SCIENTIFIC, TECHNICAL, MANAGEMENT

1 INTRODUCTION

This document summarizes the overall scientific and logistic opportunities for carrying out the High Latitude Ionosphere/Thermosphere Electrodynamics (HILITES) rocket campaign in Kangerlussuaq, Greenland. Detailed scientific plans are presented by individual rocket proposals, of which, this proposal enables by setting the scientific and support scene.

The lower ionosphere/thermosphere and mesosphere (ITM) region at high latitudes is steeped in complex behavior and diverse physical processes as it acts as a dynamical interface between the Earth's neutral atmosphere and the charged geospace environment. This is also a region where energy converges from sources as disparate as the magnetosphere and the troposphere. This confluence of energy is deposited into a relatively narrow altitude regime between 80 and 150 km. The response of the ITM system within this regime is strongly altitude dependent and can result in the generation of turbulence, changes in composition and temperature, modified chemical reactions, perturbations in neutral dynamics, and changes to the electrodynamic state of the system. Here, we describe a measurement program involving rockets supported by ground-based instrumentation that enables an in-depth study of these processes within the high latitude ITM region. The rocket campaign is planned to coincide with the second year of the NASA TIMED satellite mission and provide unique measurements that support the science goals of the TIMED mission. Coordinated measurements with the TIMED satellite are not required for the success of the campaign but, if possible, can certainly benefit the overall science production for both NASA programs.

The High Latitude Ionosphere/Thermosphere Electrodynamics (HILITES) rocket campaign will provide a comprehensive data set for the study of plasma and neutral processes occurring within the high-latitude ionosphere, thermosphere, and mesosphere by performing coordinated and complementary observations by sounding rockets and ground-based instrumentation near the town of Kangerlussuaq, Greenland (formerly Søndre Strømfjord). Arguably some of the most successful campaigns have been those carried out at the sites where ground-based instrumentation is clustered. Notable examples are the CONDOR campaign in Peru near the Jicamarca Radar Observatory, the two COPE campaigns in Greenland near the Sondrestrom incoherent scatter radar, and the CRRES/COQUI and COQUI II campaigns carried out in Puerto Rico near the Arecibo Observatory. The Cooperative Observations of Polar Electrodynamics (COPE) programs in 1985 and 1987 in Greenland were highly successful campaigns producing seven Ph.D. dissertations and over 35 journal publications. The HILITES campaign hopes to build from that success and take advantage of the key geophysical location of the Kangerlussuaq rocket range (67.0N, 309.1E, 74.2 magnetic latitude) and the improved ground-based instrumentation support from the Sondrestrom radar facility located approximately 13 km west of the rocket range.

The general scientific focus of the campaign, as determined in the pre-proposal meeting held in December 1998, will be to determine the plasma and neutral processes involved in the energy dissipation of the various source mechanisms and the subsequent response of the ITM system at high latitudes. The response by the system then provides feedback on the state of the ITM region, affecting how the system responds in the future. This circuitous behavior in cause and effect is poorly understood because it depends on mutual interactions amongst the various ion and neutral species over different spatial and temporal scales and on the electrical connection to more distant regions of the geospace environment. Thus, we must understand these plasma and neutral interactions and the feedback processes taking place within the ITM region in order to understand its role as the interface between space and the Earth’s atmosphere. This has proven to be a true challenge to our field because of the numerous interdependent parameters (such as neutral winds, ion and neutral composition, electric fields, electron density, ion-neutral collision frequencies, conductivities, and currents) needed to be measured at nearly the same time and over a range of scales. Thus far, ground-based and space-based measurements have been limited in their abilities to account for many of the detailed processes that take place in the region.

The sounding rocket campaign will provide unique in situ measurements of key, and otherwise, unmeasurable properties of the region. The ground-based instrumentation at the Sondrestrom facility will enhance the scientific return by providing background estimates of larger-scale neutral and plasma parameters. The detailed measurements by rockets and ground-based instruments will also address key questions posed by the NASA TIMED mission concerning energetics and the response of the ITM region to high latitude processes, but on a smaller scale than the spacecraft measurements and with more instrumentation suited for the task. If possible, TIMED flybys could provide contextual or large-scale measurements for the launches and further enhance the scientific return of the campaign.

2 OVERVIEW OF PROPOSED EXPERIMENTS

The major rocket experiments proposing for the HILITES campaign are shown in Table1.

Table 1 List of PIs and major experiments.

PI	S. Chakrabarti
Purpose	Investigation of visible and ultraviolet emissions in proton and electron aurora
Experiment type	High resolution Lyman α spectrograph, moderate resolution (1nm) EUV/FUV spectrograph, 3914 and 6300 photometers, low energy particle spectrometers, imaging energetic particle spectrometers
Vehicle	(1) Black Brant X
PI	J. Clemmons
Purpose	Joint Observations of Upper Latitude Electrodynamics
Experiment type	E-field experiment, magnetometer, Langmuir probe, electron spectrometer, ionization gauge, collision meter, suprathermal ion imager, ion drift meter, TMA canisters
Vehicle	(2) Black Brant V (instrumented payloads), (4) Taurus-Orion (TMA)
PI	G. Garbe
Purpose	Ion-neutral interactions in auroral arcs
Experiment type	Suprathermal ion mass spectrometer, Ion drift spectrometer, Near ultraviolet auroral spectrograph
Vehicle	(1) Black Brant IX
PI	T. Kane
Purpose	In situ and ground-based studies of Auroral Interaction with the Meteoric Metals
Experiment type	Photometers, electric fields, charged dust, ion mass spectrometer, narrowband IR detector, TMA canisters, falling spheres
Vehicle	(1) Black Brant V or Terrier-Orion (instrumented payload), (3) Taurus-Orions (TMA), (3) Viper Darts (falling spheres)
PI	J. LaBelle
Purpose	Rocket Observations of Auroral Roar
Experiment type	DC/AC electric field boom experiment, Langmuir probes, magnetometer, electrostatic analyzers
Vehicle	(1) Black Brant V

3 CAMPAIGN DETAILS

The HILITES campaign will be a winter campaign designed to pursue the proposed research experiments summarized in the previous section. The campaign will take place in the winter of 2001–2002 so as not to conflict with the currently scheduled campaign for Poker Flat Rocket Range. The duration of the HILITES campaign is expected to be about 8 to 12 weeks if two to three launchers are used at the remote site. In discussions with Bobby Flowers at Wallops, all of the heavy equipment, trailers, antenna, launchers, and so on, can be shipped to Greenland in the summer of 2001 and can be returned to Wallops via the first ship in the summer of 2002.

The proposed launch site of Kangerlussuaq, Greenland, offers many advantages over other rocket launch facilities in the arctic: Foremost is the scientific benefits afforded by the advanced ground-based instrumentation located very near to the launch site. In nearly every experiment proposed, the use of the Sondrestrom incoherent scatter radar as well as other instrumentation at the site have been requested to provide complementary measurements needed for the scientific study and/or to define launch criteria. Because much of the campaign is concentrating on E region altitudes, the radar proximity to the rocket range is important to ensure common sampling of the radar and rocket at these altitudes. This is not possible, for example, at the Andoya rocket range with the EISCAT radar because of the 130 km separation of the radar and rocket and the northward launch directions from the range. The location of the Greenland rocket range is also unique in that it provides access to the geomagnetic polar cap, auroral zone, and geomagnetic cusp during different times of the day from one location. In part, this is due to the flexibility in launching rockets to the north, east, and south of the range. Figure 1 shows a map of Greenland with range circles at 200 km intervals centered on the town of Kangerlussuaq and lines of invariant latitude. A vertical cross section through the magnetic meridian is shown in Figure 2 versus range from site. The dip angle of the magnetic field line at Kangerlussuaq is about 80.4 degrees with an invariant latitude of 74.2 degrees.

Over the past year, the Danish Meteorological Institute (DMI), the Danish Polar Center , and the Commission for Scientific Research in Greenland (consisting of Danish officials, Greenland Home Rule officials, Kangerlussuaq town authorities, Danish Civil Aviation authorities, and the US State Department) have been briefed on the proposed sounding rocket campaign, and no immediate concerns have arisen. The DMI has fully endorsed the project with its planned participation determined once the NASA decision is made concerning the campaign. The town has been fully supportive of scientific studies in the region with the Kangerlussuaq International Science Support (KISS) facility providing at reasonable cost the necessary accommodations for lodging, meetings, and storage of equipment. Discussions with town officials about the rocket campaign have been very positive with the KISS facility expected to be available for the NASA personnel throughout the period of the campaign. The Sondrestrom facility will also be able to house about 10 scientists at one time. It is expected that many of the launch decisions will be made from the Sondrestrom facility based on the measurements provided by the collocated instrumentation. Thus, reliable communications between the facility and the rocket range will need to be established for the campaign.

A number of meetings in Denmark and Greenland over the next three years will expect NASA's participation if this rocket campaign is approved. The first meeting would occur in February 2000 as the Commission for Scientific Research in Greenland convene their annual meeting. Here, representatives from NASA and the Sondrestrom facility would attend to discuss the early planning phase of the rocket campaign and discuss approval processes. Following this meeting, sometime in the summer of 2000, a trip to Nuuk and Sisimut, Greenland will be expected to brief the Greenland Home Rule authorities. In 2001, a scientific meeting will be held by the Commission for Scientific Research in Greenland to learn more about the scientific benefits afforded by such a campaign. Also, to prepare the local towns people in Greenland, town meetings in Kangerlussuaq, Nuuk, and Sismut will be necessary. A follow up meeting pre- or post-launch in 2002 may be necessary depending on issues raised during the previous meetings.

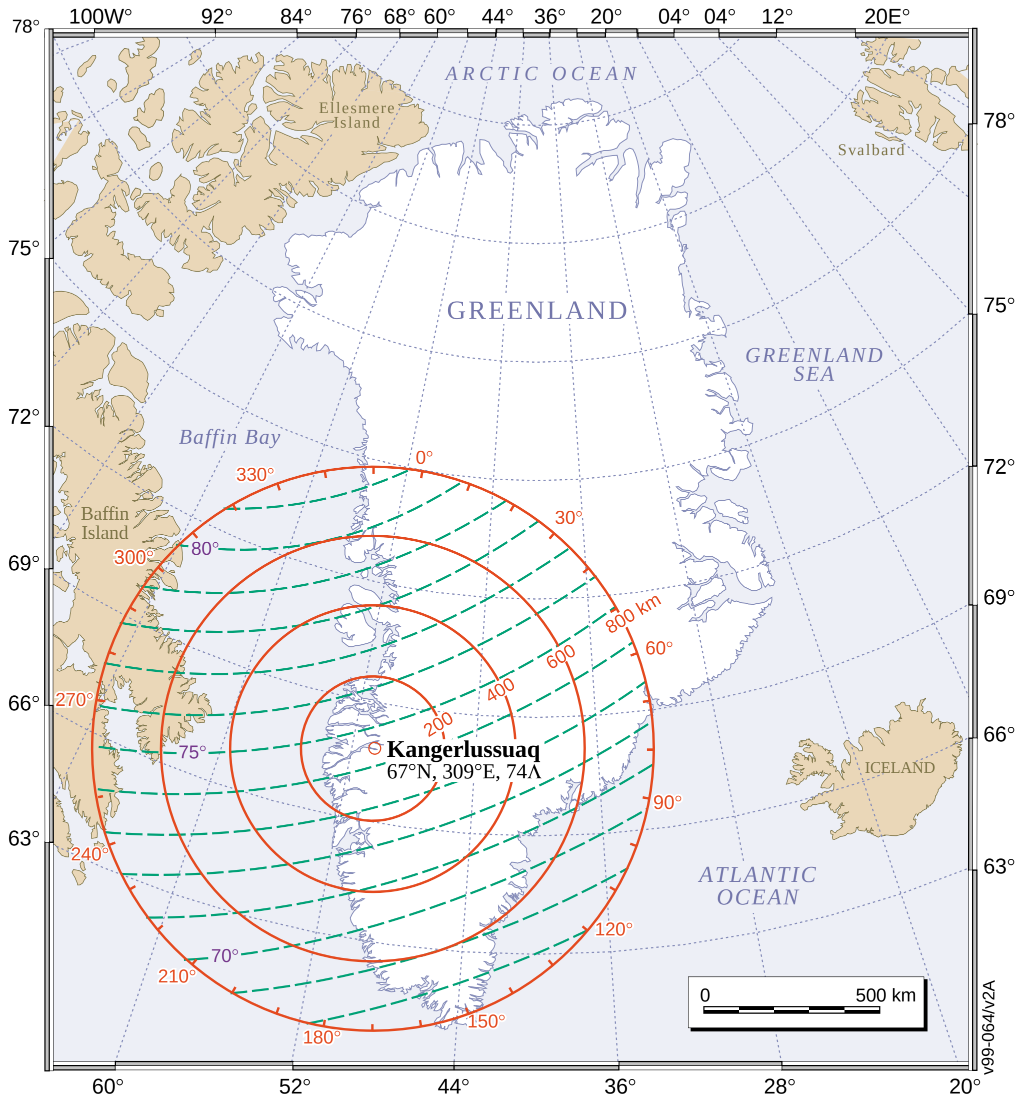

Figure 1 Map of Greenland.

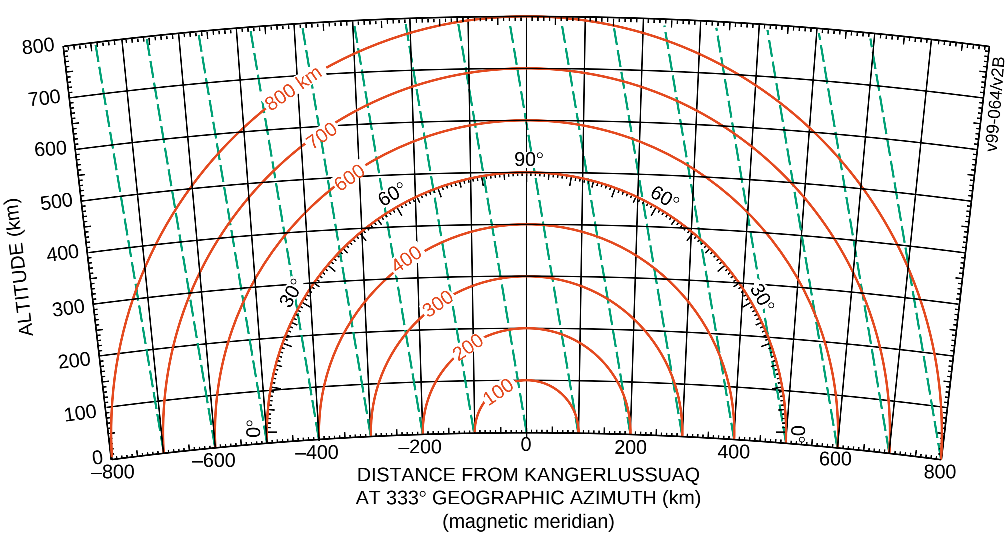

Figure 2. Vertical cross section through the magnetic meridian versus range from site

4 GROUND-BASED SUPPORT

As mentioned, the suite of instruments at the Sondrestrom facility will be critical for coordinating launch criteria and providing complementary measurements. Table 2 lists all of the instruments currently installed at or near the Sondrestrom facility and their associated principal investigators. Many of these instruments have a long heritage at the facility with plans for continued operations beyond the rocket campaign time frame. Although operated by numerous PI's many of these instruments are passive systems that operate routinely during the year. Data and special requests can be made through the individual PI's listed below. The active experiments, such as the incoherent scatter radar and the lidars, operate on a monthly schedule of requested experiments. Because of the expected demand on these instruments during the rocket campaign and the overall logistical and organizational requirements imposed on the site, a separate Sondrestrom facility ground-based support proposal will be submitted separately by Dr. Jeff Thayer of SRI International.

The buildup of instrumentation at the Sondrestrom facility over the years is a testament to the scientific benefits afforded by the clustering of instrumentation at geophysically unique and important locations. An example of the overlapping views provided by the Sondrestrom all-sky imager, imaging riometer, and incoherent scatter radar in studying the aurora is shown in Figure 3. The rocket payloads will sample the region of space well within the measurement area of these instruments and will benefit from the different complementary measurements.

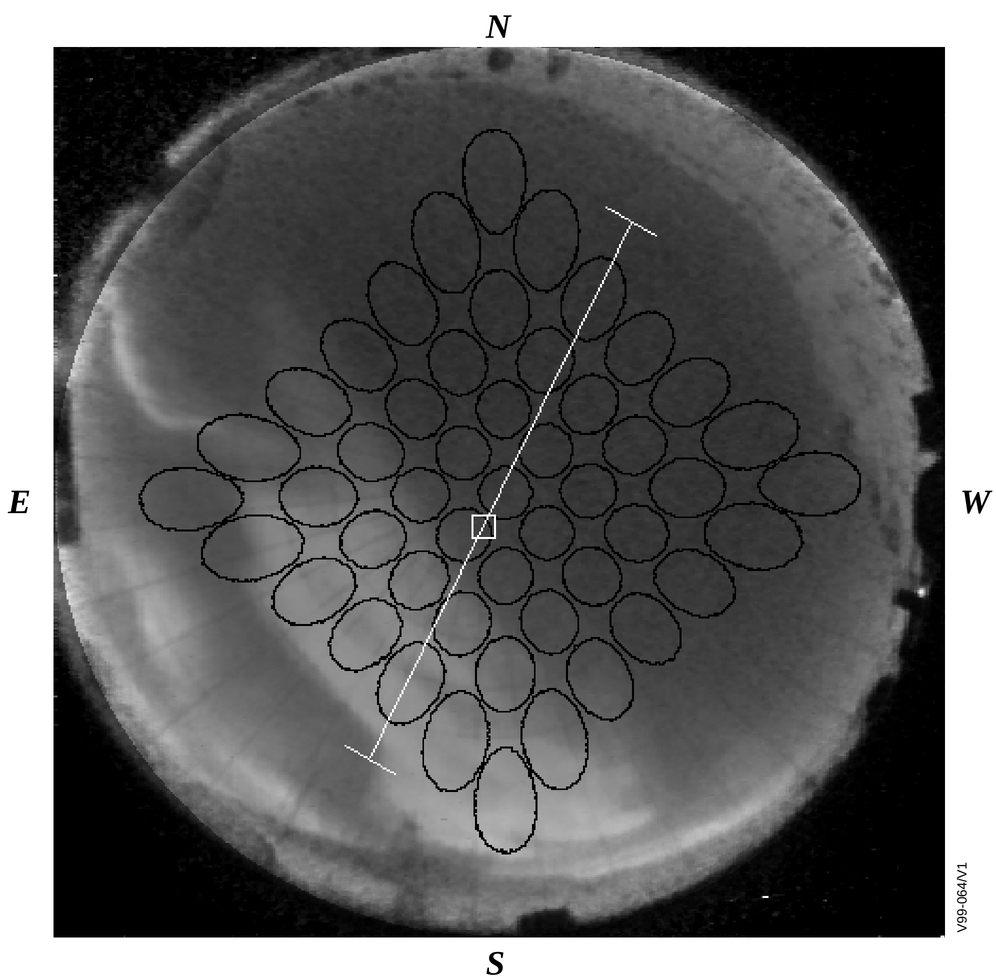

Figure 3. Combined views of the sky and aurora over Kangerlussuaq from the Sondrestrom all-sky imager, imaging riometer (black circles), and incoherent scatter radar (white line).

Table 2 Sondrestrom Optical and Radiowave Instruments 1999.

INSTRUMENT	PRINCIPAL INVESTIGATOR(S)
Incoherent Scatter Radar	Jeff Thayer/John Kelly, SRI International
Rayleigh Lidar	Jeff Thayer, SRI International
Resonance Lidar	Jeff Thayer, SRI International Brenton Watkins, University of Alaska
All-Sky Imager	Richard Doe, SRI International
Meridian Imaging Spectrometer	Gary Swenson, University of Illinois
4-Channel Photometer	Gary Swenson, University of Illinois
UV Spectrograph	James Hecht, Aerospace Corporation
Auroral Photometer	James Hecht, Aerospace Corporation
Fabry-Perot Interferometer	Tim Killeen, University of Michigan
Michelson Interferometer	Abas Sivjee, Embry-Riddle Aero. University
UV Spectrometer	Tim Killeen, University of Michigan
3-Axis Magnetometer	Eigil Friis-Christensen, DMI
MF/HF Programmable Swept Frequency Receiver (PSFR)	James LaBelle, Dartmouth College
MF Interferometer	James LaBelle, Dartmouth College
Meteor Scatter Radar	Susan Avery, University of Colorado
Micro Pulsation Magnetometer	Roger Arnoldy, University of New Hampshire
24, 30, 31 MHz Riometers	Peter Stauning, DMI
Imaging Riometer	Ted Rosenberg, University of Maryland Peter Stauning, DMI
Digisonde	Terry Bullet, USAF Phillips Laboratory
Satellite Scintillation Receiving Systems	Santi Basu, USAF Phillips Laboratory
ELF/VLF Receivers	Tony Fraser-Smith, Stanford University
Ozone Spectrometers	Torben Stockflet Jorgenson, DMI

5 TRANSPORTATION

Moving passengers to and from Kangerlussuaq, Greenland, is easy and full of options. There are two commercial airlines that approximately follow the schedules listed below.

Scandinavian Airlines (SAS) flies nonstop to and from Copenhagen, Denmark (CPH), to Kangerlussuaq (SFJ) three times a week (Monday, Wednesday and Friday) during the winter (October through May), and five times a week (Monday through Friday) during the summer (June through September).

First Air flies direct (with a stop in Iqaluit, Nunavut) from Ottawa, Canada (YOW), once a week in the winter and at least once a week in the summer. From October through May, flights leave Ottawa on Tuesday morning, and return from Kangerlussuaq on Wednesday evening. During past summers, there has been an additional flight on Saturday mornings, returning later the same day.

In support of the NSF's Polar Ice Core Office (PICO), the New York Air National Guard (NYANG) flies personnel and equipment to and from Scotia, New York, to Kangerlussuaq. Its seasonal missions typically begin in April and end in August. In past years, the NYANG has flown additional missions in the winter. All of these missions carry cargo and can accommodate passengers as needed.

Cargo can be moved to and from Kangerlussuaq as above, except for the obvious restrictions on dimensions and weight. There are additional restrictions on hazardous material sent with the passenger flights because there are no dedicated commercial cargo flights. The NYANG has been very helpful in accepting hazmat shipments.

The port at Kangerlussuaq is open during the summer months. The first ship of each season is scheduled to arrive there in late June, and the last ship departs in mid September.

6 OBSERVING CONDITIONS

Sky conditions over the Kangerlussuaq area from a 12-year record are presented below for four different local solar times. Given in days, Table 3 indicates when the sky was 3/10 or less cloudy and visibility exceeded 3 miles. Although seemingly low, the total amount of days with periods of clear skies will be higher than in any one category as it may be clear in one local time period but cloudy in another for any given day.

Table 3

PROJECT DESCRIPTION: SKY COVER LESS 3/10 AND VISIBILITY = GREATER THAN 3 MILES

	21 LST	03 LST	09 LST	15 LST
JAN	10.0	12.1	7.9	7.2
FEB	10.4	10.7	6.3	7.5
MAR	12.0	12.8	8.2	9.6
APR	10.3	10.4	8.6	9.0
MAY	5.6	5.1	5.0	4.9
JUN	6.3	7.1	6.6	5.6
JUL	4.7	5.3	6.7	4.9
AUG	5.8	6.2	6.1	5.1
SEP	6.8	7.4	4.7	4.3
OCT	8.2	7.5	4.5	5.1
NOV	8.7	8.7	6.1	6.2
DEC	11.5	12.3	8.2	7.4
ANN	100.3	105.6	78.9	76.8
POR (YRS)	12	12	12	12
NO. OBS.	4382	4382	4382	4382

The phases of the moon will impact some of the rocket measurements, such as the TMA trail experiments, as well as some ground-based instruments, such as the all-sky camera. In these cases, the new moon period is an optimal time to center a launch window with a week on either side of this date. It is expected that two to three new moon periods will be available over the course of the rocket campaign from January through March 2002. The dates for the new moon during this time period are 13 January 2002, 12 February 2002, and 13 March 2002.

The relative location of the Kangerlussuaq rocket range to the auroral oval is also pertinent information for a number of rocket measurements. The location of the site at any one time and the level of geomagnetic activity determines whether the site is sampling the polar cap, cusp, or auroral oval. Under moderate conditions and over the course of a day, the Kangerlussuaq rocket range and Sondrestrom facility will rotate under the polar cusp region around 14 UT (magnetic local time is 01:57 minutes less than Universal Time), the dusk oval and sunward convection region until 22 UT, the polar cap–auroral boundary until 06 UT, and the dawn oval and sunward convection region until 12 UT.

7 CONCLUSION

This proposal summarizes the scientific motivations and logistic details for carrying out a rocket campaign in Kangerlussuaq, Greenland. Continued attention must be given to the Danish and Greenlandic authorities throughout this process. The Sondrestrom Facility has been in good standing with these government officials over many years and can certainly help in the planning as well as operational phases of this mission. The rocket project has also been approved by Dr. Robert Robinson, the NSF Upper Atmospheric Facilities program manager, who is supportive of dedicating facility resources to the project.