 6 – Priority areas in Antarctica associated with sub-glacial lakes

1.2.6 Southeast Alaska glaciers

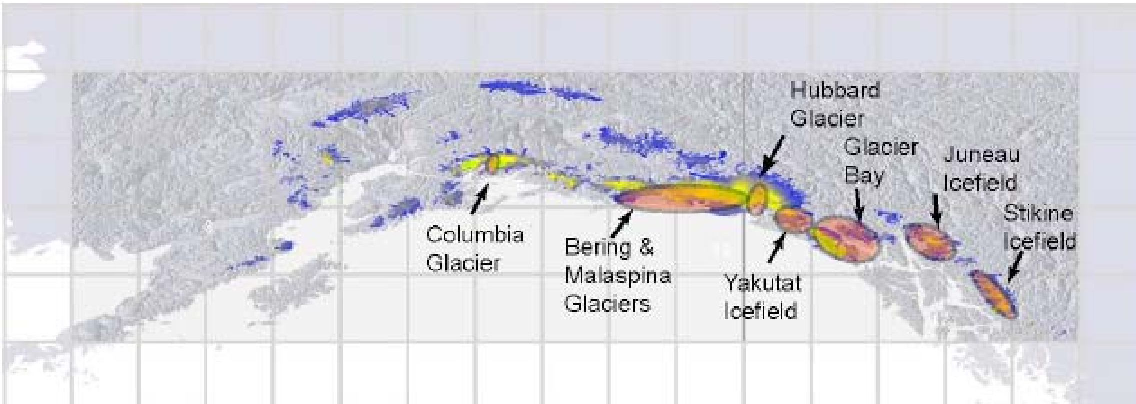


Figure 7: Glacial outlets in southeast Alaska

Priority 1: Yakutat Icefield is the most rapidly thinning icefield in Alaska (see figure 7).Bering/Bagley and Malaspina/Seward glaciers are the largest glaciers in Alaska with considerable area at low elevations and a large sensitivity to changing climate. Hubbard Glacier is an advancing tidewater glacier. The glacier periodically advances to form a freshwater lake that threatens to flood the town of Yakutat and its fisheries.

Priority 2: Glacier Bay, Stikine and Juneau Icefields are located in maritime environments with numerous tidewater glacier systems in unstable phases of retreat.

Priority 3: Columbia Glacier is Alaska's largest rapidly retreating tidewater glacier and is making large contributions to rising sea level. A network of ground measurements are available. These combined with altimetry data provide insight into processes driving dynamic ice losses.

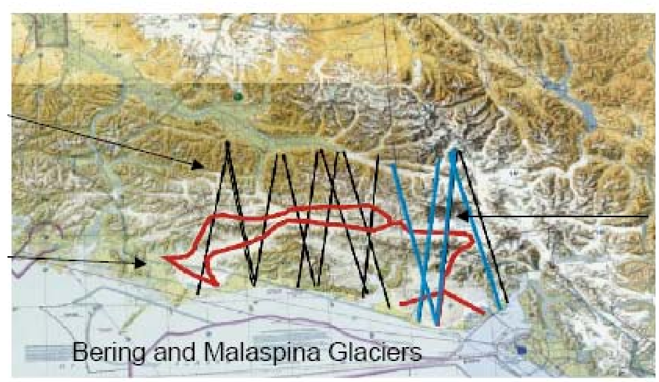


Figure 8: Subset of NASA ATM (Red) first sampled in 2005 along with ICESat lines (Black) and locations of regions included in a NASA Sponsored study (Sauber et al).

2 Payloads and Platforms

There are a number of existing aircraft and payload systems for providing coverage of ICESat priority regions and systems currently in development will likely play a large role as well. Each system is described briefly below with details on the existing system and a description of any modifications that would be required for integration and operations on available aircraft.

2.1 Instrument descriptions

The following set of instruments were reviewed by the ICESat Science Team and Mission Scientist for consideration in this study.

Instrument	**Acronym**	**Type**	**PI**
Airborne Topographic Mapper	ATM	Laser altimeter	Krabill
LVIS	LVIS	Laser altimeter	Blair
Fiber laser LIDAR	MFLL	Laser altimeter	Dobbs/ITT
Ice roughess profilometer	IRP	Laser altimeter	Maslanik
Swath Imaging Multi-polarization Photon-counting Lidar	SIMPL	Laser altimeter	Harding
Pulse compression lidar	PCL	Laser altimeter	Gogineni
Swath Mapping Laser Altimeter	SMLA	Laser altimeter	Yu
Ka-band SAR	Ka-UAVSAR	Radar sounder	Moller
PARIS	Pathfinder Airborne Radar Ice Sounder	Radar sounder	Raney
GISMO	Global Ice Sheet Mapping Orbiter	Radar sounder	Jezek / Gogineni
UKU	Ultrawideband Ku	Radar sounder	Gogineni

Table 1: Instruments considered for this analysis based on previous missions and existing NASA funded projects

2.1.1. Airborne Topographic Mapper (ATM)

Principle Investigator: Bill Krabill, GSFC

Instrument description: The Airborne Topographic Mapper (ATM) is a scanning LIDAR instrument developed at NASA Wallops Flight Facility for the Greenland ice-sheet project. It is primarily used for topographic change detection by repeating measurements over the same area over specific periods.

Current status: The instrument is available. As flown on the P-3, the system is mature. It has flown Greenland for more than 15 years and has flown the Antarctic, most recently (October 2008) out of Chile. Is already scheduled for Greenland, May 2009.

Current performance: Flies on the P-3 at 1500 ft AGL. Vertical resolution < 10 cm.

Potential upgrade: To fly higher, (e.g., on the DC-8), the system needs upgrade to higher power.

- ROM Cost ($k) $255 K
- Schedule: ~1 year

2.1.2. Laser Vegetation Imaging Sensor (LVIS)

Principle Investigator: Bryan Blair, GSFC

Instrument description: LVIS is a scanning laser altimeter, which records the returned signal from the target surface. These data are processed to generate products such as topography and vegetation coverage.

Current status: The instrument is available. It has flown in Greenland, most recently in 2007. Vertical resolution <7 cm.

Current performance: Flyable on various platforms, including P-3, DC-8

Potential upgrade: To fly both Arctic / Greenland and Antarctic in the same season, a duplicate instrument is needed.

- ROM Cost ($k) $500 K
- Schedule: 8-10 months year

Note: A facility-type instrument is planned for development for the Global Hawk to support DESDyni, ICESat 2, and LIST missions

2.1.3. Multi-functional Fiber Laser Lidar (MFLL)

Principle Investigator: Michael Dobbs, ITT Space Systems
Co-I Team: William Krabill, Mike Cisewski, CK Shum

Instrument description: MFLL offers cross-track scanning using diffractive optics in lieu of a mechanical scanner and 4 corner calibration pixels, which reduces error from attitude variations and 'campaign to campaign' bias. The transmitter is presently implemented using a fiber laser at 1um, but can be just as easily implemented at wavelengths which have been optimized for vegetation canopy, ice sheet topography, bathymetry, aerosols and clouds, lunar navigation and exploration.

Current status: The instrument is available. The Mark I system was successfully demonstrated on the B-90 in 2008. It is suitable for various aircraft, including P-3 and B-200. Currently optimized for operation at 500 to 1500m AGL (1500 to 6000 ft).

Current performance: Suitable for various aircraft, including P-3, B-200, DC-8. Vertical resolution <10 cm. System includes Applanix 610 Pos AV INS/GPS.

Potential upgrade: To fly at higher altitude (>30,000 ft) with optimum performance, a Mark II version has been designed and is ready for implementation.

- ROM Cost ($k) $100 K
- Schedule: 6-9 months

Note: ASCENDS version of instrument also provides CO2 measurements.

2.1.4. Ice Roughness Laser Profilometer

Principle Investigator: James Maslanik, University of Colorado

Instrument description: The laser profilometer is a small instrument (2-3 lbs) packaged for an Unmanned Aircraft System (UAS). It measures glacial ice surface roughness. It is also suitable for sea ice measurements.

Current status: The instrument is available. It has flown on the Aerosonde and Manta UAS and has been packaged for the SIERRA and Scan Eagle UAS. It has flown from Alaska and Greenland.

Current performance: Suitable for various aircraft, ideal for UAS. Vertical resolution <10 cm.

Potential upgrade: The system is semi-disposable. Suitable for multiple aircraft in a single mission, if duplicated

- ROM cost for duplicate instrument: $8 K
- Schedule: several months

Note: The system is scheduled for IPY flight out of Svaalbard in May 2009.

2.1.5. Swath Imaging Multi-polarization Photon-counting Lidar (SIMPL)

Principle Investigator: David Harding, GSFC

Instrument description: SIMPL is an airborne prototype in development to demonstrate laser altimetry measurement methods and components that enable efficient, high-resolution, swath mapping of topography and surface properties from space. Will be part of an Efficient Swath Mapping Laser Altimetry Demonstration.

Current status: Proof-of-concept flight is scheduled for P-3 in late 2008.

Current performance: Suitable for flight from 1500 to 25,000 ft. Vertical resolution < 7 cm.

Potential upgrades: To fly *operationally* on P-3

- ROM Cost ($k) $120 K (beyond IIP funding)
- Schedule: 1 year

To fly on the DC-8 or HIAPER

- ROM Cost ($k) $1.2 M
- Schedule: 1-2 years

To fly on S-3 or Global Hawk (requires pressurized package and automation)

- ROM Cost ($k) $2.5 M
- Schedule: 3-5 years

2.1.6. Pulse Compression Lidar

Principle Investigator: Prasad Gogineni, University of Kansas

Instrument description: The Pulse-compression Lidar is a non-scanning lidar designed for high-resolution snow surface topography.

Current status: Prototype is scheduled for test flight at 500 m AGL on the Twin Otter in spring 2009.

Current performance: Suitable for flight on P-3. Vertical resolution <50 cm with accuracy <5cm.

Potential upgrades: To fly at 35,000 ft.

- ROM Cost ($k) $775 K
- Schedule: 2 years

2.1.7. Mapping Laser Altimeter

Principle Investigator: Anthony Yu, GSFC

Instrument description: The mapping laser altimeter is a new IIP project. It is a swath-mapping laser altimeter designed to meet the goals of the proposed Lidar Surface Topography (LIST) Decadal Survey mission. It produces both altimetry and depolarization ratio data. Will be part of an Efficient Swath Mapping Laser Altimetry Demonstration.

Current status: The instrument is in development. A prototype is being readied for test flight on the Lear 25 in the summers of 2009 and 2010.

Current performance: Suitable for various aircraft, up to at least 30,000 ft. Vertical resolution TBD.

Potential upgrade: Unknown, prototype in development

2.18. Global Ice Sheet Mapping Orbiter (GISMO)

Principle Investigator: Ken Jezek, Ohio State University

Instrument description: GISMO is a NASA ESTO-funded instrument designed by a team of investigators from The Ohio State University, The University of Kansas, JPL and Vexcel Corporation. It has the ability to make 3-dimensional measurements of the thickness and base (basal) topography beneath an ice sheet up to 5 km deep.

Current status: The instrument is available. Has demonstrated more than 40 hours of successful operation on the P-3. Has flown over Greenland. Has flown with ATM.

Current performance: Potentially suitable for various aircraft.

Potential upgrades:

- Six months of effort would be required to increase the number of data channels and to redesign the antenna array for optimum implementation on the NASA-P3. Estimated cost is $600k for implementation of optimized configuration.

A system redesign is required for operation at higher altitude and speed (e.g., DC-8).

- ROM Cost ($k) $ 3M
- Schedule: >1 year

2.1.9. Pathfinder Advanced Radar Ice Sounder (PARIS)

Principle Investigator: Keith Raney, Johns Hopkins Applied Physics Lab

Instrument description: PARIS is a NASA Instrument Incubator Project with the goal to demonstrate ice thickness sounding from a high-altitude airborne radar.

Current status: The instrument is available as a demonstrator. It will be available operationally after May 2009.

Current performance: Currently configured to fly on P-3 only. Demonstration flights on P-3 with ATM took place in 2007. Flew in Chile in 2008.

Potential upgrades: Preparation for operational flight on P-3.

- ROM Cost ($k) $72 K
- Schedule: 3-6 months

Ground-up development for DC-8 capability: $2M and >1 year.

2.1.10. Ka-band SAR on G-III (UAVSAR)

Principle Investigator: Delwyn Moller, JPL

Instrument description: JPL is currently demonstrating a reconfigurable, polarimetric L-band synthetic aperture radar (SAR), specifically designed to acquire airborne repeat track SAR data for differential interferometric measurements. The single-pass Ka-band version is required for snow and ice penetration measurements. The Ka instrument has satellite demonstrator heritage.

Current status: The instrument will be demonstrated on the G-III in Greenland in May 2009.

Current performance: Suitable for various aircraft, including concept for Global Hawk. Vertical resolution < 10 cm.

Potential upgrade: Independent pod.

- ROM Cost ($k) several hundred K$
- Schedule: 3-6 months

Global Hawk, non-pod version

- ROM Cost ($k) several million $
- Schedule: 2 years

Note: The system recently won an SBIR award for further development

2.1.14 Commercial Options for ICESat Data Continuity

One option for ICESat continuity data might evolve from integrating COTS measurement capabilities on NASA aircraft. Commercially available LIDARs appear to be able to meet the 10 cm vertical accuracy requirements. This approach would need to be led by a science team that would develop a measurement plan to assure the science quality of the data, and a mission plan to address payload integration, deployment management, data archiving

Three hardware providers were selected from the web search, and were reviewed looking for off the shelf mapping instruments that appear to meet the core requirement of 10 cm vertical accuracy (See table 2).

LIDAR hardware Providers		Capibility	Hardware costs	
Optech	http://www.optech.ca/	ALTM Gemini:	$1,366,000	*
		ALTM 3100EA:	$1,142,000	*
		ALTM Orion:	$1,195,000	*
Leica	http://www.leica.com/	Quote requested		
Sigma Space	http://www.sigmaspace.com/sigma/	Scope being assessed		

* all include DashMap, ALTM-Nav, installation and full training in both software processing and hardware operations.

Table 2. LIDAR hardware providers with potential science quality mapping systems.

2.2 Platform descriptions

NASA operates a small fleet of highly modified aircraft to serve as platforms for instrument development, satellite cal/val, and to support process studies and model development. The aircraft considered in this report (see table 3) were chosen because they have the range and payload capabilities to support the instruments listed above.

Because these aircraft support a variety of science disciplines it should be assumed that this effort would have a potentially significant impact without serious consideration of interagency partnerships, commercial leaseing as well as aircraft procurement.

Platform	Cruise Altitude (ft)	Operational Altitudes (ft)	Cruise Speed (knots)	Duration (hrs)	Range (nm)
Global Hawk	55,000	42,000-65,000	335	31	11,000
G-3	42,000	500-45,000	485	7	3600
HAIPER (NSF)	41,000	1000-51000	460	14	~6000
DC-8	35,000	1000-41,000	450	10	5400
L1011 (Orbital)	35000	1000-42000	430	10.5	~5000
P-3	28,000	200-35,000	330	12	3800
Twin Otter	20,000	500-25,000	150	7	500
SUAS	3,000	100-12,000	60	11	600-1200
* small UAS include SIERRA, Aerosonde, Manta, and Scan Eagle					

Table 3: Aircraft considered for this analysis and a short summary of their specifications.

	P-3	DC-8	Global Hawk	G-III	S-3	SUAS*	HAIPER (G-V)	L-1011	Twin Otter
Greenland	x	x	x		x	x			
Arctic Sea Ice	x	x	x		x	x			
Antarctic inland		x	x				x	x	
Antarctic coastal		x	x				x	x	
Alaska				x	x	x			x

* Small Unmanned Aircraft Systems including SIERRA, Aerosonde, Scan Eagle or Manta
Note: All assets are controlled by NASA except for the HAIPER (NSF) , Twin Otter (Twin Otter Int'l), and the L-1011 (Orbital)

Table 4: Aircraft considered for this analysis and a short summary of their specifications.

3 Airborne Mission concepts for ICESat data continuity

The following mission concepts enable coverage of the priority areas defined by the NASA ICESat science team for both poles. This list of options is not exhaustive but is intended to provide enough information to weigh the cost benefit of different strategies. The following section provides details on one implantation using recommended options from this section in order to provide total cost estimates by year and site. The summary in section 4 provides an example of one implementation based upon this set of options.

3.1.1 Greenland Spring 2009

Option 1a: - P-3 flights of ATM, LVIS and GISMO (Code 1L)
Description: The ATM and P-3 teams are funded to fly in Spring 2009. This option would extend the mission to include higher altitude (~25kft) flights of LVIS and/or MFFL and other commercial sensors for large area coverage, and to assess the relative performance of candidate systems. To fly at higher altitudes ATM will require modifications that could not be achieved by March 2009. Low altitude flights provide high precision and accuracy for local areas and maintain the Krabill time series. A further extension of this option will be addressed in the Arctic sea ice mission concepts.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k) 100hrs/ 350
Estimated Aircraft Operations costs ($k): 140
Integration Costs ($k): 600
Science Team Costs ($k): 375
Total Cost ($k): 1,465

Option 1b: G-III flights of Ka-Band UAVSAR (Code 3H)
Description: The Ka-Band UAVSAR and G-III teams are already planning to test the system in Greenland in Spring 2009 in conjunction with Option 1a above. This option would extend operations to enable coincident coverage with the P-3.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 10/0
Estimated Aircraft Operations Costs ($k): 0
Integration Costs ($k): 0
Science Team Costs ($k): 0
Total Cost ($k): 0 (already funded by NASA SMD ESD Cryosphere Program)

Option 2: Medium altitude P-3 flights of LVIS and GISMO/PARIS (Code 1M)
Description: This mission would be a follow-on and extension of flights that accompanied ATM during Arctic 2007. This option would enable measurements over the entire continent, including the science priority areas.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 100/350
Estimated Aircraft Operations costs ($k): 290
Integration Costs ($k): 0
Science Team Costs ($k): 425
Total Cost ($k): 1515

3.1.2 Greenland Fall 2009

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (Code 1L)
Description: This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 100/350
Estimated Aircraft Operations costs ($k): 140
Integration Costs ($k): 0
Science Team Costs ($k): 1,125
Total Cost ($k): 1615

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (Code 2M)
Description: This option would enable coverage of the entire continent. Requires new integrations of LVIS and radar installation for GISMO/PARIS. This option assumes that P-3 ATM flight continue high resolution time series. This option would enable coverage of the entire continent.
Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130
Estimated Aircraft Operations costs ($k): 1,671
Integration Costs ($k): 3414 (LVIS & GISMO); 2000 (PARIS)
Science Team Costs ($k):
Total Cost ($k): 6870 (assuming GISMO)

3.1.2 Greenland Spring 2010

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (Code 1L)
Description: This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 100
Estimated Aircraft Operations costs ($k): 144
Integration Costs ($k): 0 (Assuming integration costs covered in 09)
Science Team Costs ($k): 1,158
Total Cost ($k): 1663

Option 2: Medium altitude DC-8 flights of ATM, LVIS & GISMO/PARIS (Code 2L)
Description: This option would enable coverage of the entire continent. Requires new integrations of LVIS and radar installation for GISMO/PARIS. This option assumes that P-3 ATM flight continue high resolution time series.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/780
Estimated Aircraft Operations costs ($k): 1721
Integration Costs ($k): 255 (ATM)
Science Team Costs ($k): 1091
Total Cost ($k): 3871

3.1.3 Greenland Fall 2010

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (1L)
Description: This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 100/350
Estimated Aircraft Operations Costs ($k): 144
Integration Costs ($k): 0
Science Team Costs ($k): 1091
Total Cost ($k): 1596

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (Code 2M)
Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series.

Base of Operations: Thule

Estimated Flight Hours/Cost ($k): 130/780
Estimated Aircraft Operations Costs ($k): 1,721
Integration Costs ($k): 0 (assuming flights in 2009)
Science Team Costs ($k): 1035
Total Cost ($k): 3559

3.1.4 Greenland Spring 2011

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (Code 1L)
Description: This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 100/371
Estimated Aircraft Operations costs ($k): 148
Integration Costs ($k): 0
Science Team Costs ($k): 1193
Total Cost ($k): 1713

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (Code 2M)
Description: This option would enable coverage of the entire landmass of Greenland. This option assumes that P-3 ATM flight continue high resolution time series. Depending on the flexibility of science requirements regarding timing of acquisitions, this option may prevent DC-8 observations in Antarctica.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/828
Estimated Aircraft Operations costs ($k): 1772
Integration Costs ($k): 0
Science Team Costs ($k): 1193
Total Cost ($k): 3793

Option 3: Medium altitude S-3 flights of SIMPL/MFLL/SMLA (Code 4N)
Description: This option would make use of this newly modified platform and provide an opportunity to test-bed operational data production from these instruments that are currently in development alongside well characterized instruments.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 80/280
Estimated Aircraft Operations costs ($k): 475
Integration Costs ($k): 2500
Science Team Costs ($k): 80
Total Cost ($k): 3334

Option 4: Medium altitude Global Hawk flights of LVIS and GISMO/PARIS (Code 5N)

Description: This option would demonstrate the utility of a UAS for providing extended range observations over all of Greenland.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 115/403
Estimated Aircraft Operations Costs ($k): 691 + 6000 one-time investment for mobile Ground Control Station
ntegration Costs ($k): 2000
Science Team Costs ($k): 1066
Total Cost ($k): 4160 or 10160 w/ GCS

3.1.5 Greenland Fall 2011

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (1L)
Description: This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 100/371
Estimated Aircraft Operations Costs ($k): 148
Integration Costs ($k): 0
Science Team Costs ($k): 1193
Total Cost ($k): 1713

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (2M)
Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series. Depending on the flexibility of science requirements regarding timing of acquisitions, this option may prevent DC-8 observations in Antarctica.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/828
Estimated Aircraft Operations costs($k): 1772
Integration Costs ($k): 0
Science Team Costs ($k): 1193
Total Cost ($k): 3793

Option 3: Medium altitude S-3 flights of ATM/LVIS & SIMPL/MFLL/SMLA (Code 4N)
Description: This option would make use of this newly modified platform and provide an opportunity to test-bed operational data production from instruments that are currently in development, alongside well-characterized instruments.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 80/280
Estimated Aircraft Operations costs ($k): 475

Integration Costs ($k): 0 (assumes NRE from Spring 2011)
Science Team Costs ($k): 79
Total Cost ($k): 834

Option 4: Medium altitude Global Hawk flights of LVIS and GISMO/PARIS (5M)
Description: This option would demonstrate the utility of a UAS for providing extended range observations over all of Greenland.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 115/403
Estimated Aircraft Operations costs ($k): 691
Integration Costs ($k): 0
Science Team Costs ($k): 1066
Total Cost ($k): 2160

3.1.6 Greenland Spring 2012

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (Code 1L)
Description: This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 100/382
Estimated Aircraft Operations costs ($k): 153
Integration Costs ($k): 0
Science Team Costs ($k): 1,229
Total Cost ($k): 1765

Option 2: Medium altitude DC-8 flights of ATM, LVIS & GISMO/PARIS (Code 2M
Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series. Depending on the flexibility of science requirements regarding timing of acquisitions, this option may prevent DC-8 observations in Antarctica.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/852
Estimated Aircraft Operations Costs ($k): 1826
Integration Costs ($k): 0
Science Team Costs ($k): 1230
Total Cost ($k): 3907

Option 3: Medium altitude S-3 flights of ATM/LVIS & SIMPL/MFLL/SMLA (Code 4N)
Description: This option would make use of this newly modified platform and provide an opportunity to testbed operational data production from these instruments that are currently in development alongside well characterized instruments.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 80/288
Estimated Aircraft Operations Costs ($k): 490
Integration Costs ($k): 0
Science Team Costs ($k): 81
Total Cost ($k): 859

Option 4: Medium altitude Global Hawk flights of LVIS and GISMO/PARIS (Code 5M)
Description: This option would demonstrate the utility of a UAS for providing extended range observations over all of Greenland.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 115/415
Estimated Aircraft Operations Costs ($k): 712
Integration Costs ($k):
Science Team Costs ($k): 1193
Total Cost ($k): 2320

3.1.7 Greenland Fall 2012

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (Code 1L)
Description: This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 100/382
Estimated Aircraft Operations Costs ($k): 152
Integration Costs ($k): 0
Science Team Costs ($k): 1193
Total Cost ($k): 1728

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (2M)
Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series. Depending on the flexibility of science requirements regarding timing of acquisitions, this option may prevent DC-8 observations in Antarctica.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/852
Estimated Aircraft Operations Costs ($k): 1825
Integration Costs ($k): 0
Science Team Costs ($k):1229
Total Cost ($k): 3907

Option 3: Medium altitude S-3 flights of SIMPL/MFLL/SMLA (4N)
Description: This option would make use of this newly modified platform and provide an opportunity to testbed operational data production from these instruments that are currently in development alongside well characterized instruments.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 80/288
Estimated Aircraft Operations Costs ($k): 489
Integration Costs ($k): 0
Science Team Costs ($k): 81
Total Cost ($k): 859

Option 4: Medium altitude Global Hawk flights of LVIS and GISMO/PARIS (Code 5M)
Description: This option would demonstrate the utility of a UAS for providing extended range observations over all of Greenland.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 115/415
Estimated Aircraft Operations Costs ($k): 712
Integration Costs ($k): 0
Science Team Costs ($k): 1098
Total Cost ($k): 2225

3.1.8 Greenland Spring 2013

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (1L)
Description: This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 100/394
Estimated Aircraft Operations Costs ($k): 157
Integration Costs ($k): 0
Science Team Costs ($k): 1266
Total Cost ($k): 1817

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (2M)
Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series. Depending on the flexibility of science requirements regarding timing of acquisitions, this option may prevent DC-8 observations in Antarctica.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/878
Estimated Aircraft Operations Costs ($k): 1881

Integration Costs ($k): 0
Science Team Costs ($k): 1266
Total Cost ($k): 4024

Option 3: Medium altitude S-3 flights of SIMPL/MFLL/SMLA (4N)
Description: This option would make use of this newly modified platform and provide an opportunity to testbed operational data production from these instruments that are currently in development alongside well characterized instruments.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 80/297
Estimated Aircraft Operations Costs ($k): 503
Integration Costs ($k): 0
Science Team Costs ($k): 83
Total Cost ($k): 885

Option 4: Medium altitude Global Hawk flights of LVIS and GISMO/PARIS (5M)
Description: This option would demonstrate the utility of a UAS for providing extended range observations over all of Greenland.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 115/428
Estimated Aircraft Operations Costs ($k): 733.08
Integration Costs ($k): 0
Science Team Costs ($k): 1131
Total Cost ($k): 2291

3.1.9 Greenland Fall 2013

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (1L)
Description: This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 100/394
Estimated Aircraft Operations Costs ($k): 158
Integration Costs ($k): 0
Science Team Costs ($k): 1266
Total Cost ($k): 1817

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (2M)
Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series. Depending on the flexibility of science requirements regarding timing of acquisitions, this option may prevent DC-8 observations in Antarctica.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/878
Estimated Aircraft Operations Costs ($k): 1881
Integration Costs ($k): 0
Science Team Costs ($k): 1266
Total Cost ($k): 4024

Option 3: Medium altitude S-3 flights of ATM/LVIS & SIMPL/MFLL/SMLA
Description: This option would make use of this newly modified platform and provide an opportunity to testbed operational data production from these instruments that are currently in development alongside well characterized instruments.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 80/297
Estimated Aircraft Operations Costs ($k): 504
Integration Costs ($k): 0
Science Team Costs ($k): 83
Total Cost ($k): 885

Option 4: Medium altitude Global Hawk flights of LVIS and GISMO/PARIS (5M)
Description: This option would demonstrate the utility of a UAS for providing extended range observations over all of Greenland.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 115/428
Estimated Aircraft Operations Costs ($k): 733
Integration Costs ($k): 0
Science Team Costs ($k): 1131
Total Cost ($k): 2291

3.1.10 Greenland Spring 2014

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (1L)
Description: This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 100/406
Estimated Aircraft Operations Costs ($k): 162
Integration Costs ($k): 0
Science Team Costs ($k): 1304
Total Cost ($k): 1872

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (2M)

Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series. Depending on the flexibility of science requirements regarding timing of acquisitions, this option may prevent DC-8 observations in Antarctica.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/904
Estimated Aircraft Operations Costs ($k): 1937
Integration Costs ($k): 0
Science Team Costs ($k): 1304
Total Cost ($k): 4145

Option 3: Medium altitude S-3 flights of SIMPL/MFLL/SMLA (Code 4N)
Description: This option would make use of this newly modified platform and provide an opportunity to testbed operational data production from these instruments that are currently in development alongside well characterized instruments.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 80/306
Estimated Aircraft Operations Costs ($k): 519
Integration Costs ($k): 0
Science Team Costs ($k): 86
Total Cost ($k): 911

Option 4: Medium altitude Global Hawk flights of LVIS and GISMO/PARIS (5M)
Description: This option would demonstrate the utility of a UAS for providing extended range observations over all of Greenland.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 115/440
Estimated Aircraft Operations Costs ($k): 755
Integration Costs ($k): 0
Science Team Costs ($k): 1165
Total Cost ($k): 2360

3.1.11 Greenland Fall 2014

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (1L)
Description: This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 100/406
Estimated Aircraft Operations Costs ($k): 162

Integration Costs ($k): 0
Science Team Costs ($k): 1304
Total Cost ($k): 1872

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (2M)
Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series. Depending on the flexibility of science requirements regarding timing of acquisitions, this option may prevent DC-8 observations in Antarctica.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/904
Estimated Aircraft Operations Costs ($k): 1937
Integration Costs ($k): 0
Science Team Costs ($k): 1304
Total Cost ($k): 4145

Option 3: Medium altitude S-3 flights of SIMPL/MFLL/SMLA (Code 4N)
Description: This option would make use of this newly modified platform and provide an opportunity to testbed operational data production from these instruments that are currently in development alongside well characterized instruments.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 80/306
Estimated Aircraft Operations Costs ($k): 519
Integration Costs ($k): 0
Science Team Costs ($k): 86
Total Cost ($k): 911

Option 4: Medium altitude Global Hawk flights of LVIS and GISMO/PARIS (Code 5M)
Description: This option would demonstrate the utility of a UAS for providing extended range observations over all of Greenland.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 115/440
Estimated Aircraft Operations Costs ($k): 755
Integration Costs ($k): 0
Science Team Costs ($k): 1165
Total Cost ($k): 2360

3.2 Arctic Sea Ice

3.2.1 Arctic Sea Ice Spring 2009

Option 1: Low altitude P-3 flights of ATM, LVIS, & GISMO/PARIS (1L)

Description: This would be an extension of an already funded deployment described in section 3.1.1 above so the estimates include only additional expenses, not the entire cost of the mission.

Base of Operations: Thule/Fairbanks
Estimated Flight Hours/Cost ($k): 39/141
Estimated Aircraft Operations Costs ($k): 52
Integration Costs ($k): 0 (assumes integration funded for Greenland flights)
Science Team Costs ($k): 118
Total Cost ($k): 1367

<u>Option 2: Low altitude SUAS flights of a laser profilometer (Code 8D)</u>
Description: This is an funded deployment that would provide limited coverage of arctic sea ice, but will demonstrate a new capability for providing high resolution measurements in remote regions.

Base of Operations: Svalbard, Norway
Estimated Flight Hours/Cost ($k): 100/120
Estimated Aircraft Operations Costs ($k): 0
Integration Costs ($k): 0
Science Team Costs ($k): 0
Total Cost ($k): 0 (already funded by UAV IPY)

<u>Option 3: Medium altitude G-III flights of Ka-Band UAVSAR (3H)</u>
Description: This mission would take advantage of a UAV IPY project to investigate the use of a Ka-Band radar for sea ice mapping. This would be an extension of a planned mission to Greenland and so costs do not include integration.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 88/220
Estimated Aircraft Operations Costs ($k): 592
Integration Costs ($k): 0
Science Team Costs ($k): 100
Total Cost ($k): 912

3.2.2 Arctic Sea Ice Fall 2009

<u>Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (1L)</u>
Description: This would be an extension of an already funded deployment described in section 3.1.1 above so the estimates include only additional expenses, not the entire cost of the mission. This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 39/137
Estimated Aircraft Operations Costs ($k): 52
Integration Costs ($k): 0
Science Team Costs ($k): 100 (Assumes extension of Greenland mission)
Total Cost ($k): 285

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (2M)
Description: This would be an extension of an already funded deployment described in section 3.1.2 above so the estimates include only additional expenses, not the entire cost of the mission. This option assumes that P-3 ATM flight continue high resolution time series. This option may prevent coverage of Antarctica because the HAIPER is unavailable and the L-1011 may not be ready.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130
Estimated Aircraft Operations Costs ($k): 1671
Integration Costs ($k): 0
Science Team Costs ($k): 1175
Total Cost ($k): 2548

3.2.3 Arctic Sea Ice Spring 2010

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS
Description: This would be an extension of an already funded deployment. This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 39/144
Estimated Aircraft Operations Costs ($k): 53
Integration Costs ($k): 0
Science Team Costs ($k): 100 (Assumes extension of Greenland mission)
Total Cost ($k): 299

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (2M)
Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series. This option may prevent coverage of Antarctica because the HAIPER is unavailable.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/803
Estimated Aircraft Operations Costs ($k): 1721
Integration Costs ($k): 0

Science Team Costs ($k): 100 (Assumes extension of Greenland mission)
Total Cost ($k): 3735

3.2.4 Arctic Sea IceFall 2010

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (1L)
Description: This would be an extension of an already funded deployment. This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 39/145
Estimated Aircraft Operations Costs ($k): 53
Integration Costs ($k): 0
Science Team Costs ($k): 100 (Assumes extension of Greenland mission)
Total Cost ($k): 298

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (2M)
Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/803
Estimated Aircraft Operations Costs ($k): 1773
Integration Costs ($k): 0
Science Team Costs ($k): 100 (Assumes extension of Greenland mission)
Total Cost ($k): 2625

3.2.5 Arctic Sea Ice Spring 2011

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (1L)
Description: This would be an extension of an already funded deployment. This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 39/145
Estimated Aircraft Operations Costs ($k): 53
Integration Costs ($k): 0
Science Team Costs ($k): 100 (Assumes extension of Greenland mission)
Total Cost ($k): 301

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (2M)

Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/828
Estimated Aircraft Operations Costs ($k): 1772
Integration Costs ($k): 0
Science Team Costs ($k): 100 (Assumes extension of Greenland mission)
Total Cost ($k): 2704

Option 3: Medium altitude Global Hawk flights of LVIS and GISMO/PARIS (5M)
Description: This option would demonstrate the utility of a UAS for providing extended range observations over all of Greenland and would be an extension of the mission described in 3.1.4.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 115/403
Estimated Aircraft Operations Costs ($k): 691
Integration Costs ($k): 3700 (one-time integration)
Science Team Costs ($k): 100 (Assumes extension of Greenland mission)
Total Cost ($k): 6041

3.2.6 Arctic Sea Ice Fall 2011

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (Code 1L)
Description: This would be an extension of an already funded deployment. This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 39
Estimated Aircraft Operations Costs ($k): 53
Integration Costs ($k): 0
Science Team Costs ($k):100 (Assumes extension of Greenland mission)
Total Cost ($k): 302

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (2M)
Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series.
Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/828
Estimated Aircraft Operations Costs ($k): 1772
Integration Costs ($k): 0
Science Team Costs ($k): 100 (Assumes extension of Greenland mission)
Total Cost ($k): 2704

Option 3: Medium altitude Global Hawk flights of LVIS and GISMO/PARIS (5M)
Description: This option would demonstrate the utility of a UAS for providing extended range observations over all of Greenland and would be an extension of the mission described in 3.1.4.
Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 115/403
Estimated Aircraft Operations Costs ($k): 691
Integration Costs ($k): 0
Science Team Costs ($k): 100 (Assumes extension of Greenland mission)
Total Cost ($k): 1187

3.2.7 Arctic Sea Ice Spring 2012

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (1L)
Description: This would be an extension of an already funded deployment. This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.
Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 39/149
Estimated Aircraft Operations Costs ($k): 55
Integration Costs ($k): 0
Science Team Costs ($k): 100
Total Cost ($k): 310

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (Code 2M)
Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series.
Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/852
Estimated Aircraft Operations Costs ($k): 1826
Integration Costs ($k): 0
Science Team Costs ($k): 100 (Assumes extension of Greenland mission)
Total Cost ($k): 2785

Option 3: Medium altitude Global Hawk flights of LVIS and GISMO/PARIS (5N)
Description: This option would demonstrate the utility of a UAS for providing extended range observations over all of Greenland and would be an extension of the mission described in 3.1.4.
Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 115/415
Estimated Aircraft Operations Costs ($k): 712
Integration Costs ($k): 0
Science Team Costs ($k): 100 (Assumes extension of Greenland mission)
Total Cost ($k): 1223

3.2.8 Arctic Sea Ice Fall 2012

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (1L)
Description: This would be an extension of an already funded deployment. This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 39/146
Estimated Aircraft Operations Costs ($k): 55
Integration Costs ($k): 0
Science Team Costs ($k): 100 (Assumes extension of Greenland mission)
Total Cost ($k): 311

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (2N)
Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/852
Estimated Aircraft Operations Costs ($k): 1826
Integration Costs ($k): 0
Science Team Costs ($k): 100
Total Cost ($k): 2785

Option 3: Medium altitude Global Hawk flights of LVIS and GISMO/PARIS (5N)
Description: This option would demonstrate the utility of a UAS for providing extended range observations over all of Greenland and would be an extension of the mission described in 3.1.4.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 115/427
Estimated Aircraft Operations Costs ($k): 712
Integration Costs ($k): 0
Science Team Costs ($k): 100 (Assumes extension of Greenland mission)
Total Cost ($k): 1223

3.2.9 Arctic Sea Ice Spring 2013

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (1L)
Description: This would be an extension of an already funded deployment. This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher

altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 39/154
Estimated Aircraft Operations Costs ($k): 56
Integration Costs ($k): 0
Science Team Costs ($k): 100
Total Cost ($k): 320

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (Code 2N)
Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/878
Estimated Aircraft Operations Costs ($k): 1881
Integration Costs ($k): 0
Science Team Costs ($k): 100
Total Cost ($k): 2785

Option 3: Medium altitude Global Hawk flights of LVIS and GISMO/PARIS (Code 5M)

Description: This option would demonstrate the utility of a UAS for providing extended range observations over all of Greenland and would be an extension of the mission described in 3.1.4.
Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 115/428
Estimated Aircraft Operations Costs ($k): 712
Integration Costs ($k): 0
Science Team Costs ($k): 100
Total Cost ($k): 1223

3.2.10 Arctic Sea Ice Fall 2013

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (Code 1L)
Description: This would be an extension of an already funded deployment. This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.
Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 39/154
Estimated Aircraft Operations Costs ($k): 56
Integration Costs ($k): 0
Science Team Costs ($k): 100
Total Cost ($k): 320

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (2M)
Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series.
Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/878
Estimated Aircraft Operations Costs ($k): 1881
Integration Costs ($k): 0
Science Team Costs ($k): 100
Total Cost ($k): 2869

Option 3: Medium altitude Global Hawk flights of LVIS and GISMO/PARIS (5N)
Description: This option would demonstrate the utility of a UAS for providing extended range observations over all of Greenland and would be an extension of the mission described in 3.1.4.
Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 115/428
Estimated Aircraft Operations Costs ($k): 733
Integration Costs ($k): 0
Science Team Costs ($k): 100
Total Cost ($k): 1260

3.2.11 Arctic Sea Ice Spring 2014

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (1L)
Description: This would be an extension of an already funded deployment. This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.
Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 39/158
Estimated Aircraft Operations Costs ($k): 58
Integration Costs ($k): 0
Science Team Costs ($k): 100
Total Cost ($k): 326

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (2M)
Description: This option would enable coverage of the entire continent. Requires new integrations of LVIS and radar installation for GISMO/PARIS. This option assumes that P-3 ATM flight continue high resolution time series.
Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/904
Estimated Aircraft Operations Costs ($k): 755
Integration Costs ($k): 0
Science Team Costs ($k): 100
Total Cost ($k): 2955

Option 3: Medium altitude Global Hawk flights of LVIS and GISMO/PARIS (5M)
Description: This option would demonstrate the utility of a UAS for providing extended range observations over all of Greenland and would be an extension of the mission described in 3.1.4.
Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 115/440
Estimated Aircraft Operations Costs ($k): 755
Integration Costs ($k): 0
Science Team Costs ($k): 100
Total Cost ($k): 1298

3.2.12 Arctic Sea Ice Fall 2014

Option 1: Medium altitude P-3 flights of ATM, LVIS, GISMO/PARIS (1L)
Description: This would be an extension of an already funded deployment. This option assumes upgrades to the ATM to enable flights at 20-25kft for greater coverage. Higher altitudes introduce some risk of schedule delays incurred by low lying clouds but margins have been included in the schedule.
Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 39
Estimated Aircraft Operations Costs ($k): 58
Integration Costs ($k): 0
Science Team Costs ($k): 100
Total Cost ($k): 330

Option 2: Medium altitude DC-8 flights of LVIS & GISMO/PARIS (Code 2M)
Description: This option would enable coverage of the entire continent. This option assumes that P-3 ATM flight continue high resolution time series.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 130/904
Estimated Aircraft Operations Costs ($k): 1937
Integration Costs ($k): 0
Science Team Costs ($k): 100
Total Cost ($k): 2955

Option 3: Medium altitude Global Hawk flights of LVIS and GISMO/PARIS (Code 5M)
Description: This option would demonstrate the utility of a UAS for providing extended range observations over all of Greenland and would be an extension of the mission described in 3.1.4.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 115/440
Estimated Aircraft Operations Costs ($k): 755
Integration Costs ($k): 0
Science Team Costs ($k): 100
Total Cost ($k): 1309

3.3 Antarctic sea ice and coastal glaciers

3.3.1 Antarctic sea ice and coastal glaciers Spring 2009

Option 1: Low altitude P-3 (Chilean) flights of ATM, LVIS and PARIS
Description: This option would follow on the success of the recently completed missions in Fall 2008 and repeat coverage of the Antarctic peninsula only.
Base of Operations: Puenta Arenas

Estimated Flight Hours/Cost ($k): TBD
Estimated Aircraft Operations Costs ($k): TBD
Integration Costs ($k): TBD
Science Team Costs ($k): TBD
Total Cost ($k): TBD

3.3.2 Antarctic sea ice and coastal glaciers Fall 2009

Option 1: Medium altitude DC-8 flights of ATM, LVIS, & GISMO/PARIS (2L)
Description: This option assumes upgrades to the DC-8 to provide antennae, upgrades to ATM, and a new LVIS integration. Sea ice tracks C & D are not accessible via this option.
Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/870
Estimated Aircraft Operations Costs ($k): 1801
Integration Costs ($k): 2775
Science Team Costs ($k): 1175
Total Cost ($k): 6549

Option 2: Medium altitude L-1011 flights of ATM, LVIS & GISMO/PARIS (9L)
Description: This option includes that a safe and airworthy pod can be designed for the belly to attach where Pegasus are interfaced and launched. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame.
Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1000
Estimated Aircraft Operations Costs ($k): 1200
Integration Costs ($k): 3669
Science Team Costs ($k): 1175

Total Cost ($k): 7044

3.3.3 Antarctic sea ice and coastal glaciers Spring 2010

Option 1: Medium altitude DC-8 flights of ATM, LVIS, & GISMO/PARIS (2L)
Description: This option assumes upgrades to the DC-8 to provide antennae, upgrades to ATM, and a new LVIS integration. Sea ice tracks C & D are not accessible via this option.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 145/896
Estimated Aircraft Operations Costs ($k): 1855
Integration Costs ($k): 0
Science Team Costs ($k): 1210
Total Cost ($k): 3961

Option 2: Medium altitude L-1011 flights of ATM, LVIS & GISMO/PARIS (9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1030
Estimated Aircraft Operations Costs ($k): 1236
Integration Costs ($k): 0
Science Team Costs ($k): 1210
Total Cost ($k): 3476

3.3.4 Antarctic sea ice and coastal glaciers Fall 2010

Option 1: Medium altitude DC-8 flights of ATM, LVIS, & GISMO/PARIS (2L)
Description: This option assumes upgrades to the DC-8 to provide antennae, upgrades to ATM, and a new LVIS integration. Sea ice tracks C & D are not accessible via this option.
Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/896
Estimated Aircraft Operations Costs ($k): 1855
Integration Costs ($k):
Science Team Costs ($k): 1210
Total Cost ($k): 3961

Option 2: Medium altitude HAIPER flights of ATM, LVIS/MFLL (6AB)
Description: Would require upgrades to ATM and new integrations for all instruments.

This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k): 1614
Science Team Costs ($k): 709
Total Cost ($k): 3544

Option 3: Medium altitude L-1011 flights of ATM, LVIS & GISMO/PARIS (9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1030
Estimated Aircraft Operations Costs ($k): 1236
Integration Costs ($k): 0
Science Team Costs ($k): 1210
Total Cost ($k): 3476

3.3.5 Antarctic sea ice and coastal glaciers Spring 2011

Option 1: Medium altitude DC-8 flights of ATM, LVIS, & GISMO/PARIS (2L)
Description: This option assumes upgrades to the DC-8 to provide antennae, upgrades to ATM, and a new LVIS integration. Sea ice tracks C & D are not accessible via this option.
Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 145/922
Estimated Aircraft Operations Costs ($k): 1910
Integration Costs ($k): 0
Science Team Costs ($k): 1246
Total Cost ($k): 4080

Option 2: Medium altitude HAIPER flights of ATM, LVIS (6AB)
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/323
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k): 0

Science Team Costs ($k): 709
Total Cost ($k): 1930

Option 3: Medium altitude Global Hawk flights of ATM, LVIS & GISMO/PARIS (Code 5L)
Description: We have identified an already existing radome that may enable LVIS integration but this option would require upgrades to ATM and MFLL. This option would enable coverage of all regions of interest.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 140/490
Estimated Aircraft Operations Costs ($k): 821
Integration Costs ($k): 2000
Science Team Costs ($k): 1246
Total Cost ($k): 4557

Option 4: Medium altitude L-1011 flights of ATM, LVIS & GISMO/PARIS (Code 9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1060
Estimated Aircraft Operations Costs ($k): 1273
Integration Costs ($k): 0
Science Team Costs ($k): 1210
Total Cost ($k): 3476

3.3.6 Antarctic sea ice and coastal glaciers Fall 2011

Option 1: Medium altitude DC-8 flights of ATM, LVIS, & GISMO/PARIS (2L)
Description: This option assumes upgrades to the DC-8 to provide antennae, upgrades to ATM, and a new LVIS integration. Sea ice tracks C & D are not accessible via this option.
Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/922
Estimated Aircraft Operations Costs ($k): 1910
Integration Costs ($k): 0
Science Team Costs ($k): 1246
Total Cost ($k): 4080

Option 2: Medium altitude HAIPER flights of ATM, LVIS/MFLL (6AB)
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/323
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k): 0
Science Team Costs ($k): 709
Total Cost ($k): 1930

Option 3: Medium altitude Global Hawk flights of ATM, LVIS & GISMO/PARIS (Code 5L)
Description: The Global Hawk project has identified an already existing Northrup Grumman radome that may facilitate LVIS integration but this option would require upgrades to ATM and MFLL. This option would enable coverage of all regions of interest.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 140/490
Estimated Aircraft Operations Costs ($k): 821
Integration Costs ($k): 2000
Science Team Costs ($k): 1246
Total Cost ($k): 4557

Option 4: Medium altitude L-1011 flights of ATM, LVIS/MFLL & GISMO/PARIS (9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1061
Estimated Aircraft Operations Costs ($k): 1236
Integration Costs ($k): 0
Science Team Costs ($k): 1210
Total Cost ($k): 3476

3.3.7 Antarctic sea ice and coastal glaciers Spring 2012

Option 1: Medium altitude DC-8 flights of ATM, LVIS & GISMO/PARIS (Code 2L)
Description: This option assumes upgrades to the DC-8 to provide antennae, upgrades to ATM, and a new LVIS integration. Sea ice tracks C & D are not accessible via this option.
Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/951
Estimated Aircraft Operations Costs ($k): 1968
Integration Costs ($k): 0
Science Team Costs ($k): 1284

Total Cost ($k): 4202

Option 2: Medium altitude HAIPER flights of ATM, LVIS/MFLL (6AB)
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/323
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k): 0
Science Team Costs ($k): 730
Total Cost ($k): 1951

Option 3: Medium altitude Global Hawk flights of ATM, LVIS & GISMO/PARIS (Code 5L)
Description: We have identified an already existing radome that may enable LVIS integration but this option would require upgrades to ATM and MFLL. This option would enable coverage of all regions of interest.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 140/505
Estimated Aircraft Operations Costs ($k): 846
Integration Costs ($k): 0
Science Team Costs ($k): 1283
Total Cost ($k): 2634

Option 4: Medium altitude L-1011 flights of ATM, LVIS/MFLL & GISMO/PARIS (9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1093
Estimated Aircraft Operations Costs ($k): 1311
Integration Costs ($k): 0
Science Team Costs ($k): 1284
Total Cost ($k): 3687

3.3.8 Antarctic sea ice and coastal glaciers Fall 2012

Option 1: Medium altitude DC-8 flights of ATM, LVIS & GISMO/PARIS (2L)

Description: This option assumes upgrades to the DC-8 to provide antennae, upgrades to ATM, and a new LVIS integration. Sea ice tracks C & D are not accessible via this option.

Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/951
Estimated Aircraft Operations Costs ($k): 1968
Integration Costs ($k): 0
Science Team Costs ($k): 1284
Total Cost ($k): 4202

Option 2: Medium altitude HAIPER flights of ATM, LVIS (6AB)
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/323
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k): 0
Science Team Costs ($k): 730
Total Cost ($k): 1951

Option 3: Medium altitude Global Hawk flights of ATM, LVIS & GISMO/PARIS (5L)
Description: We have identified an already existing radome that may enable LVIS integration but this option would require upgrades to ATM and MFLL. This option would enable coverage of all regions of interest.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 140/520
Estimated Aircraft Operations Costs ($k): 846
Integration Costs ($k): 0
Science Team Costs ($k): 1283
Total Cost ($k): 2634

Option 4: Medium altitude L-1011 flights of ATM, LVIS/MFLL & GISMO/PARIS
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1093
Estimated Aircraft Operations Costs ($k): 1311
Integration Costs ($k): 0
Science Team Costs ($k): 1284

Total Cost ($k): 3688

3.3.9 Antarctic sea ice and coastal glaciers Spring 2013

Option 1: Medium altitude DC-8 flights of ATM, LVIS, & GISMO/PARIS (2L)
Description: This option assumes upgrades to the DC-8 to provide antennae, upgrades to ATM, and a new LVIS integration. Sea ice tracks C & D are not accessible via this option.

Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/979
Estimated Aircraft Operations Costs ($k): 2027
Integration Costs ($k): 0
Science Team Costs ($k): 1322
Total Cost ($k): 4329

Option 2: Medium altitude HAIPER flights of ATM, LVIS (Code 6AB)
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/323
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k):
Science Team Costs ($k): 752
Total Cost ($k): 1973

Option 3: Medium altitude Global Hawk flights of ATM, LVIS/MFLL & GISMO/PARIS (Code 5L)
Description: We have identified an already existing radome that may enable LVIS integration but this option would require upgrades to ATM and MFLL. This option would enable coverage of all regions of interest.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 140/520
Estimated Aircraft Operations Costs ($k): 871
Integration Costs ($k):
Science Team Costs ($k): 1322
Total Cost ($k): 2713

Option 4: Medium altitude L-1011 flights of ATM, LVIS & GISMO/PARIS (Code 9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod.

NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1216
Estimated Aircraft Operations Costs ($k): 1350
Integration Costs ($k): 0
Science Team Costs ($k): 1322
Total Cost ($k): 3798

3.3.10 Antarctic sea ice and coastal glaciers Fall 2013

<u>Option 1: Medium altitude DC-8 flights of ATM, LVIS/MFLL, & GISMO/PARIS (Code 2L)</u>
Description: This option assumes upgrades to the DC-8 to provide antennae, upgrades to ATM, and a new LVIS integration. Sea ice tracks C & D are not accessible via this option.
Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/979
Estimated Aircraft Operations Costs ($k): 2027
Integration Costs ($k): 0
Science Team Costs ($k): 1322
Total Cost ($k): 4329

<u>Option 2: Medium altitude HAIPER flights of ATM, LVIS/MFLL (6AB)</u>
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/323
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k):
Science Team Costs ($k): 752
Total Cost ($k): 1973

<u>Option 3: Medium altitude Global Hawk flights of ATM, LVIS & GISMO/PARIS (Code 5L)</u>
Description: We have identified an already existing radome that may enable LVIS integration but this option would require upgrades to ATM and MFLL. This option would enable coverage of all regions of interest.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 140/520
Estimated Aircraft Operations Costs ($k): 871
Integration Costs ($k):

Science Team Costs ($k): 1322
Total Cost ($k): 2713

Option 4: Medium altitude L-1011 flights of ATM, LVIS/MFLL & GISMO/PARIS (Code 9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1126
Estimated Aircraft Operations Costs ($k): 1350
Integration Costs ($k): 0
Science Team Costs ($k): 1322
Total Cost ($k): 3798

3.3.11 Antarctic sea ice and coastal glaciers Spring 2014

Option 1: Medium altitude DC-8 flights of ATM, LVIS, & GISMO/PARIS (Code 2L)
Description: This option assumes upgrades to the DC-8 to provide antennae, upgrades to ATM, and a new LVIS integration. Sea ice tracks C & D are not accessible via this option.

Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/1009
Estimated Aircraft Operations Costs ($k): 2088
Integration Costs ($k): 0
Science Team Costs ($k): 1362
Total Cost ($k): 4459

Option 2: Medium altitude HAIPER flights of ATM, LVIS (6AB)
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/323
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k): 0
Science Team Costs ($k): 775
Total Cost ($k): 1996

Option 3: Medium altitude Global Hawk flights of ATM, LVIS & GISMO/PARIS (5L)

Description: We have identified an already existing radome that may enable LVIS integration but this option would require upgrades to ATM and MFLL. This option would enable coverage of all regions of interest.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 140/535
Estimated Aircraft Operations Costs ($k): 897
Integration Costs ($k): 0
Science Team Costs ($k): 1362
Total Cost ($k): 2795

Option 4: Medium altitude L-1011 flights of ATM, LVIS & GISMO/PARIS (Code 9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1159
Estimated Aircraft Operations Costs ($k): 1391
Integration Costs ($k): 0
Science Team Costs ($k): 1362
Total Cost ($k): 3913

3.3.12 Antarctic sea ice and coastal glaciers Fall 2014

Option 1: Medium altitude DC-8 flights of ATM, LVIS, & GISMO/PARIS (2L)
Description: This option assumes upgrades to the DC-8 to provide antennae, upgrades to ATM, and a new LVIS integration. Sea ice tracks C & D are not accessible via this option.

Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/1009
Estimated Aircraft Operations Costs ($k): 2088
Integration Costs ($k): 0
Science Team Costs ($k): 1362
Total Cost ($k): 4459

Option 2: Medium altitude HAIPER flights of ATM, LVIS/MFLL (6AB)
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered but this option would not provide radar sounding.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/323

Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k): 0
Science Team Costs ($k): 775
Total Cost ($k): 1996

Option 3: Medium altitude Global Hawk flights of ATM, LVIS & GISMO/PARIS (5L)
Description: We have identified an already existing radome that may enable LVIS integration but this option would require upgrades to ATM and MFLL. This option would enable coverage of all regions of interest.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 140/535
Estimated Aircraft Operations Costs ($k): 897
Integration Costs ($k): 0
Science Team Costs ($k): 1362
Total Cost ($k): 2795

Option 4: Medium altitude L-1011 flights of ATM, LVIS & GISMO/PARIS (9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/535
Estimated Aircraft Operations Costs ($k): 1391
Integration Costs ($k): 0
Science Team Costs ($k): 1362
Total Cost ($k): 3913

3.4 Antarctic sub-glacial lakes

3.4.1 Antarctic sub-glacial lakes Spring 2009

No current options exist for this time period given the need to integrate new instruments on either the DC-8, L-1011, or HAIPER and no project in place.

The cost estimates below represent the deployment costs of all Antarctic missions, including coverage of sea ice, coastal glacial outlets, and sub-glacial lakes within a 30 day period. If the sub-glacial lake missions are chosen separately the cost will be roughly half of the cost of the estimates below.

3.4.2 Antarctic sub-glacial lakes Fall 2009

Option 1: Medium altitude DC-8 flights of ATM, LVIS, GISMO/PARIS (2L)
Description: Assumes costs associated with new upgrades to ATM, MFFL, and the radars. This option would also require installation of new antennae system as described in section 3.3.x. All sub-glacial lakes but “Totten” are covered with this option.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 145/870
Estimated Aircraft Operations Costs ($k): 1801
Integration Costs ($k): 0 (Integration costs bookkept in Antarctic coastal)
Science Team Costs ($k): 1175
Total Cost ($k): 3846

Option 2: Medium altitude L-1011 flights of ATM, LVIS & GISMO/PARIS (9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1000
Estimated Aircraft Operations Costs ($k): 1200
Integration Costs ($k): 0
Science Team Costs ($k): 1175
Total Cost ($k): 3375

3.4.3 Antarctic sub-glacial lakes Spring 2010

Option 1: Medium altitude DC-8 flights of ATM, LVIS, GISMO/PARIS (Code 2L)
Description: Includes costs associated with new upgrades to ATM, MFFL, and the radars. This option would also require installation of new antennae system as described in section 3.3.x. All sub-glacial lakes but “Totten” are covered with this option.
Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/896
Estimated Aircraft Operations Costs ($k): 1855
Integration Costs ($k): 0
Science Team Costs ($k): 1210
Total Cost ($k): 3961

Option 2: Medium altitude L-1011 flights of ATM, LVIS/MFLL & GISMO/PARIS (Code 9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1030
Estimated Aircraft Operations Costs ($k): 1236
Integration Costs ($k): 0
Science Team Costs ($k):1210
Total Cost ($k): 3476

3.4.4 Antarctic sub-glacial lakes Fall 2010

<u>Option 1: Medium altitude DC-8 flights of ATM, LVIS/MFLL, GISMO/PARIS (2L)</u>
Description: Includes costs associated with new upgrades to ATM, MFFL, and the radars. This option would also require installation of new antennae system as described in section 3.3.x. All sub-glacial lakes but “Totten” are covered with this option.

Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/896
Estimated Aircraft Operations Costs ($k): 1855
Integration Costs ($k): 0
Science Team Costs ($k): 1210
Total Cost ($k): 3961

<u>Option 2: Medium altitude HAIPER flights of ATM & LVIS (6AB)</u>
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered but this option would not provide radar sounding.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/323
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k): 0
Science Team Costs ($k): 730
Total Cost ($k): 1951

<u>Option 3: Medium altitude L-1011 flights of ATM, LVIS & GISMO/PARIS (9L)</u>
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1030
Estimated Aircraft Operations Costs ($k): 1236
Integration Costs ($k): 0
Science Team Costs ($k):1210
Total Cost ($k): 3476

3.4.5 Antarctic sub-glacial lakes Spring 2011

Option 1: Medium altitude DC-8 flights of ATM, LVIS, GISMO/PARIS (2L)
Description: Includes costs associated with new upgrades to ATM, MFFL, and the radars. This option would also require installation of new antennae system as described in section 3.3.x. All sub-glacial lakes but "Totten" are covered with this option.

Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/923
Estimated Aircraft Operations Costs ($k): 1911
Integration Costs ($k):
Science Team Costs ($k): 1246
Total Cost ($k): 4080

Option 2: Medium altitude HAIPER flights of ATM & LVIS (6AB)
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered but this option would not provide radar sounding.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/323
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k): 0
Science Team Costs ($k): 752
Total Cost ($k): 1973

Option 3: Medium altitude Global Hawk flights of ATM, LVIS/MFLL & GISMO/PARIS (5L)
Description: This mission would require upgrades to the platform and instruments. The Global Hawk team has identified an already existing Northrup Grumman radome that may enable LVIS class integration. This option would enable coverage of all regions of interest.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 140/490
Estimated Aircraft Operations Costs ($k): 821
Integration Costs ($k): 0
Science Team Costs ($k): 1246
Total Cost ($k): 2557

Option 4: Medium altitude L-1011 flights of ATM, LVIS & GISMO/PARIS (Code 9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod.

NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1061
Estimated Aircraft Operations Costs ($k): 1273
Integration Costs ($k): 0
Science Team Costs ($k): 1246
Total Cost ($k): 3581

3.4.6 Antarctic sub-glacial lakes Fall 2011

<u>Option 1: Medium altitude DC-8 flights of ATM, LVIS/MFLL, GISMO/PARIS (Code 2L)</u>
Description: Includes costs associated with new upgrades to ATM, MFFL, and the radars. This option would also require installation of new antennae system as described in section 3.3.x. All sub-glacial lakes but “Totten” are covered with this option.

Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/923
Estimated Aircraft Operations Costs ($k): 1911
Integration Costs ($k):
Science Team Costs ($k): 1246
Total Cost ($k): 4080

<u>Option 2: Medium altitude HAIPER flights of ATM & LVIS (Code 6AB)</u>
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered but this option would not provide radar sounding.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/323
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k): 0
Science Team Costs ($k): 752
Total Cost ($k): 1973

<u>Option 3: Medium altitude Global Hawk flights of ATM, LVIS & GISMO/PARIS (Code 5L)</u>
Description: This mission would require upgrades to the platform and instruments. The Global Hawk team has identified an already existing Northrup Grumman radome that may enable LVIS class integration. This option would enable coverage of all regions of interest.

Base of Operations: Puenta Arenas/Christchurch

Estimated Flight Hours/Cost ($k): 140/490
Estimated Aircraft Operations Costs ($k): 821
Integration Costs ($k): 0
Science Team Costs ($k): 1246
Total Cost ($k): 2557

Option 4: Medium altitude L-1011 flights of ATM, LVIS & GISMO/PARIS (9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1061
Estimated Aircraft Operations Costs ($k): 1273
Integration Costs ($k): 0
Science Team Costs ($k): 1246
Total Cost ($k): 3581

3.4.7 Antarctic sub-glacial lakes Spring 2012

Option 1: Medium altitude DC-8 flights of ATM, LVIS, GISMO/PARIS (2L)
Description: Includes costs associated with new upgrades to ATM, MFFL, and the radars. This option would also require installation of new antennae system as described in section 3.3.x. All sub-glacial lakes but "Totten" are covered with this option.

Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/951
Estimated Aircraft Operations Costs ($k): 1968
Integration Costs ($k):
Science Team Costs ($k): 1283
Total Cost ($k): 4202

Option 2: Medium altitude HAIPER flights of ATM & LVIS (6AB)
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered but this option would not provide radar sounding.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/323
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k): 0
Science Team Costs ($k): 775
Total Cost ($k): 1996

Option 3: Medium altitude Global Hawk flights of ATM, LVIS & GISMO/PARIS (5L)
Description: This mission would require upgrades to the platform and instruments. The Global Hawk team has identified an already existing Northrup Grumman radome that may enable LVIS class integration. This option would enable coverage of all regions of interest.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 140/534
Estimated Aircraft Operations Costs ($k): 846
Integration Costs ($k): 0
Science Team Costs ($k): 1251
Total Cost ($k): 2630

Option 4: Medium altitude L-1011 flights of ATM, LVIS/MFLL & GISMO/PARIS (9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1093
Estimated Aircraft Operations Costs ($k): 1311
Integration Costs ($k): 0
Science Team Costs ($k): 1284
Total Cost ($k): 3688

3.4.8 Antarctic sub-glacial lakes Fall 2012

Option 1: Medium altitude DC-8 flights of ATM, LVIS, GISMO/PARIS (Code 2L)
Description: Includes costs associated with new upgrades to ATM, MFFL, and the radars. This option would also require installation of new antennae system as described in section 3.3.x. All sub-glacial lakes but “Totten” are covered with this option.

Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/951
Estimated Aircraft Operations Costs ($k): 1968
Integration Costs ($k): 0
Science Team Costs ($k): 1283
Total Cost ($k): 4202

Option 2: Medium altitude HAIPER flights of ATM & LVIS (Code 6AB)
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered but this option would not provide radar sounding.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/322
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k): 0
Science Team Costs ($k): 775
Total Cost ($k): 1996

Option 3: Medium altitude Global Hawk flights of ATM, LVIS/MFLL & GISMO/PARIS (Code 5L)
Description: This mission would require upgrades to the platform and instruments. The Global Hawk team has identified an already existing Northrup Grumman radome that may enable LVIS class integration. This option would enable coverage of all regions of interest.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 140/505
Estimated Aircraft Operations Costs ($k): 846
Integration Costs ($k): 0
Science Team Costs ($k): 1251
Total Cost ($k): 2630

Option 4: Medium altitude L-1011 flights of ATM, LVIS/MFLL & GISMO/PARIS (9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1093
Estimated Aircraft Operations Costs ($k): 1311
Integration Costs ($k): 0
Science Team Costs ($k): 1284
Total Cost ($k): 3688

3.4.9 Antarctic sub-glacial lakes Spring 2013

Option 1: Medium altitude DC-8 flights of ATM, LVIS/MFLL, GISMO/PARIS (Code 2L)
Description: Includes costs associated with new upgrades to ATM, MFFL, and the radars. This option would also require installation of new antennae system as described in section 3.3.x. All sub-glacial lakes but "Totten" are covered with this option.

Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/980
Estimated Aircraft Operations Costs ($k): 2027
Integration Costs ($k): 0

Science Team Costs ($k): 1322
Total Cost ($k): 4329

Option 2: Medium altitude HAIPER flights of ATM & LVIS (Code 6AB)
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered but this option would not provide radar sounding.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/323
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k): 0
Science Team Costs ($k): 798
Total Cost ($k): 2019

Option 3: Medium altitude Global Hawk flights of ATM, LVIS & GISMO/PARIS (Code 5L)
Description: This mission would require upgrades to the platform and instruments. The Global Hawk team has identified an already existing Northrup Grumman radome that may enable LVIS class integration. This option would enable coverage of all regions of interest.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 140/520
Estimated Aircraft Operations Costs ($k): 846
Integration Costs ($k): 0
Science Team Costs ($k): 1322
Total Cost ($k): 2688

Option 4: Medium altitude L-1011 flights of ATM, LVIS/MFLL & GISMO/PARIS (Code 9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1126
Estimated Aircraft Operations Costs ($k): 1350
Integration Costs ($k): 0
Science Team Costs ($k): 1322
Total Cost ($k): 3798

3.4.10 Antarctic sub-glacial lakes Fall 2013

Option 1: Medium altitude DC-8 flights of ATM, LVIS, GISMO/PARIS (Code 2L)
Description: Includes costs associated with new upgrades to ATM, MFFL, and the radars. This option would also require installation of new antennae system as described in section 3.3.x. All sub-glacial lakes but "Totten" are covered with this option.

Base of Operations: Puenta Arenas
Estimated Flight Hours/Cost ($k): 145/980
Estimated Aircraft Operations Costs ($k): 2027
Integration Costs ($k): 0
Science Team Costs ($k): 1322
Total Cost ($k): 4329

Option 2: Medium altitude HAIPER flights of ATM & LVIS (Code 6AB)
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered but this option would not provide radar sounding.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/323
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k): 0
Science Team Costs ($k): 798
Total Cost ($k): 2019

Option 3: Medium altitude Global Hawk flights of ATM, LVIS/MFLL & GISMO/PARIS (Code 5L)
Description: This mission would require upgrades to the platform and instruments. The Global Hawk team has identified an already existing Northrup Grumman radome that may enable LVIS class integration. This option would enable coverage of all regions of interest.
Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 140/520
Estimated Aircraft Operations Costs ($k): 846
Integration Costs ($k): 0
Science Team Costs ($k): 1322
Total Cost ($k): 2688

Option 4: Medium altitude L-1011 flights of ATM, LVIS/MFLL & GISMO/PARIS (Code 9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch

Estimated Flight Hours/Cost ($k): 200/1126
Estimated Aircraft Operations Costs ($k): 1350
Integration Costs ($k): 0
Science Team Costs ($k): 1322
Total Cost ($k): 3798

3.4.11 Antarctic sub-glacial lakes Spring 2014

Option 1: Medium altitude DC-8 flights of ATM, LVIS/MFLL, GISMO/PARIS (Code 2L)
Description: Includes costs associated with new upgrades to ATM, MFFL, and the radars. This option would also require installation of new antennae system as described in section 3.3.x. All sub-glacial lakes but "Totten" are covered with this option.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 145/1009
Estimated Aircraft Operations Costs ($k): 2088
Integration Costs ($k): 0
Science Team Costs ($k): 1362
Total Cost ($k): 4459

Option 2: Medium altitude HAIPER flights of ATM & LVIS (Code 6AB)
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered but this option would not provide radar sounding.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/323
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k): 0
Science Team Costs ($k): 822
Total Cost ($k): 2043

Option 3: Medium altitude Global Hawk flights of ATM, LVIS & GISMO/PARIS (5L)
Description: This mission would require upgrades to the platform and instruments. The Global Hawk team has identified an already existing Northrup Grumman radome that may enable LVIS class integration. This option would enable coverage of all regions of interest.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 140/535
Estimated Aircraft Operations Costs ($k): 871
Integration Costs ($k): 0
Science Team Costs ($k): 1362

Total Cost ($k): 2769

Option 4: Medium altitude L-1011 flights of ATM, LVIS/MFLL & GISMO/PARIS (Code 9L)
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1159
Estimated Aircraft Operations Costs ($k): 1391
Integration Costs ($k): 0
Science Team Costs ($k): 1362
Total Cost ($k): 3912

3.4.12 Antarctic sub-glacial lakes Fall 2014

Option 1: Medium altitude DC-8 flights of ATM, LVIS/MFLL, GISMO/PARIS (Code 2L)
Description: Includes costs associated with new upgrades to ATM, MFFL, and the radars. This option would also require installation of new antennae system as described in section 3.3.x. All sub-glacial lakes but “Totten” are covered with this option.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 145/1009
Estimated Aircraft Operations Costs ($k): 2088
Integration Costs ($k): 0
Science Team Costs ($k): 1362
Total Cost ($k): 4459

Option 2: Medium altitude HAIPER flights of ATM & LVIS/MFLL (Code 6AB)
Description: Would require upgrades to ATM and new integrations for all instruments. This option would require interagency cooperation with NSF and NCAR, the operating organization. All regions of interest can be covered but this option would not provide radar sounding.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 96/323
Estimated Aircraft Operations Costs ($k): 898
Integration Costs ($k): 0
Science Team Costs ($k): 822
Total Cost ($k): 2043

Option 3: Medium altitude Global Hawk flights of ATM, LVIS/MFLL & GISMO/PARIS (Code 5L)

Description: This mission would require upgrades to the platform and instruments. The Global Hawk team has identified an already existing Northrup Grumman radome that may enable LVIS class integration. This option would enable coverage of all regions of interest.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 140/535
Estimated Aircraft Operations Costs ($k): 871
Integration Costs ($k): 0
Science Team Costs ($k): 1362
Total Cost ($k): 2769

<u>Option 4: Medium altitude L-1011 flights of ATM, LVIS & GISMO/PARIS (Code 9L)</u>
Description: This option assumes that the upfront cost for the pod have been paid for in year 2009. This would require upgrades to instruments and new integrations in the pod. NASA has an existing Blanket Purchase Agreement with Orbital but contracting and safety reviews may be a challenge in this time frame. No data on coverage.

Base of Operations: Puenta Arenas/Christchurch
Estimated Flight Hours/Cost ($k): 200/1159
Estimated Aircraft Operations Costs ($k): 1391
Integration Costs ($k): 0
Science Team Costs ($k): 1362
Total Cost ($k): 3912

3.5 Southeast Alaskan glaciers

3.5.1 Southeast Alaskan glaciers Spring 2009

<u>Option 1: Low altitude Twin Otter flights of ATM (Code 7A)</u>
Description: These areas were previously flown by ATM in 2005 and so cost estimates are reliable and no additional integrations are required. All regions can be covered.

Base of Operations: TBD
Estimated Flight Hours/Cost ($k): 120/117
Estimated Aircraft Operations Costs ($k): 100
Integration Costs ($k):
Science Team Costs ($k): 170
Total Cost ($k): 387

<u>Option 2: Medium altitude G-III flights of Ka-Band UAVSAR (Code 3K)</u>
Description: This option would require an extended operations prior to or following the planned Greenland deployment in Spring 2009. This prototype instrument will require significant modifications to become operational beyond Spring 2009. All regions can be covered.

Base of Operations: DFRC
Estimated Flight Hours/Cost ($k): 82/205
Estimated Aircraft Operations Costs ($k): 341
Integration Costs ($k): 0
Science Team Costs ($k): 170
Total Cost ($k): 646

3.5.2 Southeast Alaskan glaciers Fall 2009

Option 1: Low altitude Twin Otter flights of ATM (Code 7A)
Description: These areas were previously flown by ATM in 2005 and so cost estimates are reliable and no additional integrations are required. All regions can be covered.

Base of Operations: TBD
Estimated Flight Hours/Cost ($k): 120/117
Estimated Aircraft Operations Costs ($k): 100
Integration Costs ($k):
Science Team Costs ($k): 170
Total Cost ($k): 387

Option 2: Medium altitude G-III flights of Ka-Band UAVSAR (Code 3K)
Description: This option includes costs associated with building an operational capability. All regions can be covered.

Base of Operations: DFRC
Estimated Flight Hours/Cost ($k): 82/205
Estimated Aircraft Operations Costs ($k): 341
Integration Costs ($k): 0
Science Team Costs ($k): 170
Total Cost ($k): 646

Option 3: Low/Medium altitude Lear 25 flights of SIMPL, MFLL or other commercial sensor (10N)
Description: SIMPL has already been integrated, but other instruments would require a new integration and upgrades. All regions covered.
Base of Operations: Juneau
Estimated Flight Hours/Cost ($k): 73/183
Estimated Aircraft Operations Costs ($k): 332
Integration Costs ($k): 0
Science Team Costs ($k): 79
Total Cost ($k): 593

3.5.3 Southeast Alaskan glaciers Spring 2010

Option 1: Low altitude Twin Otter flights of ATM (Code 7A)

Description: These areas were previously flown by ATM in 2005 and so cost estimates are reliable and no additional integrations are required. All regions can be covered.

Base of Operations: TBD
Estimated Flight Hours/Cost ($k): 120/124
Estimated Aircraft Operations Costs ($k): 103
Integration Costs ($k): 0
Science Team Costs ($k): 175
Total Cost ($k): 398

Option 2: Medium altitude G-III flights of Ka-Band UAVSAR (3K)
Description: This option includes costs associated with building an operational capability. All regions can be covered.

Base of Operations: DFRC
Estimated Flight Hours/Cost ($k): 82/217
Estimated Aircraft Operations Costs ($k): 351
Integration Costs ($k):
Science Team Costs ($k): 103
Total Cost ($k): 665

Option 3: Low/Medium altitude Lear 25 flights of SIMPL, MFLL or other commercial (Code 10N)
Description: SIMPL has already been integrated, but other instruments would require a new integration and upgrades. All regions covered.

Base of Operations: Juneau
Estimated Flight Hours/Cost ($k): 73/183
Estimated Aircraft Operations Costs ($k): 332
Integration Costs ($k): 0
Science Team Costs ($k): 79
Total Cost ($k): 593

3.5.4 Southeast Alaskan glaciers Fall 2010

Option 1: Low altitude Twin Otter flights of ATM (7A)
Description: These areas were previously flown by ATM in 2005 and so cost estimates are reliable and no additional integrations are required. All regions can be covered.

Base of Operations: TBD
Estimated Flight Hours/Cost ($k): 120/120
Estimated Aircraft Operations Costs ($k): 103
Integration Costs ($k): 0
Science Team Costs ($k): 175
Total Cost ($k): 398

Option 2: Medium altitude G-III flights of Ka-Band UAVSAR (3K)
Description: This option includes costs associated with building an operational capability. All regions can be covered.

Base of Operations: DFRC
Estimated Flight Hours/Cost ($k): 82/211
Estimated Aircraft Operations Costs ($k): 351
Integration Costs ($k):
Science Team Costs ($k): 103
Total Cost ($k): 665

Option 3: Low/Medium altitude Lear 25 flights of SIMPL, MFLL or other commercial (Code 10N)
Description: SIMPL has already been integrated, but other instruments would require a new integration and upgrades. All regions covered.

Base of Operations: Juneau
Estimated Flight Hours/Cost ($k): 73/183
Estimated Aircraft Operations Costs ($k): 332
Integration Costs ($k): 0
Science Team Costs ($k): 79
Total Cost ($k): 594

3.5.5 Southeast Alaskan glaciers Spring 2011

Option 1: Low altitude Twin Otter flights of ATM (Code 7A)
Description: These areas were previously flown by ATM in 2005 and so cost estimates are reliable and no additional integrations are required. All regions can be covered.

Base of Operations: TBD
Estimated Flight Hours/Cost ($k): 120/124
Estimated Aircraft Operations Costs ($k): 109
Integration Costs ($k):
Science Team Costs ($k): 180
Total Cost ($k): 410

Option 2: Medium altitude G-III flights of Ka-Band UAVSAR (Code 3K)
Description: This option includes costs associated with building an operational capability. All regions can be covered.

Base of Operations: DFRC
Estimated Flight Hours/Cost ($k): 82/217
Estimated Aircraft Operations Costs ($k): 362
Integration Costs ($k): 0
Science Team Costs ($k): 107
Total Cost ($k): 685

Option 3: Low/Medium altitude Lear 25 flights of SIMPL, MFLL or other commercial (Code 10N)
Description: SIMPL has already been integrated, but other instruments would require a new integration and upgrades. All regions covered.

Base of Operations: Juneau
Estimated Flight Hours/Cost ($k): 73/188
Estimated Aircraft Operations Costs ($k): 342
Integration Costs ($k): 0
Science Team Costs ($k): 79
Total Cost ($k): 608

Option 4: Low/Medium altitude S-3B flights of SIMPL, MFLL or other commercial (4N)
Description: This option would make use of this newly modified platform and provide an opportunity to testbed operational data production from these instruments that are currently in development.

Base of Operations: Anchorage
Estimated Flight Hours/Cost ($k): 70/245
Estimated Aircraft Operations Costs ($k): 398
Integration Costs ($k): 2500 (if not covered by Greenland deployments)
Science Team Costs ($k): 79
Total Cost ($k): 722 (w/o integration costs)

3.5.6 Southeast Alaskan glaciers Fall 2011

Option 1: Low altitude Twin Otter flights of ATM (7A)
Description: These areas were previously flown by ATM in 2005 and so cost estimates are reliable and no additional integrations are required. All regions can be covered.

Base of Operations: TBD
Estimated Flight Hours/Cost ($k): 120/124
Estimated Aircraft Operations Costs ($k): 107
Integration Costs ($k):
Science Team Costs ($k): 180
Total Cost ($k): 410

Option 2: Medium altitude G-III flights of Ka-Band UAVSAR (3K)
Description: This option includes costs associated with building an operational capability. All regions can be covered.

Base of Operations: DFRC
Estimated Flight Hours/Cost ($k): 82/217
Estimated Aircraft Operations Costs ($k): 362

Integration Costs ($k): 0
Science Team Costs ($k): 107
Total Cost ($k): 685

Option 3: Low/Medium altitude Lear 25 flights of SIMPL, MFLL or other commercial (10N)
Description: SIMPL has already been integrated, but other instruments would require a new integration and upgrades. All regions covered.

Base of Operations: Juneau
Estimated Flight Hours/Cost ($k): 73/188
Estimated Aircraft Operations Costs ($k): 342
Integration Costs ($k): 0
Science Team Costs ($k): 79
Total Cost ($k): 608

Option 4: Low/Medium altitude S-3B flights of SIMPL, MFLL or other commercial (4N)
Description: This mission would take advantage of payloads already integrated and flown over Greenland

Base of Operations: Anchorage
Estimated Flight Hours/Cost ($k): 70/245
Estimated Aircraft Operations Costs ($k): 398
Integration Costs ($k): 0
Science Team Costs ($k): 79
Total Cost ($k): 722

3.5.7 Southeast Alaskan glaciers Spring 2012

Option 1: Low altitude Twin Otter flights of ATM (Code 7A)
Description: These areas were previously flown by ATM in 2005 and so cost estimates are reliable and no additional integrations are required. All regions can be covered.

Base of Operations: TBD
Estimated Flight Hours/Cost ($k): 120/127
Estimated Aircraft Operations Costs ($k): 109
Integration Costs ($k): 0
Science Team Costs ($k): 186
Total Cost ($k): 422

Option 2: Medium altitude G-III flights of Ka-Band UAVSAR (Code 3K)
Description: This option includes costs associated with building an operational capability. All regions can be covered.

Base of Operations: Thule
Estimated Flight Hours/Cost ($k): 82/224

Estimated Aircraft Operations Costs ($k): 373
Integration Costs ($k): 0
Science Team Costs ($k): 109
Total Cost ($k): 706

Option 3: Low/Medium altitude Lear 25 flights of SIMPL, MFLL or other commercial (Code 10N)
Description: SIMPL has already been integrated, but other instruments would require a new integration and upgrades. All regions covered.

Base of Operations: Juneau
Estimated Flight Hours/Cost ($k): 73/194
Estimated Aircraft Operations Costs ($k): 352
Integration Costs ($k): 0
Science Team Costs ($k): 81
Total Cost ($k): 627

Option 4: Low/Medium altitude S-3B flights of SIMPL, MFLL or other commercial (4N)
Description: This mission would take advantage of payloads already integrated and flown over Greenland

Base of Operations: Anchorage
Estimated Flight Hours/Cost ($k): 70/252
Estimated Aircraft Operations Costs ($k): 409
Integration Costs ($k): 0
Science Team Costs ($k): 81
Total Cost ($k): 743

3.5.8 Southeast Alaskan glaciers Fall 2012

Option 1: Low altitude Twin Otter flights of ATM (7A)
Description: These areas were previously flown by ATM in 2005 and so cost estimates are reliable and no additional integrations are required. All regions can be covered.

Base of Operations: TBD
Estimated Flight Hours/Cost ($k): 120/127
Estimated Aircraft Operations Costs ($k): 109
Integration Costs ($k): 0
Science Team Costs ($k): 186
Total Cost ($k): 422

Option 2: Medium altitude G-III flights of Ka-Band UAVSAR (3K)
Description: This option includes costs associated with building an operational capability. All regions can be covered.

Base of Operations: DFRC
Estimated Flight Hours/Cost ($k): 82/224
Estimated Aircraft Operations Costs ($k): 373
Integration Costs ($k): 0
Science Team Costs ($k): 109
Total Cost ($k): 706

Option 3: Low/Medium altitude Lear 25 flights of SIMPL, MFLL or other commercial (Code 10N)
Description: SIMPL has already been integrated, but other instruments would require a new integration and upgrades. All regions covered.

Base of Operations: Juneau
Estimated Flight Hours/Cost ($k): 73/194
Estimated Aircraft Operations Costs ($k): 352
Integration Costs ($k): 0
Science Team Costs ($k): 81
Total Cost ($k): 627

Option 4: Low/Medium altitude S-3B flights of SIMPL, MFLL or other commercial (4N)
Description: This mission would take advantage of payloads already integrated and flown over Greenland

Base of Operations: Anchorage
Estimated Flight Hours/Cost ($k): 70/252
Estimated Aircraft Operations Costs ($k): 409
Integration Costs ($k): 0
Science Team Costs ($k): 81
Total Cost ($k): 743

3.5.9 Southeast Alaskan glaciers Spring 2013

Option 1: Low altitude Twin Otter flights of ATM (Code 7A)
Description: These areas were previously flown by ATM in 2005 and so cost estimates are reliable and no additional integrations are required. All regions can be covered.

Base of Operations: TBD
Estimated Flight Hours/Cost ($k): 120/131
Estimated Aircraft Operations Costs ($k): 113
Integration Costs ($k): 0
Science Team Costs ($k): 191
Total Cost ($k): 435

Option 2: Medium altitude G-III flights of Ka-Band UAVSAR (Code 3K)
Description: This option includes costs associated with building an operational capability. All regions can be covered.

Base of Operations: DFRC
Estimated Flight Hours/Cost ($k): 82/204
Estimated Aircraft Operations Costs ($k): 383
Integration Costs ($k): 0
Science Team Costs ($k): 112
Total Cost ($k): 727

Option 3: Low/Medium altitude Lear 25 flights of SIMPL, MFLL or other commercial (Code 10N)
Description: SIMPL has already been integrated, but other instruments would require a new integration and upgrades. All regions covered.

Base of Operations: Juneau
Estimated Flight Hours/Cost ($k): 73/199
Estimated Aircraft Operations Costs ($k): 362
Integration Costs ($k): 0
Science Team Costs ($k): 83
Total Cost ($k): 646

Option 4: Low/Medium altitude S-3B flights of SIMPL, MFLL or other commercial (Code 3N)
Description: This mission would take advantage of payloads already integrated and flown over Greenland

Base of Operations: Anchorage
Estimated Flight Hours/Cost ($k): 70/260
Estimated Aircraft Operations Costs ($k): 421
Integration Costs ($k): 0
Science Team Costs ($k): 83
Total Cost ($k): 765

3.5.10 Southeast Alaskan glaciers Fall 2013

Option 1: Low altitude Twin Otter flights of ATM (Code 7A)
Description: These areas were previously flown by ATM in 2005 and so cost estimates are very reliable and no additional new integration work is required. All regions can be covered.

Base of Operations: TBD
Estimated Flight Hours/Cost ($k): 120/131
Estimated Aircraft Operations Costs ($k): 113
Integration Costs ($k): 0
Science Team Costs ($k): 191
Total Cost ($k): 435

Option 2: Medium altitude G-III flights of Ka-Band UAVSAR (Code 3K)
Description: This option includes costs associated with building an operational capability. All regions can be covered.

Base of Operations: DFRC
Estimated Flight Hours/Cost ($k): 82/231
Estimated Aircraft Operations Costs ($k): 383
Integration Costs ($k): 0
Science Team Costs ($k): 112
Total Cost ($k): 727

Option 3: Low/Medium altitude Lear 25 flights of SIMPL, MFLL or other commercial (Code 10N)
Description: SIMPL has already been integrated, but other instruments would require a new integration and upgrades. All regions covered.

Base of Operations: Juneau
Estimated Flight Hours/Cost ($k): 73/199
Estimated Aircraft Operations Costs ($k): 362
Integration Costs ($k): 0
Science Team Costs ($k): 83
Total Cost ($k): 646

Option 4: Low/Medium altitude S-3B flights of SIMPL, MFLL or other commercial (Code 4N)
Description: This mission would take advantage of payloads already integrated and flown over Greenland

Base of Operations: Anchorage
Estimated Flight Hours/Cost ($k): 70/260
Estimated Aircraft Operations Costs ($k): 421
Integration Costs ($k): 0
Science Team Costs ($k): 83
Total Cost ($k): 765

3.5.11 Southeast Alaskan glaciers Spring 2014

Option 1: Low altitude Twin Otter flights of ATM (7A)
Description: These areas were previously flown by ATM in 2005 and so cost estimates are reliable and no additional integrations are required. All regions can be covered.

Base of Operations: TBD
Estimated Flight Hours/Cost ($k): 120/135
Estimated Aircraft Operations Costs ($k): 116
Integration Costs ($k): 0

Science Team Costs ($k): 197
Total Cost ($k): 448

Option 2: Medium altitude G-III flights of Ka-Band UAVSAR (3K)
Description: This option includes costs associated with building an operational capability. All regions can be covered.

Base of Operations: DFRC
Estimated Flight Hours/Cost ($k): 82/238
Estimated Aircraft Operations Costs ($k): 395
Integration Costs ($k): 0
Science Team Costs ($k): 116
Total Cost ($k): 749

Option 3: Low/Medium altitude Lear 25 flights of SIMPL, MFLL or other commercial (Code 10N)
Description: SIMPL has already been integrated, but other instruments would require a new integration and upgrades. All regions covered.

Base of Operations: Juneau
Estimated Flight Hours/Cost ($k): 73/205
Estimated Aircraft Operations Costs ($k): 374
Integration Costs ($k): 0
Science Team Costs ($k): 86
Total Cost ($k): 665

Option 4: Low/Medium altitude S-3B flights of SIMPL, MFLL or other commercial (Code 4N)
Description: This mission would take advantage of payloads already integrated and flown over Greenland

Base of Operations: Anchorage
Estimated Flight Hours/Cost ($k): 70/268
Estimated Aircraft Operations Costs ($k): 434
Integration Costs ($k): 0
Science Team Costs ($k): 86
Total Cost ($k): 788

3.5.12 Southeast Alaskan glaciers Fall 2014

Option 1: Low altitude Twin Otter flights of ATM (Code 7A)
Description: These areas were previously flown by ATM in 2005 and so cost estimates are reliable and no additional integrations are required. All regions can be covered.

Base of Operations: TBD
Estimated Flight Hours/Cost ($k): 120/135

Estimated Aircraft Operations Costs ($k): 116
Integration Costs ($k): 0
Science Team Costs ($k): 197
Total Cost ($k): 448

Option 2: Medium altitude G-III flights of Ka-Band UAVSAR (Code 3K)
Description: This option includes costs associated with building an operational capability. All regions can be covered.

Base of Operations: DFRC
Estimated Flight Hours/Cost ($k): 82/238
Estimated Aircraft Operations Costs ($k): 395
Integration Costs ($k): 0
Science Team Costs ($k): 116
Total Cost ($k): 749

Option 3: Low/Medium altitude Lear 25 flights of SIMPL, MFLL or other commercial (Code 10N)
Description: SIMPL has already been integrated, but other instruments would require a new integration and upgrades. All regions covered.

Base of Operations: Juneau
Estimated Flight Hours/Cost ($k): 73/205
Estimated Aircraft Operations Costs ($k): 374
Integration Costs ($k): 0
Science Team Costs ($k): 86
Total Cost ($k): 665

Option 4: Low/Medium altitude S-3B flights of SIMPL, MFLL or other commercial (Code 4N)
Description: This mission would take advantage of payloads already integrated and flown over Greenland

Base of Operations: Anchorage
Estimated Flight Hours/Cost ($k): 70/268
Estimated Aircraft Operations Costs ($k): 434
Integration Costs ($k): 0
Science Team Costs ($k): 86
Total Cost ($k): 788

4 Summary

This report provides a set of airborne options for providing ICESat-like data from aircraft in order to provide ice altimetry data, through the launch of ICEsat 2 in 2014, over priority regions of the Arctic and Antarctic. The ICEsat science team has provided recommendations on areas that should be covered in order to preserve the integrity of the long term data record. Airborne missions could cover an estimated 90% of the total area required by Fall 2009 and 100% of the total areas by Fall 2010.

The summary table below provides an example of a mission series that might be implemented from the options above. The yearly mission totals represent Spring and Fall missions in each year, and include 1) aircraft operations, 2) integration costs derived from instrument and platform teams, and 3) science team participation during the mission. Non-recurring engineering is described in Table 6 and these estimates are included in the mission totals.

It should be noted that in 2011 there is a significant investment in new integration work on the new Global Hawk and S-3 platforms in anticipation of the maturity of a number of new instruments including SIMPL (Harding), SMLA (Yu), PCL (Gogineni) and MFLL Mark II (Dobbs). This implementation assumes a fly-off in 2011 to determine the best platform payload combinations for any given region.

One of many caveats is that such an aggressive program will likely prevent other science disciplines from having access to these platforms. Significant coordination will be required with the National Science Foundation (NSF) for Antarctic operations and use of the HAIPER for near term coverage of all Antarctic priority regions. A strong relationship with the Department of Defense will also be necessary to enable airlifts of opportunity.

Lastly, it should be noted that because this activity will likely benefit instrument selection and algorithm development for DESDyni, ICEsat 2, and LIST, there could be certain portions of the instrument down-select, or entire missions that might be covered under one of these mission lines to offset these estimates.

Flight Configurations	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**Totals**
Greenland	1L,1M, 3H; 1L	1L; 1L	1L,4N; 1L,4N	1L; 1L	1L; 1L	1L; 1L	
Arctic Sea Ice	1L; 1L	1L; 1L	1L; 1L	1L; 1L	1L; 1L	1L; 1L	
Antarctic sub-glacial	0; 0	2L; 6AB	6AB; 5L	5L; 5L	5L; 5L	5L; 5L	
Antarctic coastal	0; 2L	2L; 6AB	6AB; 5L	5L; 5L	5L; 5L	5L; 5L	
Alaska SE	7A, 3H; 7A, 3K	7A; 7A	7A; 7A	7A; 7A	7A; 7A	7A; 7A	
ROM Mission Costs	($k)	($k)	($k)	($k)	($k)	($k)	($k)
Greenland	$4,495	$3,259	$5,047	$3,492	$3,636	$3,744	**$23,673**
Arctic Sea Ice	$580	$596	$602	$620	$640	$658	**$3,696**
Antarctica	$6,549	$7,505	$6,487	$5,268	$5,426	$5,588	**$36,823**
Alaska SE	$2,066	$796	$820	$844	$870	$896	**$6,292**
Additional Costs	($k)	($k)	($k)	($k)	($k)	($k)	($k)
GH grnd st'n	$3,000	$2,000	$1,000				**$6,000**
GH AV-7		$3,000	$1,000				**$4,000**
GHM L&R	$4,000	$2,000					**$6,000**
Duplicate ATM & LVIS	$1,000						**$1,000**
FTEs ($250/yr/ea)	$625	$1,000	$1,125	$875	$875	$875	**$5,375**
WYEs ($250/yr/ea)	$1,125	$1,875	$2,125	$1,625	$1,625	$1,625	**$10,000**
Reserves (15%)	$3,516	$3,305	$2,731	$1,909	$1,961	$2,008	**$15,429**
Totals by year	**$26,956**	**$25,336**	**$20,937**	**$14,633**	**$15,033**	**$15,394**	**$118,288**

Notes:

1) x;x denotes option by season (Spring; Fall)
2) Ka-SAR/G-III flights in Greenland Spring 2009 are in-kind
3) Instrument/Aircraft downselect occurs in 2011
4) Coverage of arctic sea ice is a 1 month extension of yearly P-3 deployments to Greenland
5) The Antarctica estimate encompasses sea ice, coastal, and sub-glacial lakes
6) Assumes routine in-kind airlifts of opportunity from DoD (~$8-10M)

Table 4: Flight configurations and budget details for one example of a reasonable program implementation

Code	Instrument	Type	PI
A	ATM	Laser altimeter	Krabill
B	LVIS	Laser altimeter	Blair
C	MFFL	Laser altimeter	Dobbs/ITT
D	Ice roughess profilometer	Laser altimeter	Maslanik
E	SIMPL	Laser altimeter	Harding
F	PCL	Laser altimeter	Gogineni
G	Mapping Laser Altimeter	Laser altimeter	Yu
H	Ka-band UAVSAR	Radar sounder	Moller
I	PARIS	Radar sounder	Raney
J	GISMO	Radar sounder	Jezek / Gogineni
K	ultrawideband Ku	Radar sounder	Gogineni
L	ATM, LVIS, GISMO/PARIS	Combination	Team
M	LVIS, GISMO/PARIS	Combination	Team
N	SIMPL, SMLA, MFLL, PCL	Combination	Team
O	GISMO/PARIS	Combination	Team

Code	Platform
1	P-3
2	DC-8
3	G-3
4	S-3
5	Global Hawk
6	HAIPER (NSF)
7	B/200/Twin Otter
8	SUAS
9	L-1011
10	Lear 25

Table 5: Platform/payload configuration codes for Table 4 above

Instrument	2009	2010	2011	2012	2013	2014	Total
ATM	510						
LVIS	740	325	2500				
GISMO	600						
PARIS	2600						
SIMPL			2500				
	4450	325	2500				**7275**

Notes
ATM includes P-3 & DC-8
LVIS includes DC-8, P-3, and GH
SIMPL is a placeholder for GH integration of new instruments

Table 6: Estimated non-recurring engineering for platform/payload combinations described in Table 4 above.