Collaborative Research: Development of a Power and Communication System for Remote Autonomous GPS and Seismic Stations in Antarctica


1. Project Summary:

Major advances in addressing many compelling questions in polar geoscience require continuous recording of GPS and seismic data. Logistic expenses require systems that can operate unattended for multiple years. This project is developing a new system that will enable the polar science community to obtain critical new data sets to address many fundamental questions about the nature and behavior of the crust and mantle beneath Antarctica and its relationship to ice sheet dynamics and climate.

New technological achievements in GPS receivers and seismometers make it possible to use off-the-shelf units for autonomous recording in polar regions, and we are developing power and communication systems to permit year-round autonomous station operation. In this development effort, IRIS and UNAVCO are teaming with the Antarctic GPS and seismology scientists to design and build a reliable power/communication system for autonomous polar station operation. The power/communication units built will form the nucleus of a new IRIS/UNAVCO equipment pool, and will allow the science community to achieve the first long-duration deployment of continuously recording GPS and seismic stations across the Antarctic continent during the International Polar Year (2007-2009).

The goals of this project are to use the latest power and communication technologies, linked with the collective experience/expertise of the science community and IRIS/UNAVCO staff, to 1) design, integrate, and test a scalable power and communication system optimized for ease of deployment and reliable multiyear operation in severe polar environments; and 2) provide an initial pool of these systems for deployment and testing in science experiments. This progress report provides a summary of the UNAVCO effort through Year 3.

A no cost extension has been provided for the purpose of contracted services to enable the use of RUDICS technology for Iridium communications from remote sites. RUDICS is an Iridium communication protocol that allows connectivity from the remote site directly to the internet, eliminating the need for a base Iridium modem (and the associated airtime charges that accompany it). RUDICS also provides greater data throughput which is significant for high-rate GPS applications, and allows data transfer using standard internet protocols which will enable our communication system to support devices other than the Trimble NetRS GPS receiver. Being tied to this particular receiver is currently a limitation of the system we are using. The option of using RUDICS with the NSF/DoD issued SIM cards has only become practical over the past year. Two private
companies, SRI International and Xeos Technologies, have developed a RUDICS capability for other NSF science applications. We are now in a position to leverage this progress for our GPS applications, and a one year no-cost extension will allow us to apply any remaining project funds to this effort that will ultimately broaden the user base for the power and communication systems developed under this MRI grant. This is above and beyond the stated project and the project as proposed will be completed per the original schedule.

2. Year 1 Major Milestones and status update:

A) Prototype site for development and engineering evaluation installed near UNAVCO

Installed prior to the Year 1 Antarctic field season at Marshall Colorado, south of Boulder, the polar remote station test bed provides a secure and accessible area where a wide variety of systems and components can be field tested for prolonged periods of time (Figure 1).

The Minna Bluff prototype GPS-Iridium system (a new configuration) was tested here to monitor long term performance. Iridium short-burst data and wind turbine testing was performed at the site. The Iggy Ridge MRI prototype system also underwent burn-in testing here prior to deployment. In August 2007 a new system was deployed based on the Year 1 MRI design to allow a local development site of the same configuration as current field system kits. Tests at this station have included improved configurations for the GPS receiver and Iridium modem, a new Iridium antenna, and optimized Iridium data download techniques.

Further details on testing at Marshall:
http://facility.unavco.org/project_support/polar/remote/test.html

Figure 1 – (a) System DVEL at Marshall, Colorado testbed site.
B) Install wind system prototype on Niwot Ridge for winter testing

Niwot Ridge provides a unique alpine proving ground on the continental divide above Boulder, and is exposed to severe (80mph+ gusts) winds, drifting snow, rime icing, and spindrift (Figure 2). Installed in August 2006, the frame and enclosure set-up is a preliminary design, and the field installation highlighted several needed changes that have been incorporated in field kits. This system continues to serve as a wind turbine test site, and the system electronics were updated in September 2007 to match the current MRI best practices design, i.e. a POLENET system with Iridium data retrieval. The intent is to not disturb this site unless there is a problem, when it would become a backyard “failure analysis” opportunity.

For a chronology of testing at Niwot Ridge:
http://facility.unavco.org/project_support/polar/remote/test.html
State of health data for station NIWT:
http://facility.unavco.org/project_support/polar/remote/SOH/

Figure 2 – (a) Upgrading site NIWT to POLENET configuration (summer conditions)
(b) Winter conditions at the Niwot Ridge.

C) Install McMurdo (GPS+ full data retrieval) engineering testbed

The UNAVCO McMurdo test facility was installed in summer 2005-06. This system serves a dual purpose of advanced component testing and acquisition of engineering data on power system performance. GPS data from this site is downloaded daily and archived at UNAVCO.

In summer 2006-07, it was fitted with a Trimble NetRS system utilizing point-to-point Ethernet radio communications to McMurdo Station, along with two wind turbines and a weather station (Figure 3). Eleven channels of engineering data
were also recorded and yielded a valuable quantitative history of system behavior during winter shutdown and spring startup.

In summer 2007-08 the station was modified to test a solar + SLA battery system with lithium battery backup. Operation of seismic equipment on lithium batteries on the polar plateau has been proven by PASSCAL and this station is a step toward a plateau GPS system by demonstrating power switching between dual power supplies of SLA and lithium batteries. Since June 25 2008, this receiver has been running on lithium batteries.

For a chronology of testing at McMurdo:
http://facility.unavco.org/project_support/polar/remote/test.html
State of health data for station MILF:
http://facility.unavco.org/project_support/polar/remote/SOH/

Figure 3: (a) McMurdo Station Testbed configuration for winter 2007. (b) Configuration for winter 2008 showing lithium battery backup.

A simplified GPS system was also installed at the IRIS-GSN SPRESSO seismic site near South Pole Station. This installation consisted of a small plastic case buried 12” under the snow surface and received power and ethernet communications directly from the SPRESSO building. This station operated continuously throughout the winter, demonstrating that GPS equipment can survive plateau deployments with a small amount of tight-fitting foam insulation. This station also provided useful ice strain data to the GSN group.

In late 2007 the receiver was remotely power cycled and allowed to cold soak between restarts. The receiver failed after approximately 50 cycles, demonstrating limited ability of the equipment to restart after extreme cold exposure. The receiver has been returned to the manufacturer for failure analysis.
D) Install GPS+data retrieval prototype to continent margin site of scientific interest with dataflow

A prototype GPS station was built on Minna Bluff in February 2007 (Figure 4). This location was chosen due to its extremely windy conditions and usefulness as a future POLENET site. The goal of this effort was a field shakedown of a mass-produceable system that is easy to transport and set up, withstands the harshest environments, and has the potential to provide year-round power. The station was installed in two flights on a Bell 212 helicopter with a three-person crew. With an overall station weight was less than 1300 lbs, it met the MRI design requirement to keep the total system weight below 1500 lbs. Although an intermittent power connection resulted in data gaps and the turbine itself was damaged by windborne debris, the wind turbine provided enough power for this system to run through winter 2007. The mechanical and electrical components were also proven during this test.

State of health data for station MIN0:
http://facility.unavco.org/project_support/polar/remote/SOH/

Data volume summary for station MIN0:
http://archive.unavco.org/query/data_volume_all?stn=min0

Figure 4. (a) Original installation of Minna Bluff Prototype MIN0.   (b) MIN0 antenna.

The design of station MIN0 has since been refined to increase reliability and minimize field installation time to a single day visit, and the improved design was used as a basis for POLENET GPS deployments (Figure 5). The MRI effort and the current POLENET activities in Greenland and Antarctica have resulted in a great leap forward for remote polar permanent GPS systems, and many of the system assemblies have been outsourced for mass production. More detailed information on the polar GPS system:
http://www.unavco.org/polartechnology
E) Report on recommended ‘best practice’ system configuration, provided to science community to implement for IPY installations in 2007-08

i) UNAVCO Polar Technology website

Rather than producing a verbose report, we have built the UNAVCO Polar Technology website [www.unavco.org/polartechnology](http://www.unavco.org/polartechnology) and regularly update it to provide a current view of best-practices components and GPS system designs, test reports, and related information. It is consistent with what we are recommending for remote polar applications and is the key product of the MRI project as it documents the outcome of the development effort. Our intent is to seek out expertise, critique, and assistance from the appropriate greater community experts, and we expect the field kits that we provide to reflect “best practices”. This site is crosslinked to the PASSCAL Polar web page for seismic focused content, and to the PolarPower page for a broader overview of polar power systems.

ii) Summary of continental margin system design Version 1.0

Although the system continues to evolve, the UNAVCO continental margin GPS design has reached a level of maturity that Version 1.0 has been reviewed and documented. Following are technical details on this system.

Logistics performance:

a. Light aircraft deployable design. Compatible with Bell 212, 222 helicopters, Twin Otter fixed-wing aircraft. ~1100 lbs total system weight.
b. Individual modules weigh 70 lbs or less.
c. Designed for two year minimum service interval. POLENET Greenland network is approaching 12 month interval. POLENET Antarctica network is entering its first winter.
d. Installation procedure and toolkits optimized for three person field teams.
e. Minimal field wiring with “plug-and-play” connectors.
f. Fieldwork is minimized with simple status checks, component swaps, etc.
g. Compatible with “near year-round” operation in case delivering a year-round power system is not practical. MRI year 1 system OBH1 and POLENET Greenland system SCBY demonstrated smooth spring startup after winter shutdown.
h. No air-transport-restricted materials.

Power system:

http://facility.unavco.org/project_support/polar/remote/power.html

b. Solar panels: 2x80W poly-crystalline silicon photovoltaic modules.
   Solar panel model will vary base on current availability.
d. Power board: custom board with breakers and spring-loaded terminal blocks.
e. Battery: Deka 8G31ST sealed lead acid gel cell.
f. Battery wiring: Custom quick-connect battery jumpers.
g. Power connections: ITT Cannon military connectors and cable assemblies with rugged, cold-flexible cable. Unique pin-outs for batteries, solar, and wind connections.
h. System schematic diagram: see link from above webpage.

Communication system:

http://facility.unavco.org/project_support/polar/remote/comms.html

a. Near-field sites: Intuicom Ethernet bridge radio and Yagi antenna provide Ethernet connection to Trimble NetRS receiver and point-to-point comms to research station.
b. Deep field sites: Iridium A3LA modem and SAF-2040B antenna provide serial link to Trimble NetRS receiver from UNAVCO.
c. Iridium download hub: A robust, scalable Iridium download hub is operational at UNAVCO, and is currently downloading 40+ remote stations.
d. Iridium SBD study: A feasibility study and proof-of-concept deployment was performed using Iridium short burst data (SBD) mode to stream data to an IP socket on a data collection computer.
3. Year 2 Major Milestones and status update:

A) Basic (no wind or advanced battery technology) systems available for research deployments, testing, and community feedback

Over 40 GPS stations based on the MRI continental margin design have been fielded in Greenland and Antarctica since July 2007, a majority installed under the POLENET project. As of July 2008 the status of POLENET networks is shown in Figure 6, where green indicates that data files are currently being retrieved.

Figure 6. (a) Status of POLENET Antarctica network as of July 2008. (b) Status of POLENET Greenland network as of July 2008.
Also, the MRI project provided five best-practice “science kit” systems for community evaluation and feedback during the 2007-08 Antarctic field season (Figure 7). Two of these became POLENET sites CRDI and PECE, differing from the other POLENET sites in that they had a single enclosure and half the number of batteries and solar panels. One system was delivered to Slawek Tulaczyk’s glaciology project on Whillans Ice Stream in west Antarctica (station WHL1), one to Robert Bindschadler’s project on Pine Island Glacier (PIG1), and one to Philip Kyle’s Mt. Erebus project (MACZ). All of these systems were successfully fielded by the PI field teams except for MACZ which, due to weather, was installed by UNAVCO during a late-season break in the conditions. Useful feedback on the system design was solicited and obtained from the PI field teams.

Figure 7. (a) MRI Science Kit PIG1 near Pine Island Glacier. (b) MRI Science Kit MACZ on Mt. Erebus.

B) Integrate McMurdo test site to GPS+Seismic+data retrieval, year-round operation.

A new integrated GPS+seismic station was installed on Observation Hill in February 2008 (Figure 8). This station (MCMX) combines a PASSCAL polar seismic system with a UNAVCO polar GPS system on a single structural frame, with a single power supply system and battery bank. A single point-to-point ethernet radio was also shared, allowing full GPS and seismic data retrieval. It is anticipated that this system will demonstrate shared Iridium communications during Year 3.

This station demonstrates that although the UNAVCO and PASSCAL polar remote systems often use different hardware, the two designs can be seamlessly integrated as a single system, requiring only custom power and communications cables between the two enclosures and a slight modification to the standard UNAVCO structural frame.

State of health data for station MCMX:
C. Add South Pole test site w/ GPS+Seismic+wind+data retrieval upgrade existing seismic system as necessary.

The first prototype GPS system for plateau operation was deployed at South Pole in January 2008. This system incorporates two Forgen 1000 wind turbines, a vacuum insulated enclosure, and active system heating. The batteries are enclosed in a vacuum insulated chamber while the electronics are housed above in a foam enclosure and use their own power for self heating. The mechanical design and rigging scheme were optimized for efficient installation on snow surfaces. Finally, a separately-powered datalogger continues to record thirteen channels of voltage, current, and temperature data during winter 2008. A mid-winter download was performed by the station Cusp Technician, yielding valuable engineering data about system behavior during the onset of winter.

This station was an attempt to operate a plateau system of minimal complexity, using SLA batteries and an electrical design similar to our proven continental margin system. The electronics performed flawlessly and the station ran continuously through the onset of winter, however power ran out in mid-June. There are two primary reasons for this shortened lifetime. First, the vacuum panels used were ruggedized for field use, which resulted in a diminished insulating capability due to poor fit. Second, the wind turbines used were larger versions of the Forgen 500, which we have used with reasonable success at continental margin sites. However, these turbines were simply not powerful enough to take necessary advantage of light but steady plateau winds and did not deliver sufficient heat and charge to the battery bank.
A more advanced plateau design is being developed and will be deployed in early 2009. This system will incorporate a more powerful wind turbine with bearings rated for extreme cold, more advanced power and thermal management, and improved insulation.

State of health data for station SPUD:
http://facility.unavco.org/project_support/polar/remote/SOH/

![Plateau prototype system SPUD at South Pole](image)

![Electronics and datalogging system](image)

Figure 9. (a) Plateau prototype system SPUD at South Pole (b) Electronics and datalogging system.

D. Install GPS+wind+data retrieval, year-round, prototype on Polar Plateau site of scientific interest.

In conjunction with POLENET and with recon assistance from ANSMET, a second plateau prototype was installed in the Miller Range at the edge of the plateau. Since the site experiences extreme winds, the continental margin mechanical design was employed. However this station also employed high efficiency foam insulation and active heating from a solar panel to improve late-season charging and extend lifetime of the SLA batteries. In this sense, station IGGY is a hybrid which incorporates elements of both margin and plateau designs. The station was also fitted with an integrated weather station.

Communications with the site were lost in late March during a storm. The most likely problem is a broken Iridium antenna. These antennas have proven to be somewhat fragile, and such a failure was observed at a site in Greenland where the system otherwise ran continuously through the winter. More robust Iridium antennas have been purchased and tested which will be installed at all future GPS sites and retrofitted at existing sites as opportunity arises. We expect to
obtain recon in early season 2008-08 to identify the problem, and a site visit is planned for later in the season.

State of health data for station IGGY:
http://facility.unavco.org/project_support/polar/remote/SOH/
Met data plot at:
http://www.geology.ohio-state.edu/TAMDEF/Data/iggy_time1.png

![Figure 10. (a) “Iggy Ridge” in the Miller Range. (b) Plateau “hybrid” system IGGY.](image)

**E. Visit Minna Bluff to add 2nd Forgen 500, add collocated seismic site.**

Year 1 prototype MIN0 was revisited in February 2008, the first time a remote MRI design GPS station had been visited after a year’s operation. A full site inspection was performed which revealed no damage to the GPS antenna, solar panels, wiring, or structural system. The intermittent power problem observed during 2007 was repaired and a co-located but independent seismic prototype station was also installed at the site.

The only damaged component was the Forgen 500 wind turbine, which was impacted by windborne debris. Although it would still spin and produce power in high winds, it would most likely not have powered the system through winter 2008 as it did through winter 2007. However, the success of this turbine during its first winter at an extreme location – a south-facing cliff edge at Minna Bluff - demonstrates the validity of a small size, low power, vertical axis wind turbine for use on the continental margin. It is our opinion that such a turbine with an improved mechanical design would be optimal for these applications. Two new Forgen 500 turbines were installed and as of July 2008 they are still providing power to the system, which has run continuously since the site visit with no data gaps.
F. Analysis of data on all prototype and community instrument deployments, identify improvements required for systems.

i) Feedback from community deployments

Between the MRI prototypes and testbed systems, POLENET networks, the five MRI science kits, and other PI deployments, a large number of GPS systems based on the MRI design have been installed at polar locations. UNAVCO has actively solicited feedback from the diverse array of personnel who have used this hardware and incorporated many suggestions into the design. The installation procedure has been optimized for a three person team and an instruction manual will be produced prior to the 2008-09 Antarctic field season. Reliable suppliers for all hardware and production capability at UNAVCO have been established. This system is now mature enough that in spring 2008, version 1.0 of the continental margin GPS system was finalized and documented.

ii) Acquisition of engineering data

UNAVCO continues to retrieve valuable datasets from remote GPS sites. Temperature and voltage data are obtained during each data download and are made available online at:

http://facility.unavco.org/project_support/polar/remote/SOH/

Three detailed year-round engineering datasets have also been obtained from Antarctic locations. Data from GPS systems at Observation Hill were recorded.
during 2006 and 2007, and data collection is ongoing at South Pole during 2008. Combined with laboratory tests at UNAVCO, these comprise a comprehensive, objective, and very relevant set of technical information on performance of systems and components. Where applicable, technical information is presented in report form at

http://www.unavco.org/polartech

iii) Ongoing development

Since the nature of remote polar instrumentation essentially results in a one-year design cycle, the limited number of deployments under the MRI project will not yield a large statistical picture of system failures. However, since the POLENET project is occurring simultaneously with MRI technology development, a much more comprehensive picture of system reliability is being obtained. Every visit to an existing site is taken as an opportunity for detailed troubleshooting and retrieving valuable information about long-term system health. Post-mortem analyses are performed on failed components. State of health data from remote sites are also closely monitored and archived. As a result, the continental margin GPS system design continues to be refined.

G. Update best practices documentation.

Several times per year, as new data is obtained and changes are made to system design, updates to the UNAVCO polar technology website are performed. This resource is kept current with the best practices that we are recommending.

New additions to the website include updated information on all continental margin system components, CAD drawings for custom-fabricated parts, current state-of-health data plots for all remote polar GPS stations, detailed test reports for system power consumption, and notes on why we selected and designed various components for polar use. An instruction manual for installation of this system will be completed prior to the 2008-09 Antarctic field season.

H. Advanced systems available for research deployments, testing, and community feedback.

The continental margin systems available from UNAVCO for the 2008-09 Antarctic season contain several improvements over the previous year’s version. For example, the fragile Iridium antennas are being replaced by more robust models, and several configuration changes to the GPS receiver, Iridium modem, and UNAVCO download system have improved communications reliability and data throughput. Also, increased power output from the new Forgen 500 design may require power diversion, which can be used as a measure of active heating for margin systems. Integration of lithium battery packs as backup power for GPS systems is also being tested.
4. Year 3 major milestones and status update:

A. Add wind turbines to continent margin science site

A single Forgen 500 wind turbine was added to the continental margin prototype site at Minna Bluff in Year 1. This turbine was found damaged in Year 2, and replaced with two similar turbines in Year 2. During the winter, the telemetered state-of-health data indicated that both wind turbines had failed, and the decision was made to abandon wind turbines at this extremely windy site and add an auxiliary box of batteries as the best long term solution during the Year 3 visit. The batteries were added and are expected to provide year-round operation. The two wind turbines had sheared shafts. Post-season follow up revealed the shear was caused by torsion and due to the bearings seizing. Replacement bearings have been identified, and are now also available from the manufacturer or as an in-house modification at UNAVCO. It should also be noted that for both year 1 and year 2, the damaged turbines still provided enough power to keep the MIN0 GPS site collecting data all year, when it would have otherwise shut down in June.

B. Analysis of data on all prototype and community instrument deployments, identify improvements required for systems

Feedback was solicited and received from the science teams that had received field kits in Year 2, including:

Ted Scambos – Recovery Lakes
David Holland – Pine Island Glacier
Sridhar Anandakrishnan – WAIS
Slawek Tulaczyk – Whillans Ice Stream
Terry Wilson and the POLENET team – POLENET Antarctica
Mike Bevis and the GNET team – Greenland GNET project

Most of the feedback was constructive and detail oriented, and most of it has been incorporated to system design. The latter two PIs also voiced major concerns to our sponsors, which resulted in an external and independent design review. The design review findings are included at the end of this report.
C. Advanced systems (wind, lithium battery capable, but not provided from MRI funding) available for research deployments (such as IPY POLENET), testing and community feedback

Forgen 500 continental margin wind turbines were deployed en masse in on the GNET and POLENET projects in 2007 and 2008. Site maintenance visits in Antarctica in Year 3 revealed two issues with these turbines:

1) The manufacturer’s “low temperature” bearings still have a tendency to seize in the cold and shear the turbine shaft. A remedy for this has been identified by both UNAVCO and the manufacturer.

2) Wind turbine regulation is required at the windiest sites. The manufacturer recommends using the turbines without any regulation, an approach which has been demonstrated with good success at many polar locations. However at the most extreme sites this can result in damaged batteries. A simple wind turbine regulator is now a standard part of the system power board for future installations and service visits at all sites.

After soliciting the greater Polar community for recommendations on medium size (~100W) wind turbines suitable for use on the Polar Plateau, three rose to the surface and were purchased for further testing: the Aerogen 4 non-furling version, the Ampair 100, and the Rutland 910-3. The Aerogen 4 was selected after laboratory and field testing, and was fielded at both the South Pole test-bed and at the two Recovery Lakes GPS sites.

The use of lightweight, non-rechargeable, cold-rated lithium batteries was adapted from the systems regularly used by PASSCAL. Three systems with lithium battery backup power are fielded at the McMurdo test-bed and for the Recovery Lakes sites.
Figure 12: Polar plateau design prototype deployed at the South Pole.
The system enclosure is buried as a buffer against extreme temperature swings, has high efficiency vacuum panel insulation, Iridium communications, active heating, and wind and solar power sources for year-round autonomous operation. Similar systems were installed in the Recovery Lakes region from the Norway-US IPY Traverse in January 2009.

The Recovery Lakes GPS sites are on the cutting edge of both polar research (collecting data tied to subglacial hydrology) and application of technologies customized to minimize the system weight, yet operate year-round on the polar plateau. Two systems were deployed by Ted Scambos from the Norway-US IPY traverse. These systems operate with only 6 lead acid batteries, have lithium batteries for backup, use the Aerogen 4 wind turbine and solar panels for year round power, have vacuum insulated enclosures for the extreme cold, and active heating to keep the instruments above minimum operating temperatures. As of mid-winter 2009 the systems are performing well and there has been no need to draw upon the primary lithium batteries.
D. Upgrade field systems installed in Year 1, 2, for long term autonomous operation (as warranted by funded science initiatives)

This bullet refers mainly to adding wind turbines or lithium batteries to MRI provided systems that were initially fielded without them, since selecting these components were Year 2 deliverables that would be ready for field use in Year 3. After rescheduling tasks to accommodate POLENET and GNET projects, wind turbine selection was moved up a year and fielded with the original installations. The longer range upgrade plan is to add batteries when site repair visits are necessary anyway and the aircraft cargo capacity is available. This was done for the Minna Bluff POLENET site, and is planned for the Pecora and Cordiner Peak POLENET sites in 2010.

E. Capability to install sites to standard, proven configurations

Standardized “best-practices” systems from UNAVCO are well documented at www.unavco.org/polarntechnology, and systems for various projects and geographical locations share common components, identical connectors, etc. which minimizes the need for labor intensive and inefficient “one-off” systems.

F. Field proven systems, support, data handling, as-built documentation available off-the-shelf from IRIS and UNAVCO

PASSCAL also provides well documented, standardized, best-practices systems, and there has been a fair amount of knowledge transfer between the facilities during the design process. However, the project vision of interchangeable, standardized systems spanning the two facilities will not be achieved, and the reasons for this will be addressed in the final report. Also, to make systems truly off-the-shelf, additional funding for procurement is required, and a status update will be included in the final report.

5. Community activities:

A Polar Networks Science Committee was expanded to include better Arctic science representation with the addition of Meredith Nettles and Mark Fahnestock. This committee reports to both the IRIS and UNAVCO boards of directors, and in addition to the new members consist of Doug Wiens (chair), Terry Wilson (co-chair), Sridhar Anandakrishnan, Rick Aster, Carol Raymond, and Bob Smalley.

The first PNSC meeting was held at UNAVCO in March 2007 with two days of productive technical discussions related to upcoming science project needs and some significant differences in system requirements between the GPS and seismic communities. UNAVCO E&O Director Susan Eriksson joined the PNSC meeting to discuss Polar E&O. Susan summarized a wide range of polar efforts ranging from RESESS/SOARS interns to professional meeting activities.
In 2008, the UNAVCO E&O department also worked with IRIS/PASSCAL on an Active Earth display which highlights the achievements of the POLENET project.

UNAVCO supported four interns during year 1, including one (Ezer Patlan of the University of Texas at El Paso) funded by the Polar MRI project. In Year 2, UNAVCO supported 9 interns, also including one funded by the MRI.

The second PNSC meeting was held at PASSCAL in March 2008. Year 2 progress was presented to the committee and direction was received as to the most important areas on which to concentrate future work, and the Year 3 major milestones were reviewed along with the project logistics assumptions.

The third PNSC meeting was held at UNAVCO in May 2009. Year 3 progress was presented to the committee, the longer term staffing requirement of supporting network operations was discussed, and the recent external design review at UNAVCO was presented to the committee. Robert Smalley and Rick Aster will rotate off the committee, with Leigh Stearns and TBD as replacements.

6. External design review report:

Major Research Instrumentation Project:
Development of a Power and Communication System for Remote Autonomous GPS and Seismic Stations in Antarctica

Review Committee Report

March 13, 2009

The review committee met with Bjorn Johns and Seth White of UNAVCO at the offices of UNAVCO in Boulder, Colorado on March 12 and 13, 2009. The committee was directed by Renee Crain of NSF to assess the performance of UNAVCO on the Polar Service’s NSF/OPP Major Research Instrumentation (MRI) Project. Specifically the committee was directed to answer the following questions:

1. Is UNAVCO at the leading edge of polar system designs for the target applications?
2. Is the project meeting stated deliverables and milestones?
3. How does the product measure up to the grant award size?
4. Are there other relevant field-tested designs that should be applied to this design?
5. Are there major issues with the design?
6. Are there minor but correctable issues that can be addressed in the design?
7. Evaluate the list of issues and planned corrective actions – are evolving design changes, failures and lessons learned being addressed effectively?

The committee met for a total of twelve hours during which UNAVCO presented a technical design overview and current status. There were many technical discussions during and after the presentation. The committee was encouraged by UNAVCO to ask
questions and to dig as deeply as necessary to answer the above questions. We found the UNAVCO representatives to be informative and forthcoming.

The following are the unanimous findings of the committee.

- Is UNAVCO at the leading edge of polar system designs for the target applications?

The MRI system is at the leading edge of polar field system technology.

The committee is not aware of any competitive designs that would provide better performance or lower cost. While there are recent technologies such as rechargeable lithium ion batteries that would improve the MRI system, these technologies are not yet suitable for polar environments.

There are indications that the Trimble Net/RS receiver, which is central to the MRI design, will be discontinued sometime in the next year. The MRI system also needs to evolve in order to deal with this type of component obsolescence.

- Is the project meeting stated deliverables and milestones?

As listed in Section 4, Project Milestones in the proposal, the project has met the early milestones by the date of this review and the Year 3 milestones have either been completed or are on track for timely completion.

- How does the product measure up to the grant award size?

The committee was favorably impressed with the quality of the MRI design considering the amount of the grant. NSF received true value for its investment.

- Are there other relevant field-tested designs that should be applied to this design?

The committee is not aware of any field-tested designs that could be applied at this time. However, there are some new technologies that may be suitable for the MRI system in the foreseeable future. As they develop, these new technologies (advances in GPS receivers, more efficient solar cells, wind turbines, microcontrollers, communications, and battery technology) should be investigated and tested in order to keep the MRI system at the leading edge.

- Are there major issues with the design?

The committee found no major design issues. However, we strongly recommend that a watchdog timer be incorporated in all new systems and retrofitted to existing systems as they are serviced. It is the experience of the committee that, due to complex system components and interactions, undetected sporadic bugs will exist in fielded systems. The watchdog timer serves as a last line of defense and is considered good design practice.

- Are there minor but correctable issues that can be addressed in the design?
Most of the minor but correctable issues have already been addressed. The unresolved issues are being properly tracked and addressed. Improved documentation and user training would reduce future problems. UNAVCO is on track to complete the documentation and user training procedures by the end of the MRI grant period. The committee recommends that an independent third party review the final documentation.

- Evaluate the list of issues and planned corrective actions – are evolving design changes, failures and lessons learned being addressed effectively?

The review committee discussed each issue in detail and concurred with most of the proposed solutions. In addition, the committee offered several corrective action recommendations. The committee agrees that UNAVCO has been approaching these issues in a systematic and effective manner.

Given the time and funding constraints, UNAVCO has done a good job developing the MRI system. The committee agrees that the level of reliability achieved by the MRI system in this early stage of development is acceptable. It is unreasonable to expect the first version of a polar field system to be perfect. All potential problems cannot be anticipated. Due to field site remoteness, identifying the source of a problem could take several years. We recommend that MRI system development continue in order to improve reliability and keep it on the leading edge of technology.

Review Committee:
The committee members have extensive experience designing and field testing polar instrumentation systems.

Stephen Musko
The University of Michigan
Space Physics Research Laboratory
2455 Hayward St.
Ann Arbor, MI 48109-2143
734 936 3105

Terry Haran
Cooperative Institute for Research
In Environmental Sciences,
University of Colorado
449 UCB
Boulder, CO 80309
303 492 1847

Roy Stehle
SRI International
Center for Geospace Studies
Engineering and Systems Division
333 Ravenswood Avenue
Menlo Park, CA 94025
650 859 2552

Rob Bauer
Cooperative Institute for Research
In Environmental Sciences,
University of Colorado
449 UCB
Boulder, CO 80309
303 492 2378

UNAVCO Representatives:

Bjorn Johns

Seth White

UNAVCO Polar Services
6350 Nautilus Drive
Boulder, CO 80301-5554