

Summer 2016 IceBridge Falcon Flight Plans
8 July 2016 Draft

compiled by

John Sonntag

Introduction to Flight Plans

This document is a translation of the NASA Operation IceBridge (OIB) scientific objectives articulated in the Level 1 OIB Science Requirements, at the June IceBridge planning meeting held at the University of California - Irvine, through official science team telecons and through e-mail communication and iterations into a series of operationally realistic flight plans, intended to be flown by NASA's HU-25A Falcon ("NASA-524") aircraft. The campaign will be split into two parts. The first part will be based in Barrow, Alaska during the latter part of July and will focus on sea ice in the Beaufort Sea. The second part will be based in Kangerlussuaq, Greenland and will begin in late August and end in mid-September 2016. Note that we cannot base the Falcon aircraft in Thule during this time period, as we did in 2015, due to ongoing summer runway construction work there.

The Barrow sea ice missions will be planned and conducted in a manner different from previous IceBridge campaigns. We expect the sea ice conditions in the Beaufort Sea to be highly variable, and also somewhat unpredictable from several weeks prior to the deployment. We also expect weather conditions to be challenging, with extensive summer cloud cover present. For these reasons we do not present set flight plans at this point. The flight plans will be created in response to conditions within a few days of the flights themselves.

For each planned land ice mission, we give a map and brief text description for the mission. The missions are planned to be flown from Kangerlussuaq, Greenland. A careful reader may notice that some of the mission maps in the main part of the document highlight flightlines in green, yellow, and red colors, while other only show the black lines. The colors are a refinement added to the flight plans at a late stage of design which help the field team navigate the aircraft properly to achieve specific science goals. The colors represent the degree of "straightness" of each flight segment, where straight segments are steered using an automated technique and curved sections using a specialized manual method. Not all of the flight plans shown here have necessarily reached that mature stage of design.

This field campaign differs significantly from most prior OIB campaigns, in that we will be flying a relatively small twin-engine jet Falcon aircraft. Our use of the Falcon imposes several important operational necessities. First, its limited payload means that we will fly only two instruments – a single ATM lidar, and the DMS camera system. The DMS will be operated only for the Barrow portion of the campaign, while ATM's "Cambot" nadir camera system will be installed for the Kangerlussuaq portion of the deployment. Second, we will fly at high altitude for the Kangerlussuaq land ice missions (at least 20,000 ft above ground), since flying lower would impose unacceptable limitations on range. For Barrow, we plan to transit from Barrow to the ice edge at high altitude, then drop down to 1500' AGL to conduct the science surveys. Third, the Falcon is shorter-ranged than the P-3 or C-130 even at high-altitude, able to cover approximately 1400 nm per mission rather than the 2000 nm typical for P-3 and C-130 flights. Thus we have redesigned the flights to reduce their length, we have avoided missions primarily designed around radar measurements, and we have largely eliminated science targets difficult to address from high altitude, such as glacier centerlines with significant curvature.

Note that this document shows 16 planned land ice missions, which is more than we expect to fly this year. The extra flight plans give us operational flexibility to fly as much as possible, and scientifically productive, while we are in the field.

IceBridge Mission Statement

Operation IceBridge will employ aircraft to monitor the most sensitive and critical areas of sea ice, ice sheets and glaciers during the gap in satellite coverage caused by the failure of ICESat-1, in 2009, and the launch of ICESat-2, planned for 2016. Sensitive and critical areas include coastal Greenland and especially its outlet glaciers, coastal Antarctica including the Antarctic Peninsula and ice shelves, the sea ice of the Arctic and Antarctic and the southeast Alaskan glaciers. Data collected by IceBridge will improve our knowledge of the contribution of the Greenland and Antarctic ice sheets to sea level rise and will make fundamental contributions to the understanding of changes occurring in the extent and thickness of the polar sea ice cover. Given the societal importance of understanding changes in sea level rise and sea ice extent, IceBridge data will monitor and improve modeling efforts for sea ice, ice sheet and glaciers. IceBridge will also prepare for the future of airborne monitoring efforts of the cryosphere by adapting existing instruments for high altitude unmanned aerial systems such as the NASA Global Hawk.

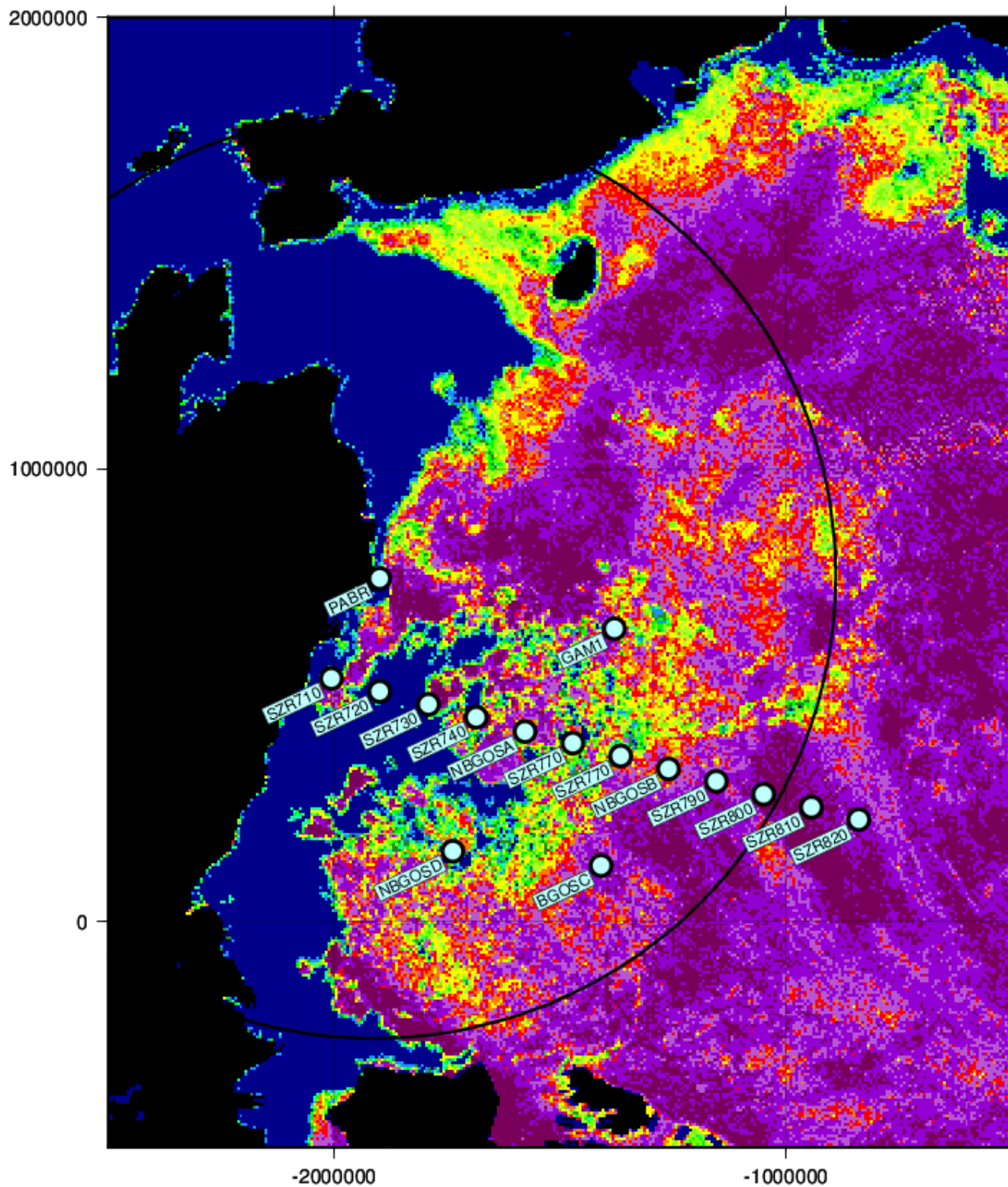
IceBridge Science Objectives

The following are the major science objectives of Operation IceBridge in priority order and are met by the following flight plans:

- 1) Make airborne laser altimetry measurements over the ice sheets and sea ice to fill in the data gap between the failure of ICESat-1 in 2009 and the launch of ICESat-2 planned for 2015.
- 2) Link measurements made by ICESat, ICESat-2, and CryoSat-2 to allow their comparison and the production of a long-term, ice sheet altimetry record.
- 3) Use airborne altimetry and radar to monitor key, rapidly changing areas of ice, including sea ice, ice sheets and glaciers, in the Arctic and Antarctic to maintain a long term observation record, improve understanding of glacial dynamics, and augment predictive models of sea level rise and sea ice cover.
- 4) In conjunction with altimetry measurements, collect other remotely sensed data to improve predictive models of sea level rise and sea ice cover, especially the following:
 - Ice sheet and sea ice thickness, structure and extent;
 - Bed topography underlying land-based ice;
 - Bathymetry beneath floating ice shelves;
 - Snow accumulation and firn structure; and
 - Other geophysical constraints that will improve estimates of the geothermal and oceanic heat flux
- 5) Adapt existing instruments for airborne remote sensing of ice by high altitude unmanned aerial systems such as the NASA Global Hawk.

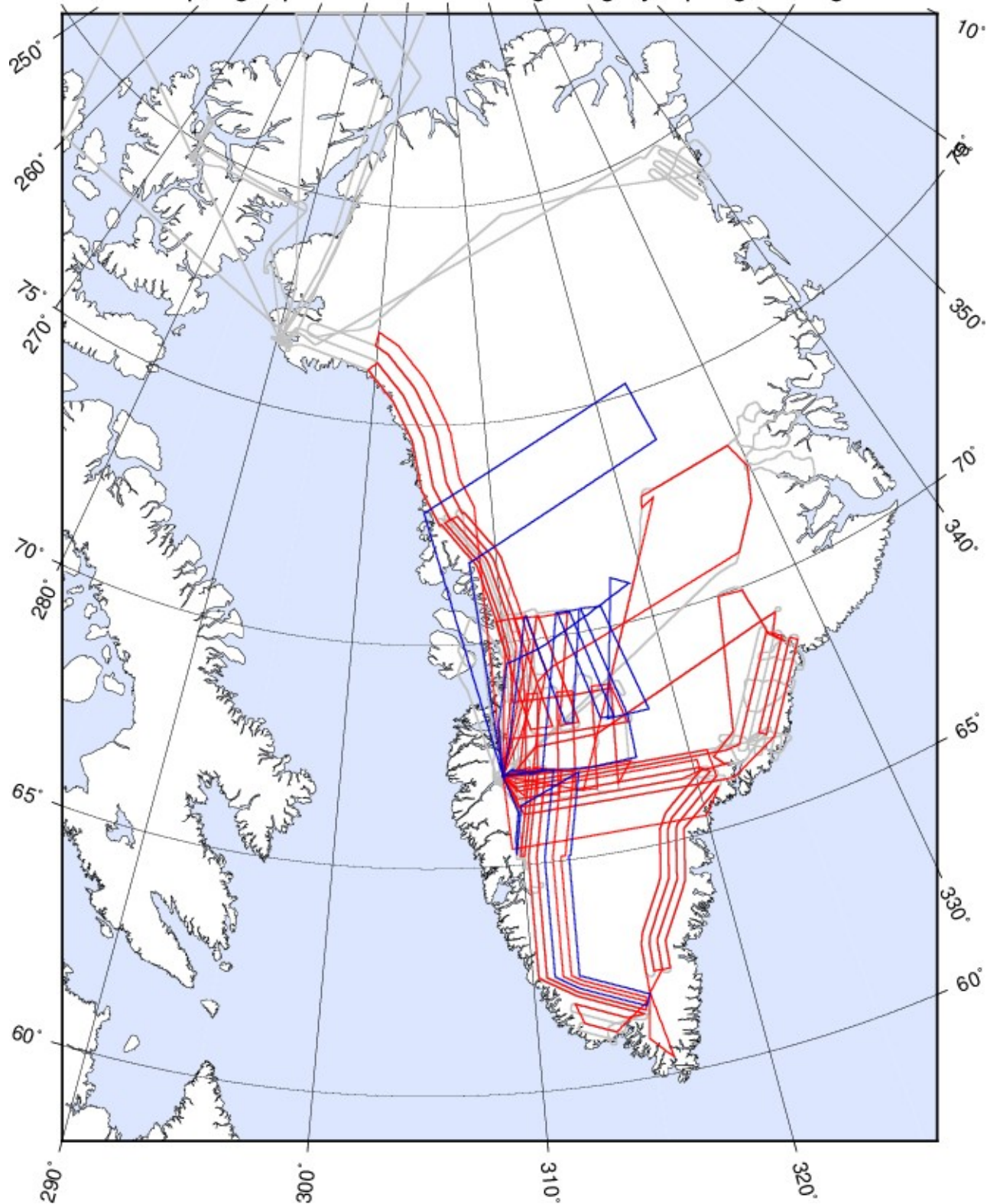
2016 Barrow Sea Ice Flights

AMSR2 Sea Ice Concentration 2016-07-05



2016 Kangerlussuaq Falcon Flights

red: spring repeats blue: other flights gray: spring P-3 flights



Falcon Land Ice – North Central Gap 02 / Kangerlussuaq

This mission is a modified version of the Spring 2015 mission of the same name. Its purpose is to capture the seasonal melt signal over central Greenland, and track that signal from low elevations on the Baffin Bay coast as far across the ice sheet as range allows, in this case across the ice divide and partway down the east side. We shortened the spring 2015 flight by removing the easternmost portions of the lines, and we also remove a coast-parallel transit line on the west plus a centerline of Rink Glacier, replacing them with direct transits.

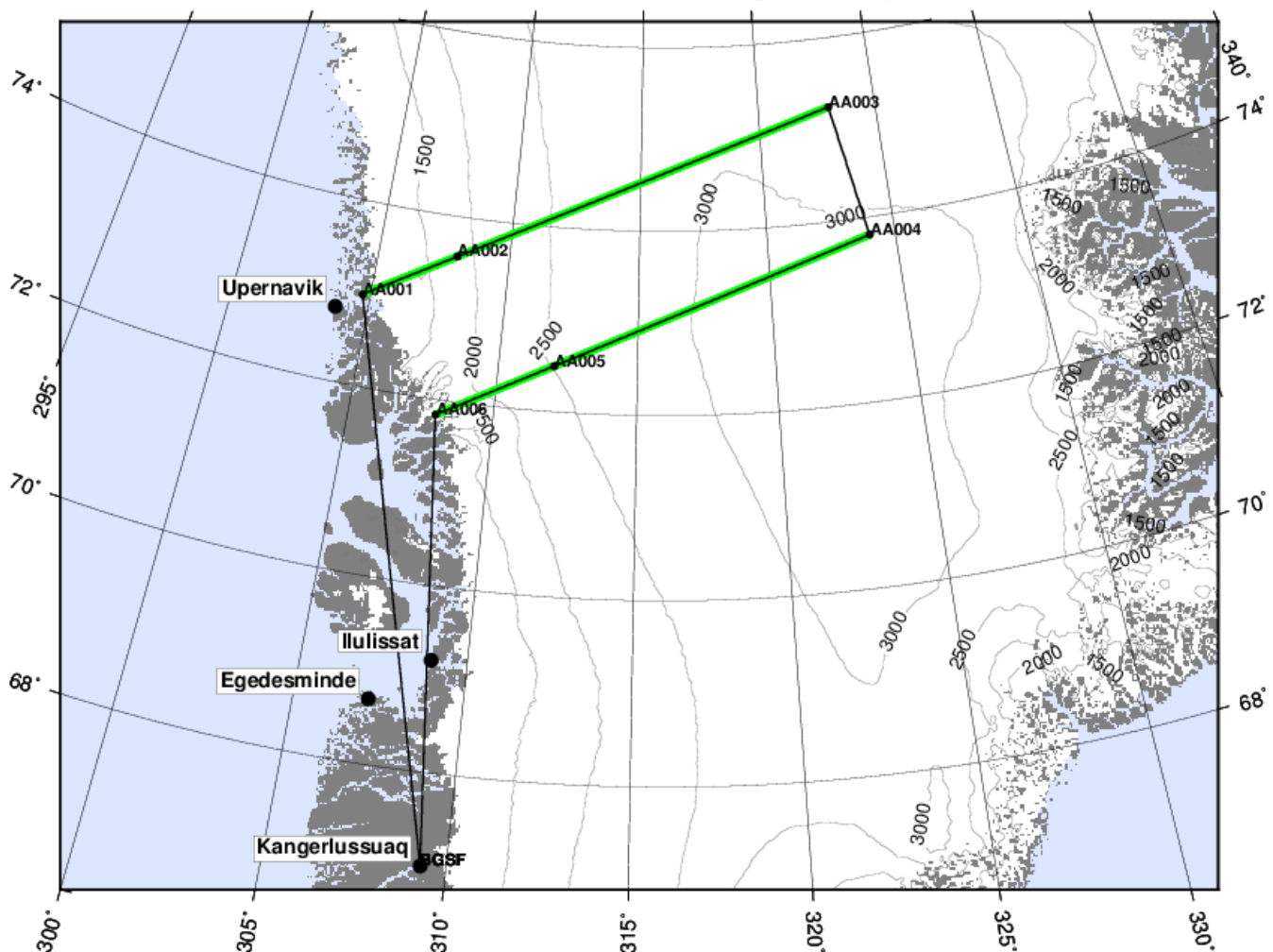
Flight Priority: low

ICESat Track: none

Last Flown: Fall 2015

Remaining Design Issues: none

Falcon North-Central Gap 02 3.5 hrs at 400 knots groundspeed



Falcon Land Ice – Northwest Coastal A / Kangerlussuaq

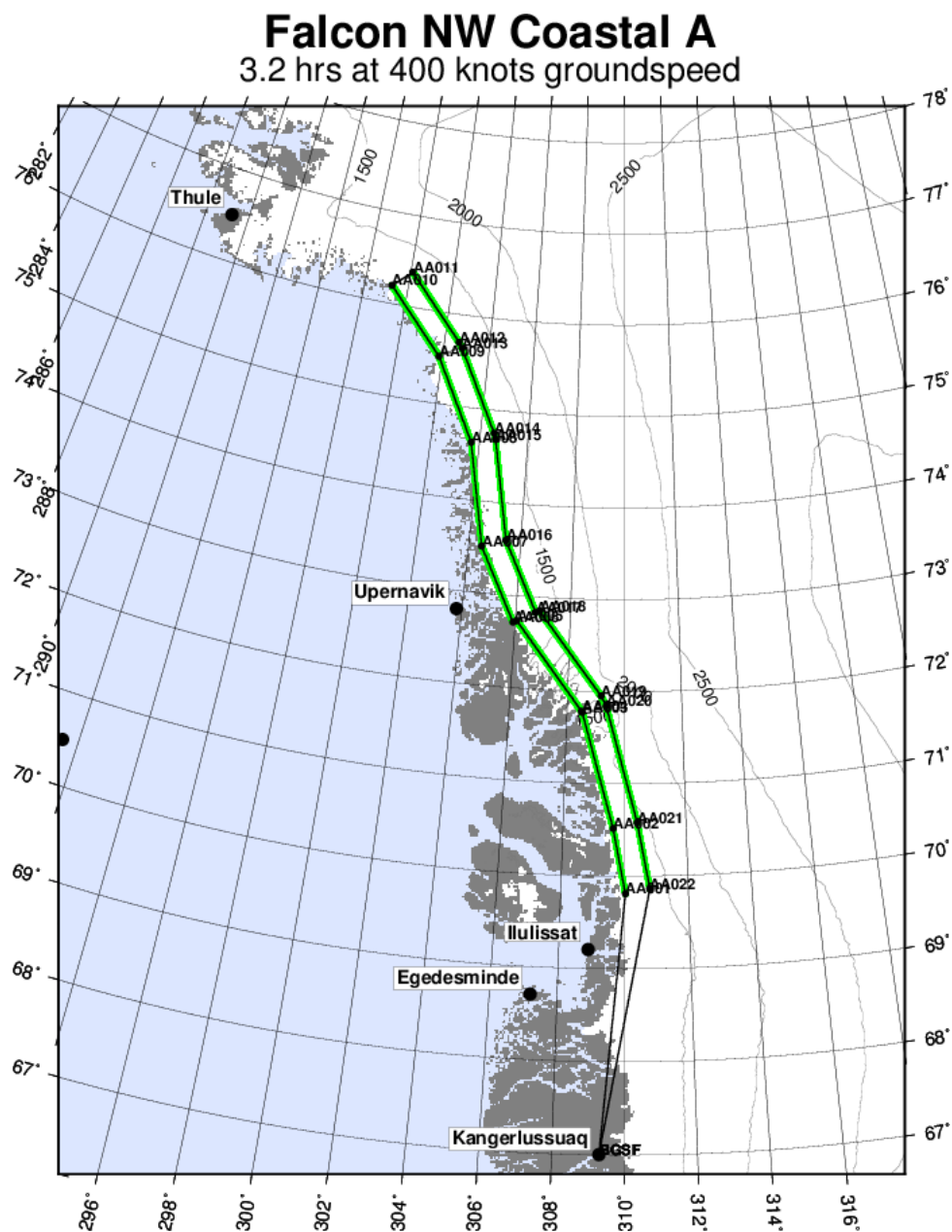
This mission combines portions of the 2016 Northwest Coastal A and Umanaq B missions, specifically the westernmost two lines from both flights. We removed the northernmost portions of the lines in order to keep the mission within the range of the Falcon. These lines are completed by the companion “Falcon Northwest Coastal B” mission.

Flight Priority: high

ICESat Track: none

Last Flown: Spring 2016

Remaining Design Issues: none



Falcon Land Ice – Northwest Coastal B / Kangerlussuaq

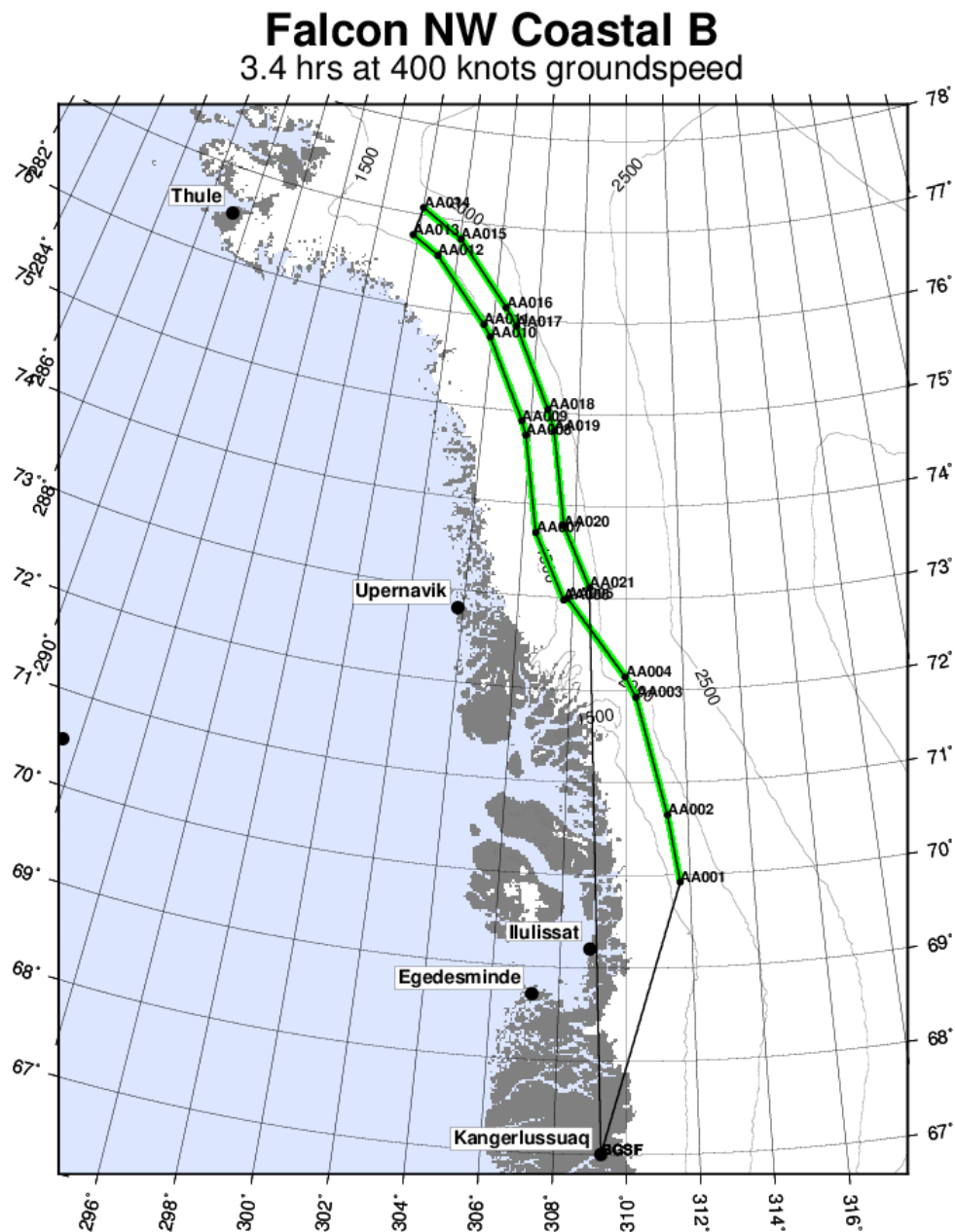
This mission combines portions of the 2016 Northwest Coastal A and Umanaq B missions, specifically the easternmost two lines from Northwest Coastal A and one of the easternmost lines from Umanaq B. We removed the northernmost portions of the Northwest Coastal A lines in order to keep the mission within the range of the Falcon. These lines are completed by the companion “Falcon Northwest Coastal A” mission.

Flight Priority: high

ICESat Track: none

Last Flown: Spring 2016

Remaining Design Issues: none



Falcon Land Ice – Mop-up 1 / Kangerlussuaq

This mission combines portions of the 2016 IceSat-2 Central and Umanaq B missions which could not be accommodated in the Falcon versions of those missions.

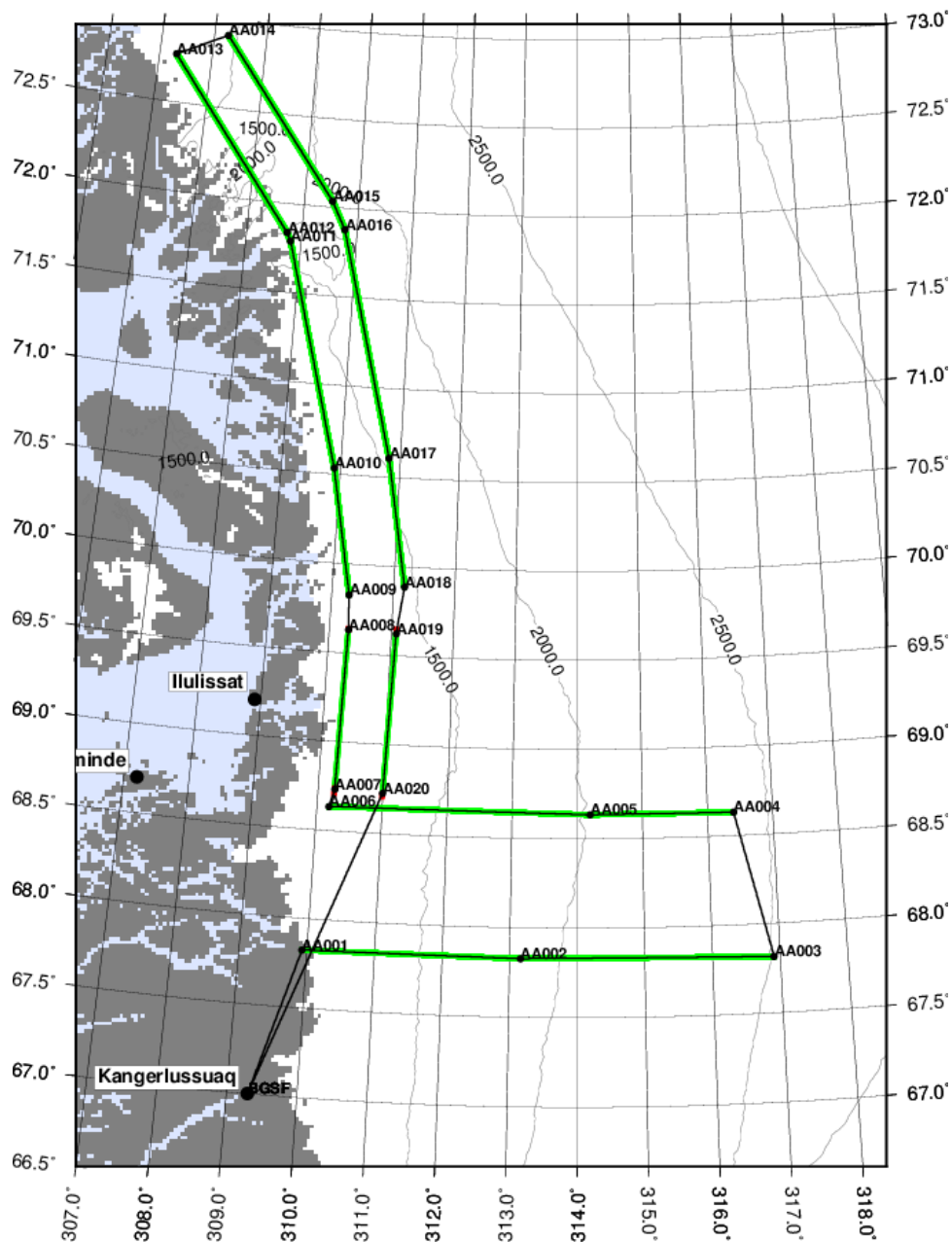
Flight Priority: high

ICESat Track: none

Last Flown: Spring 2016

Remaining Design Issues: none

Falcon Mop-Up 1 2.9 hrs at 250 knots groundspeed



Falcon Land Ice – IceSat-2 Central / Kangerlussuaq

This mission is a shortened version of the mission of the same name flown in Spring 2016. Additional portions of that original design are flown in the Falcon Mop-up 1 mission.

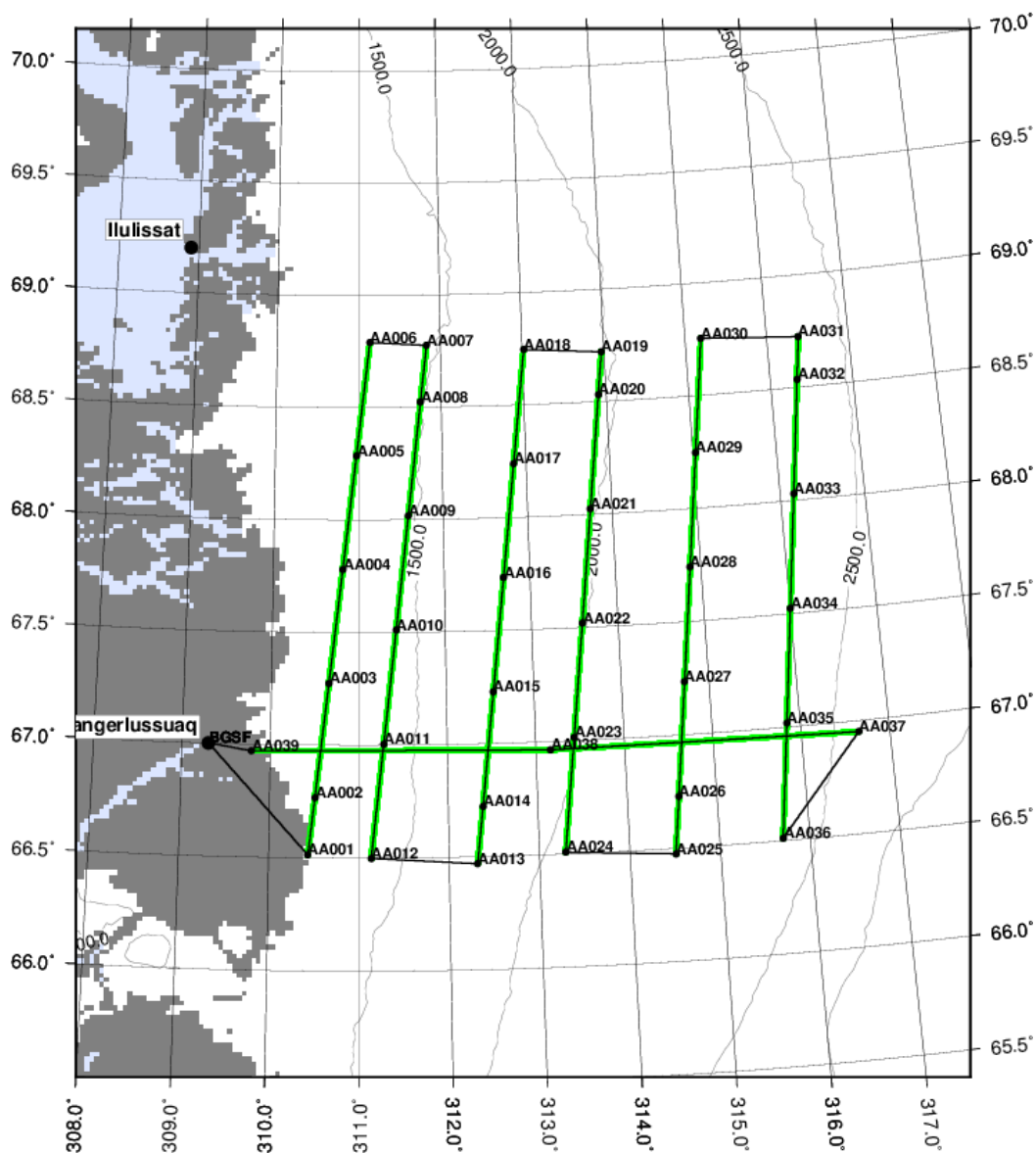
Flight Priority: high

ICESat-2 Tracks: 1169,1022,1047,0041,0422,1245,0239,0178

Last Flown: Spring 2016

Remaining Design Issues: none

Falcon IceSat-2 Central 3.6 hrs at 400 knots groundspeed



Falcon Land Ice - Thomas-Jakobshavn 01 / Kangerlussuaq

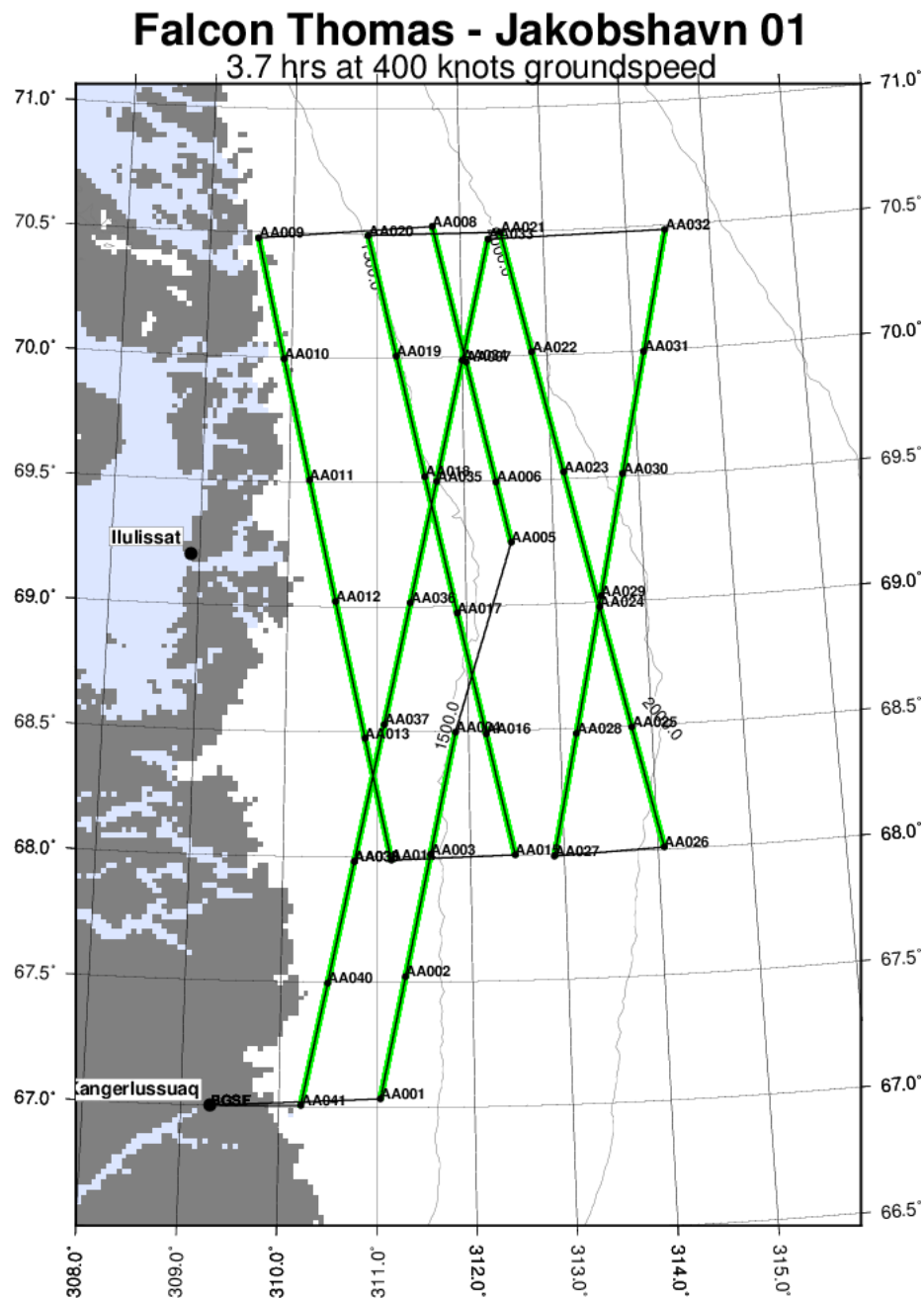
This mission is identical to the Thomas-Jakobshavn 01 mission flown in Spring 2016, but shortened by eliminating the portions of that flight devoted to the dense 10-km grid on lower Jakobshavn Glacier. It continues an IceBridge time series flown along this IceSat-1 grid every spring from 2009 to 2016.

Flight Priority: high

ICESat Track: 0323,0166,0300,0047,0285,0070,0204

Last Flown: Spring 2016

Remaining Design Issues: none



Falcon Land Ice – Jakobshavn-Eqip-Store / Kangerlussuaq

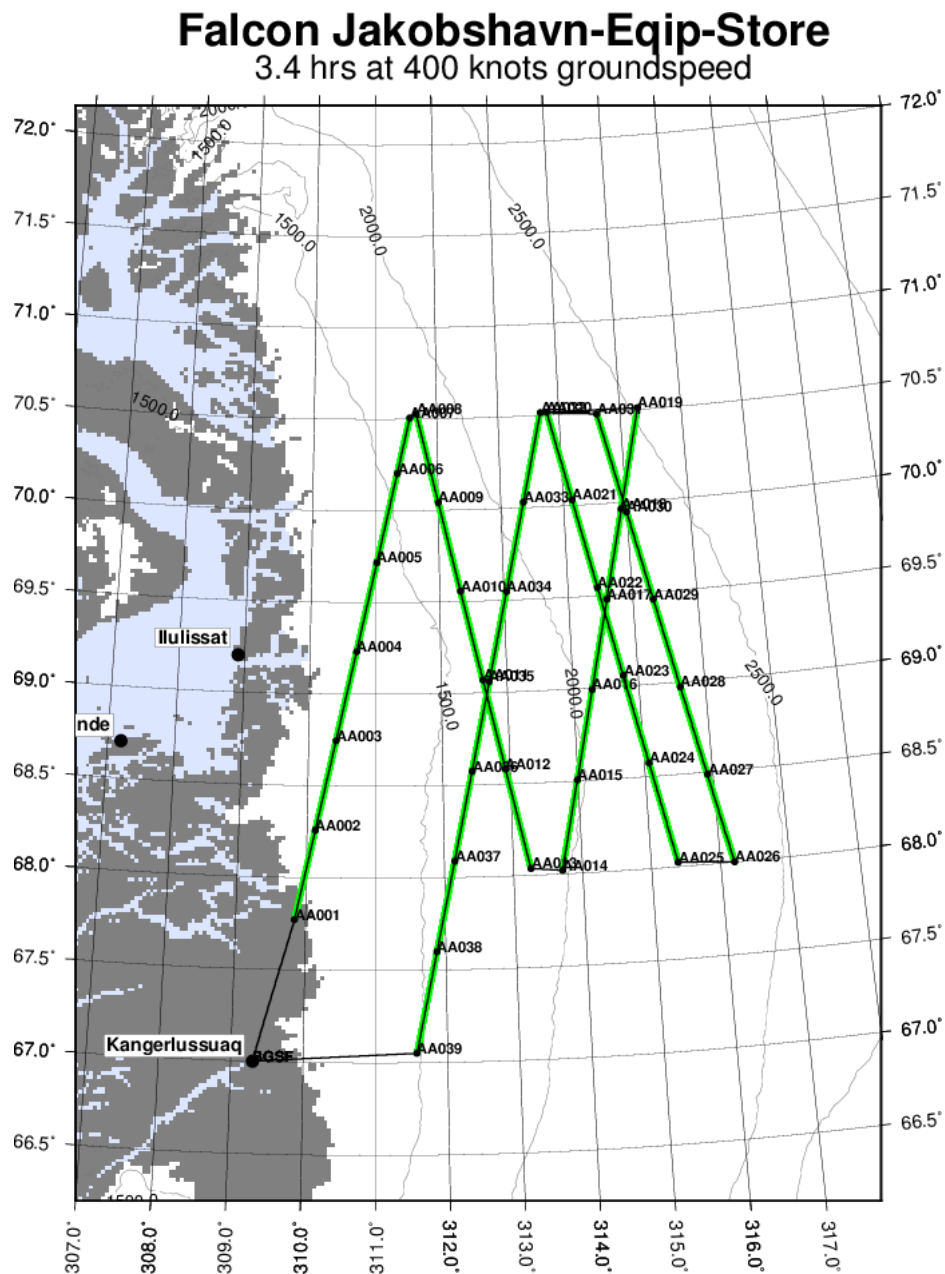
This mission is identical to the Jakobshavn-Eqip-Store flight conducted for the last several years and last flown in Fall 2015, but with the centerlines of Store, Eqip Sermia, Kangilerngata Sermia, Sermeq Kujalleq, Rink, and Kagerdlugssup Glaciers removed.

Flight Priority: low

ICESat Track: 0085,0166,0189,0032,0151,1305

Last Flown: Fall 2015

Remaining Design Issues: none



Falcon Land Ice – K-EGIG-Summit / Kangerlussuaq

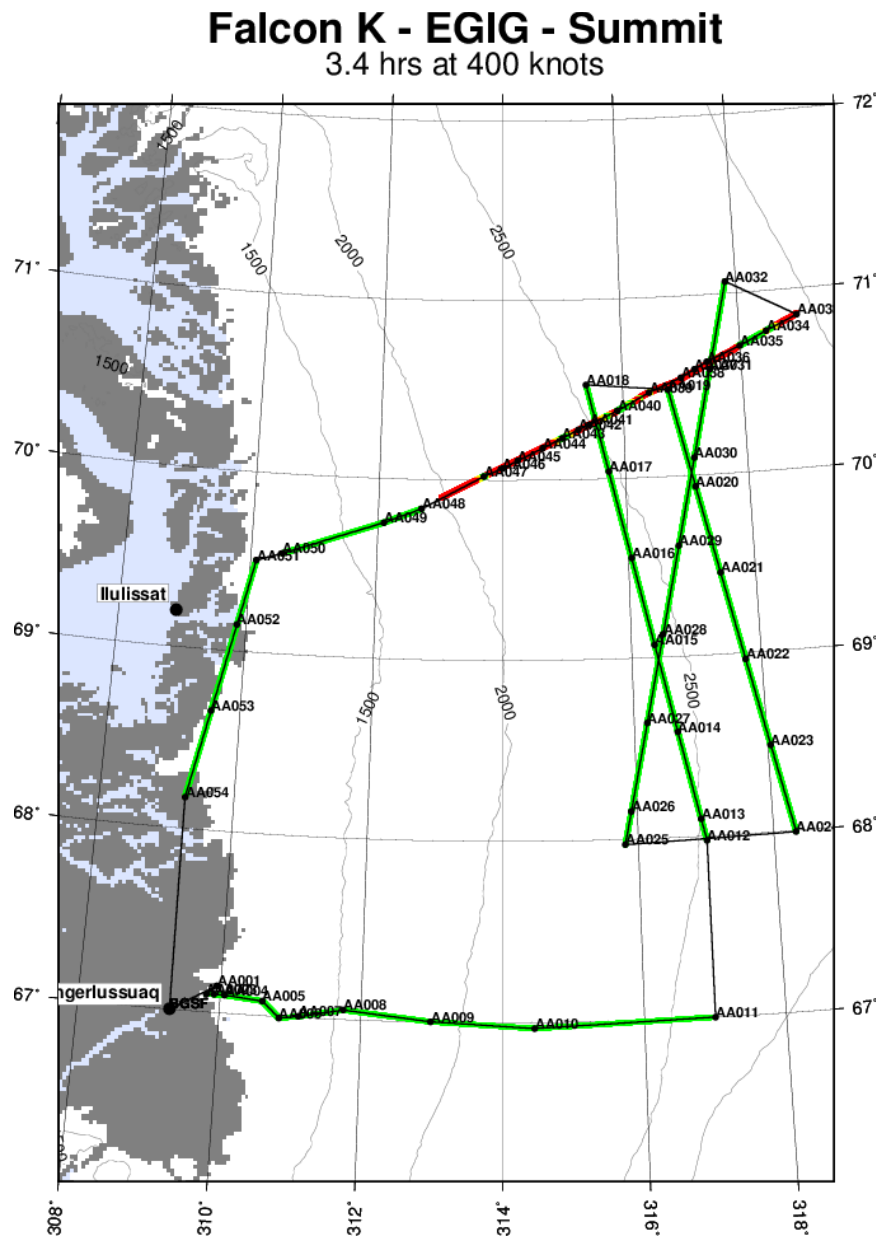
This mission is a shortened version of the baseline-priority “K-EGIG-Summit” flight last flown in Spring 2015. This version retains the three upper IceSat-1 lines in the upper Jakobshavn catchment area, the western half of the EGIG line, and the overflights of the K-Transect sites near Kangerlussuaq, but eliminates the eastern portion of the EGIG line and the IceSat-1 and IceSat-2 cal/val lines near Summit Station.

Flight Priority: low

ICESat Track: 0055,0017,0270,1320

Last Flown: Fall 2015

Remaining Design Issues: none



Falcon Land Ice – East Glaciers 01 / Kangerlussuaq

This mission is a shortened version of the East Glaciers 01 mission last flown in Spring 2015. In order to accommodate the shorter range of the Falcon jet, we eliminated six glacier centerlines in the far eastern portion of the flight. We also added an overflight of the IceSat 0412 cal/val site near Summit Camp.

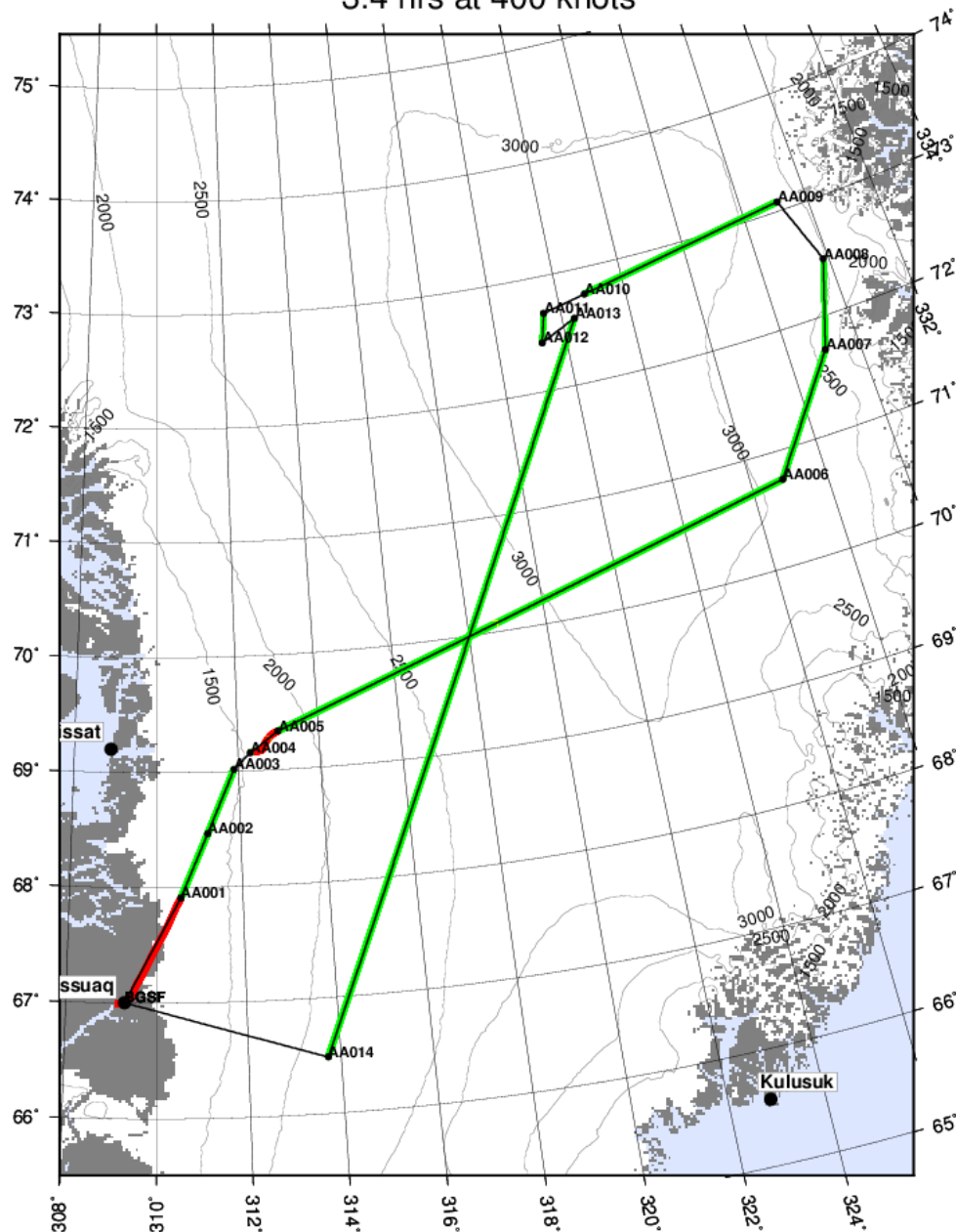
Flight Priority: high

ICESat Track: none

Last Flown: Spring 2016

Remaining Design Issues: none

Falcon East Glaciers 01 3.4 hrs at 400 knots



Falcon Land Ice – Helheim-Kangerdlugssuaq Gap B / Kangerlussuaq

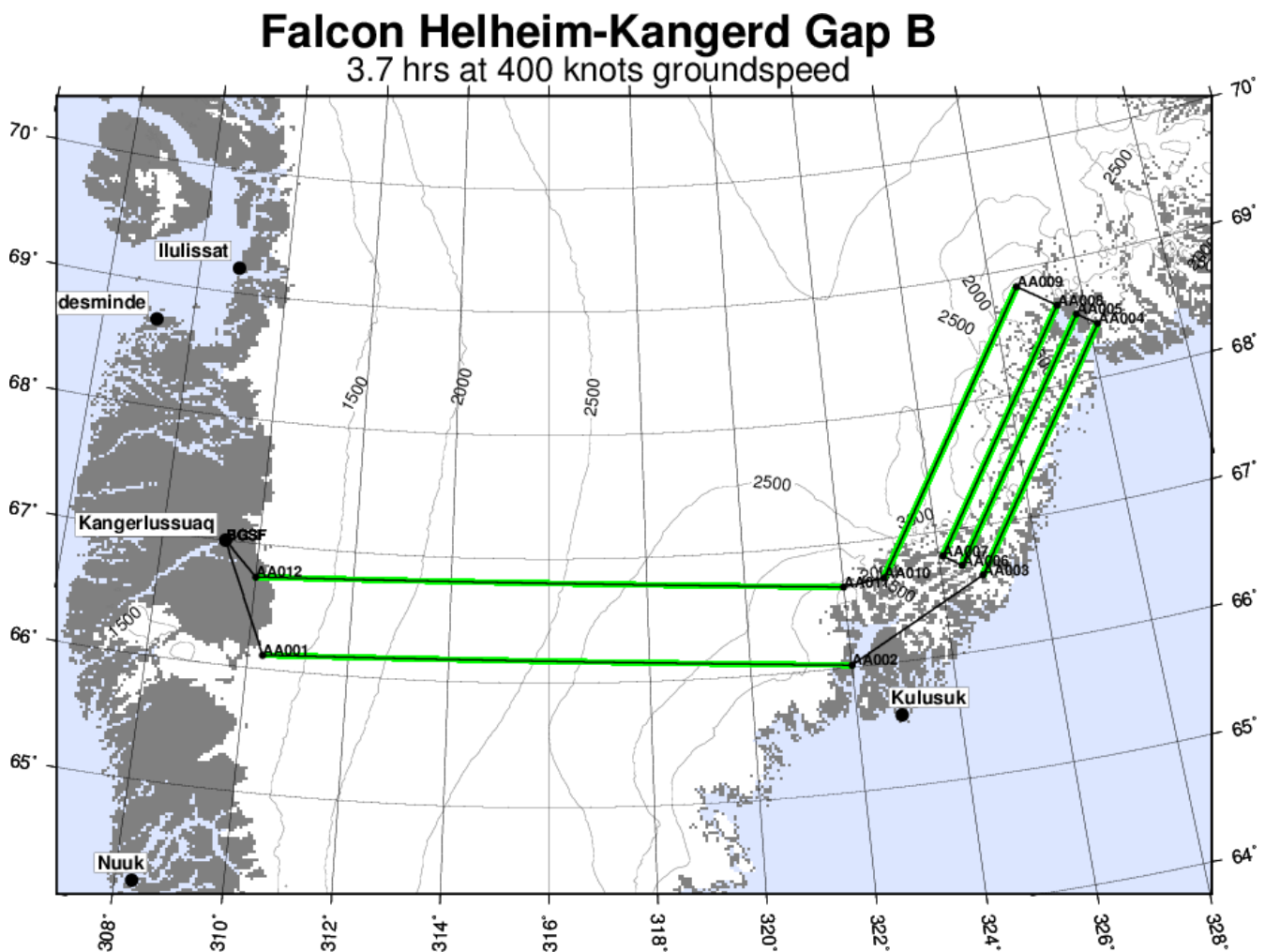
This mission is a shortened version of the Helheim Kangerdlugssuaq Gap B mission last flown in Spring 2015. In order to accommodate the shorter range of the Falcon jet, we reduced the number of coast-parallel lines from six to four, and also eliminated two glacier centerlines in the center of the region.

Flight Priority: high

ICESat Track: none

Last Flown: Spring 2016

Remaining Design Issues: none



Falcon Land Ice – Helheim-Kangerdlugssuaq / Kangerlussuaq

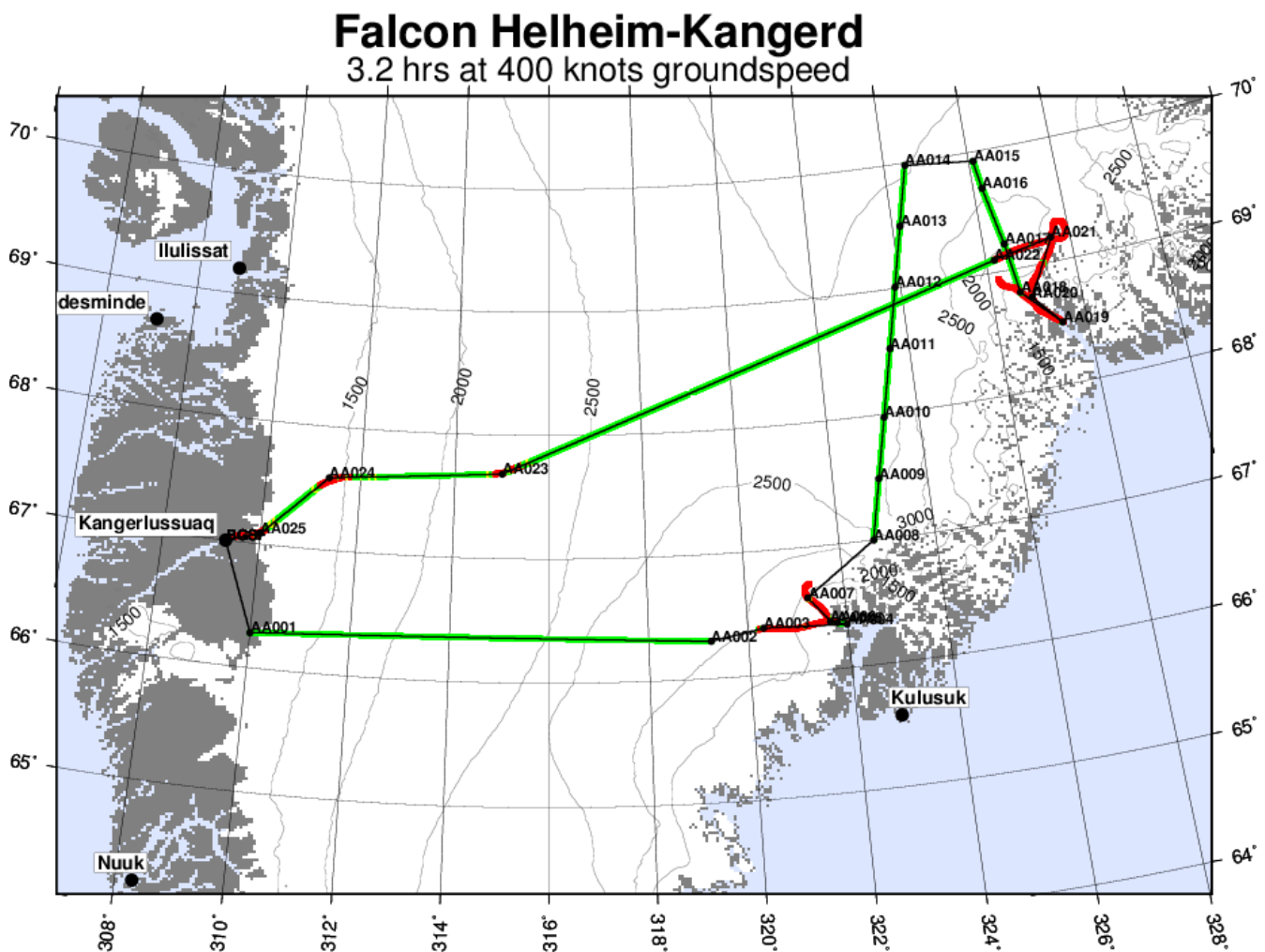
This mission is based on the Helheim-Kangerdlugssuaq mission last flown in Spring 2016. It has been shortened by removing all of the glacier centerlines from the area east of Sermilik fjord (including Midgard, Fenris, Glacier de France, and several others) and also the centerlines of two additional glaciers just south of Kangerdlugssuaq Glacier.

Flight Priority: high

ICESat Track: 0263

Last Flown: Spring 2016

Remaining Design Issues: none



Falcon Land Ice – Southeast Coastal A / Kangerlussuaq

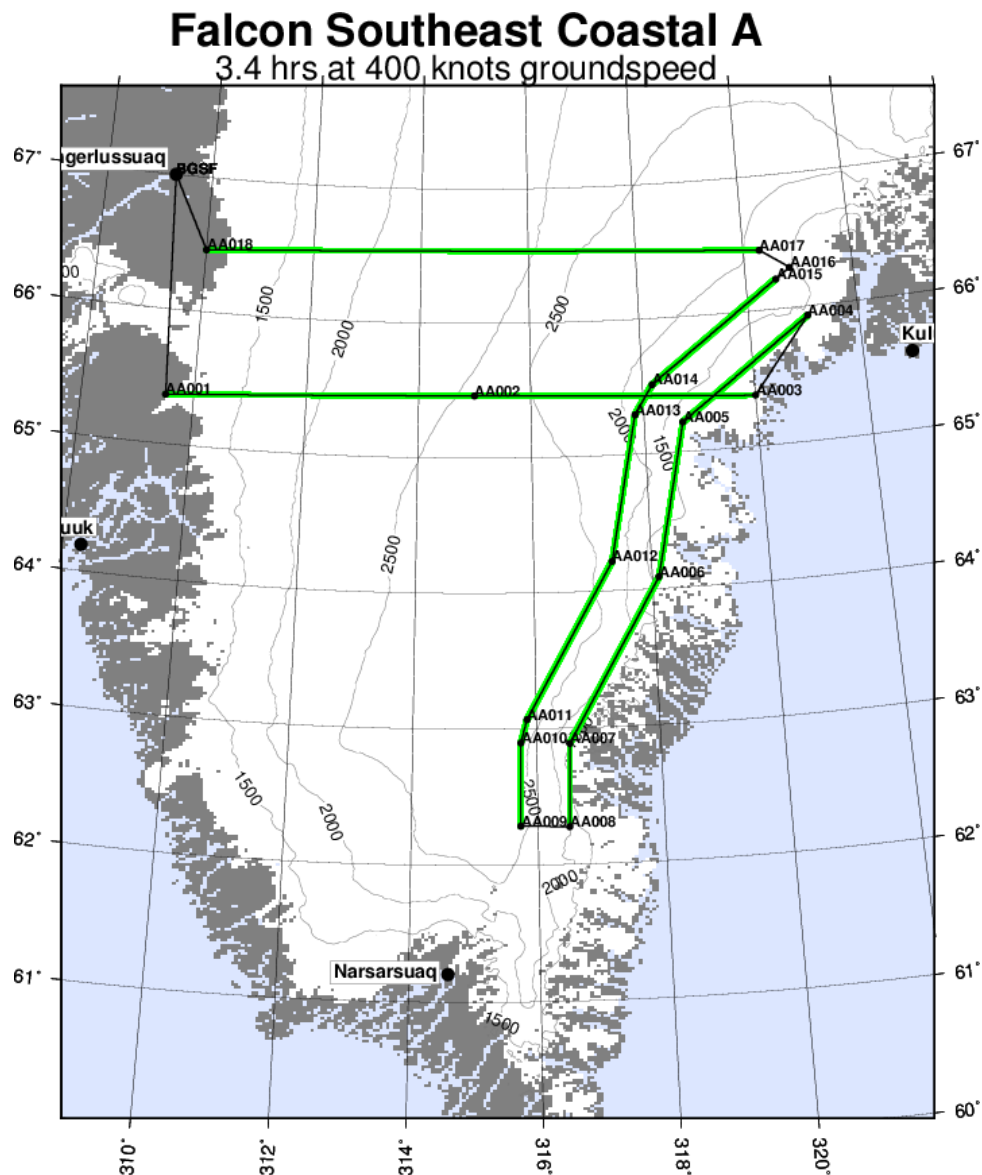
This mission is one of two (along with Southeast Coastal B) which are designed primarily to refly the “Southeast Coastal” mission from Spring 2016. These two flights work together in an interlaced (working upward from the coast) manner. This particular flight concentrates on the first and third lowermost of the coast-parallel lines. It transits to the east coast along a line from a different mission also flown in Spring 2016, in order to expand post-melt coverage farther south.

Flight Priority: high

ICESat Track: none

Last Flown: Spring 2016

Remaining Design Issues: none



Falcon Land Ice – Southeast Coastal B / Kangerlussuaq

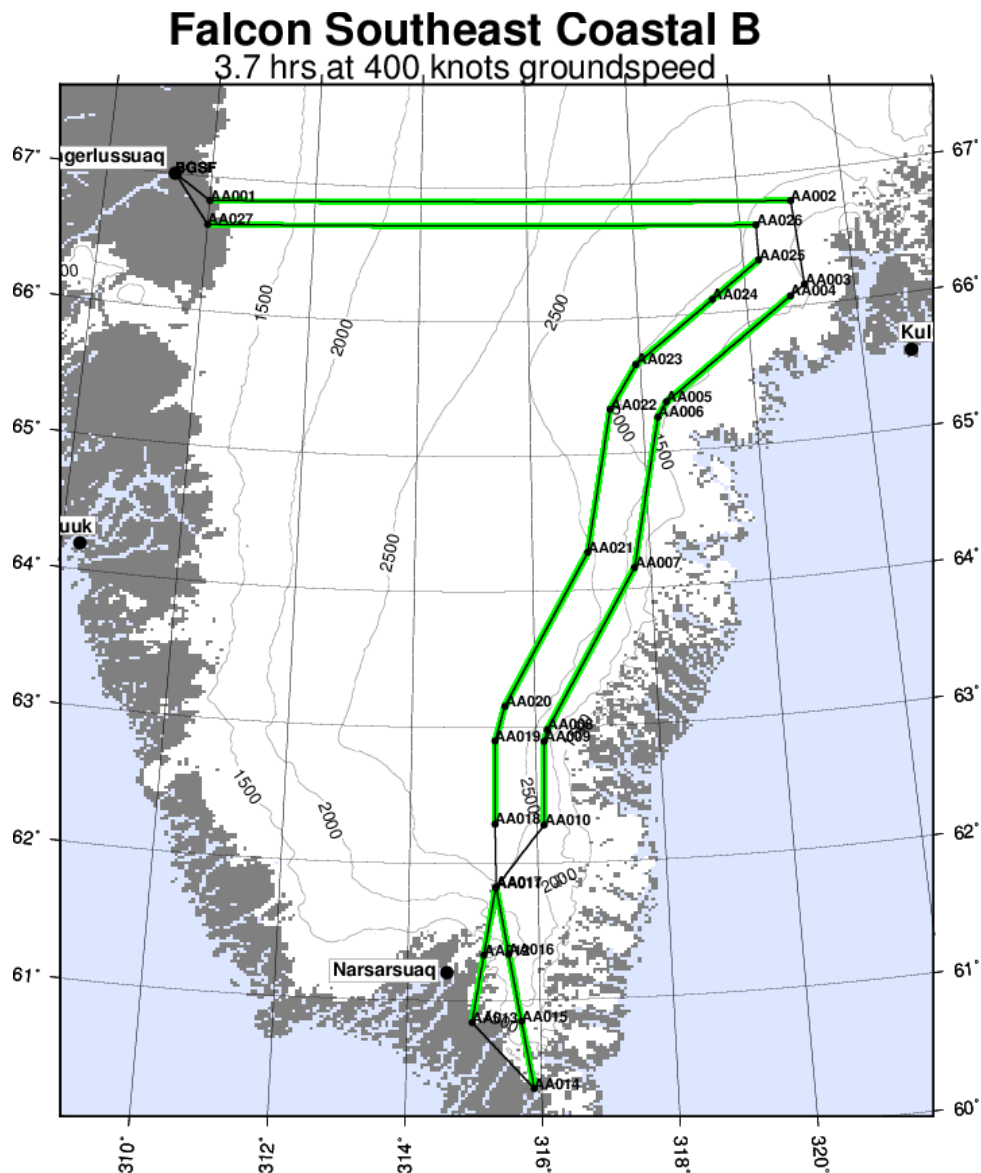
This mission is one of two (along with Southeast Coastal A) which are designed primarily to refly the “Southeast Coastal” mission from Spring 2016. These two flights work together in an interlaced (working upward from the coast) manner. This particular flight concentrates on the second and fourth lowest of the coast-parallel lines. We also refly a pair of IceSat-1 lines focused on the far southeastern lobe of the Greenland Ice Sheet last flown in 2014.

Flight Priority: high

ICESat Track: 0412,0047

Last Flown: Spring 2016

Remaining Design Issues: none



Falcon Land Ice – Southwest Coastal A / Kangerlussuaq

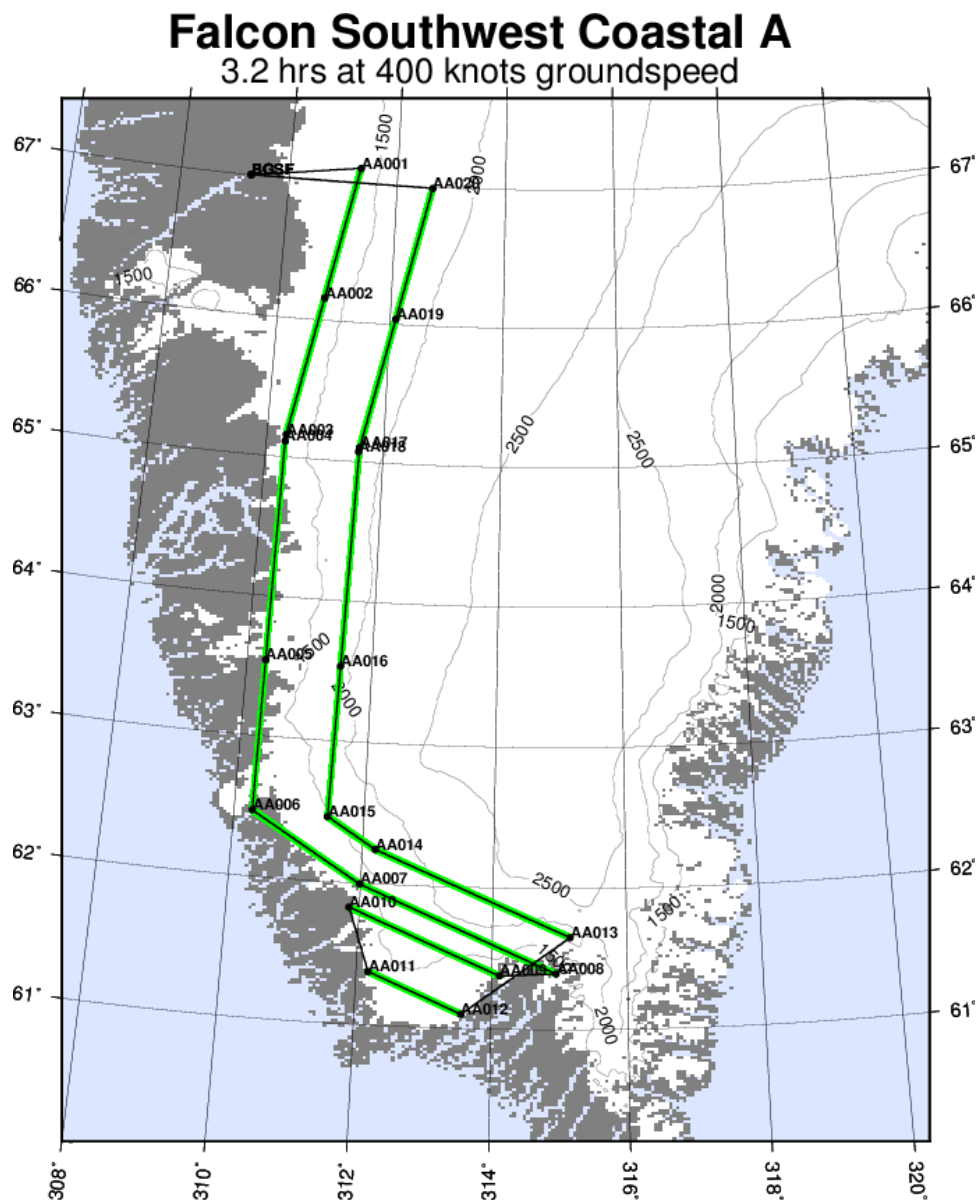
This mission is one of three (with Falcon Southwest Coastal B and C), which together re-fly most of the the “Southwest Coastal A and B” missions flown in Spring 2016. These three flights work together in an interlaced (working upward from the coast) manner. This particular flight concentrates on the first and fourth lowermost of the coast-parallel lines, plus two additional lines covering a southern lobe of the ice sheet.

Flight Priority: high

ICESat Track: none

Last Flown: Spring 2016

Remaining Design Issues: none



Falcon Land Ice – Southwest Coastal B / Kangerlussuaq

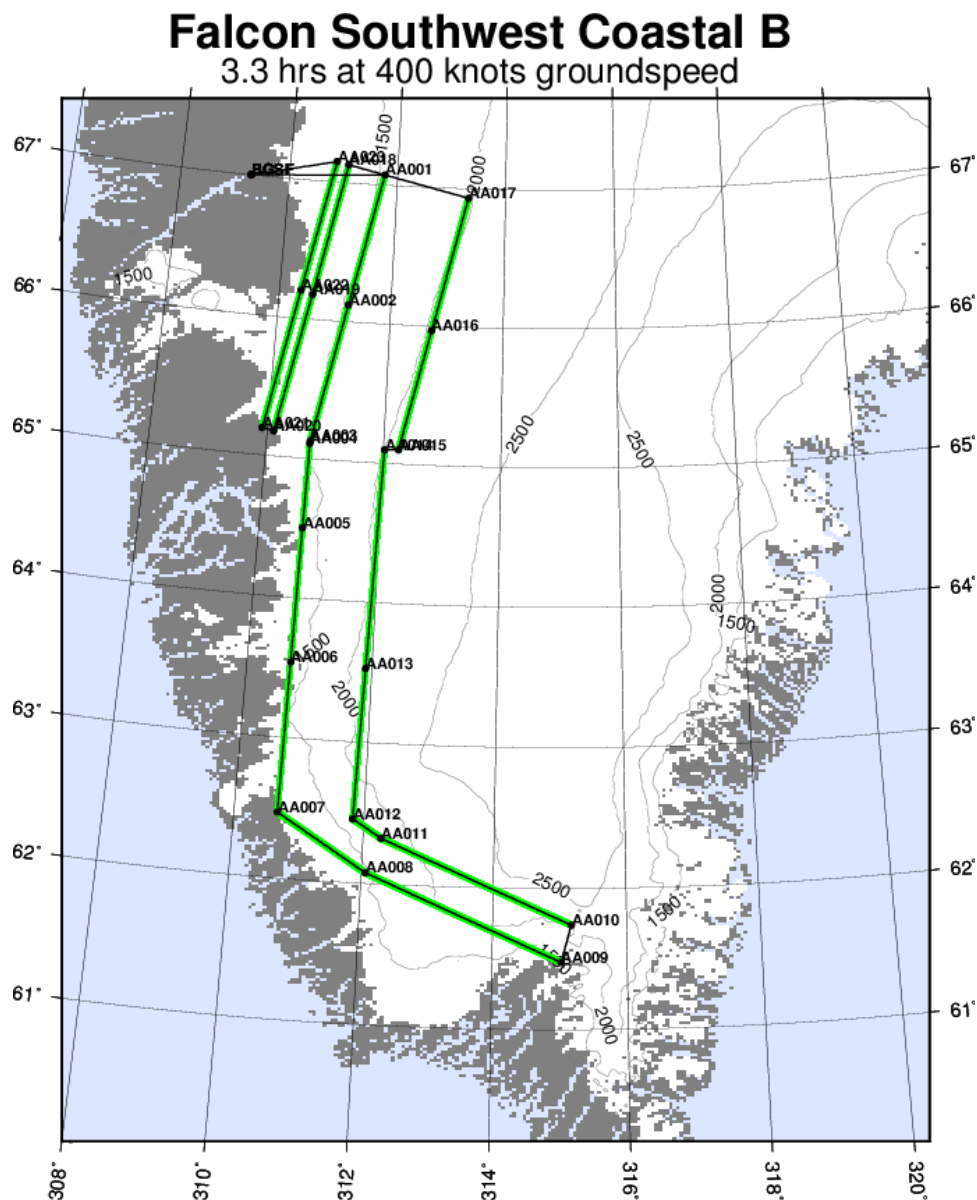
This mission is one of three (with Falcon Southwest Coastal A and C), which together re-fly most of the the “Southwest Coastal A and B” missions flown in Spring 2016. These three flights work together in an interlaced (working upward from the coast) manner. This particular flight concentrates on the second and fifth lowermost of the coast-parallel lines, plus two additional lines covering a southwestern lobe of the ice sheet near Sukkertoppen.

Flight Priority: high

ICESat Track: none

Last Flown: Spring 2016

Remaining Design Issues: none



Falcon Land Ice – Southwest Coastal C / Kangerlussuaq

This mission is one of three (with Falcon Southwest Coastal A and B), which together re-fly most of the the “Southwest Coastal A and B” missions flown in Spring 2016. This flight covers individual lines that were not flown in Spring 2016, however. These three flights work together in an interlaced (working upward from the coast) manner. This particular flight concentrates on the third and sixth lowermost of the coast-parallel lines, plus two additional lines covering a southwestern lobe of the ice sheet near Sukkertoppen.

Flight Priority: low

ICESat Track: none

Last Flown: Fall 2015

Remaining Design Issues: none

