

Appendix: Expressions of Interest

Richard Alley & Co-workers/Penn State We are interested in Pine Island Bay in at least three ways:

1) We endorse ground geophysics by S. Anandakrishnan (now at Penn State but moving to Alabama).

2) We are interested in participating in WAISCORES-related shallow ice coring and pits (as well as deep coring) for spatial and temporal variation in accumulation, climate change, and possibly elevation change. We envision a community-based effort similar to that at Siple Dome. Leadership of such an effort would be discussed with the WAISCORES effort.

3) We are interested in modeling tied to data. Penn State is building, or collaborating with Chicago (MacAyeed) in building a full suite of finite-element, finite-different and reduced-order ice-flow models with basal processes and hydrology, interactions with surroundings, and other appropriate features. Our experience is that models closely tied to data are most useful, and we offer and seek such collaboration.

We also note that ground-based work is best conducted within a remote-sensing/aerogeophysical framework. We believe that science planning for detailed ground surveys would be easier after aerogeophysical surveying.

Sridhar Anandakrishnan/U Alabama Seismic surveys will target the englacial and subglacial environments for ice-fabric and till- and sedimentary-layer-properties, respectively, to determine what the relationship is between these parameters and ice stream formation and location. Field-intensive work such as this would be carried out in collaboration with others such as Andy Smith at BAS. Opportunity exists to conduct comparative profiles onshore and offshore to contrast current and former ice stream basal properties. There is also the possibility of combined on/offshore seismic work with OBS and land-based receivers and ship-based sources.

Radar surveys will map internal layers and study the basal reflectivity changes to see if roughness and/or basal water content are associated with ice streaming (see Expression of Interest from Blankenship et al., UT).

Robert Bindschadler/NASA Dynamics & Kinematics of Pine Island & Thwaites Glacier

From recent ERS-SAR interferometry, Pine Island Glacier accelerates to ice-stream velocities (> 100 m/a) without developing shear margins. This character-

istic may help define the "onset" process. Thwaites Glacier also may exhibit a similar character, although this has not been confirmed.

Thus, my interest spans from the determination of the velocity field within Thwaites & Pine Island Glacier catchment area, assessing the character and position of streaming flow (increasing velocity with decreasing driving stress), inverse modeling the resultant velocity and geometry fields for basal conditions, and forward modeling for likely evolution of the two glacier systems.

The two glacier systems must be studied in parallel to allow for likely interaction between the basins.

D.D. Blankenship, D.L. Morse, J.M. Holt, I.W.D. Dalziel We are interested in acquiring a comprehensive set of aerogeophysical observations over the catchment, tributaries and trunk of Thwaites Glacier and its bounding ridges and divides. The objectives of this work are to understand the changes in ice dynamical state of Thwaites Glacier as its tributaries form, coalesce and go afloat as well as to understand the history of these changes and how they are related to paleoclimate, subglacial geology and off-shore processes.

Specifically, we are interested in using surface/bed morphology, bed echo character, surface/volume scattering and internal layering observations from a comprehensive "phase-coherent" radar survey to understand both present and past ice dynamics. This airborne survey would include laser altimetry for improved driving stress and mass balance calculations as well as measurement of gravity and magnetic anomalies for subglacial geology. In addition, we would plan to complement the airborne work with ground-based radar studies performed in concert with seismic experiments designed specifically to understand the englacial and subglacial environments associated with tributary and "ice stream" formation (see Statement of interest from S. Anandakrishnan).

These geophysical experiments would be undertaken in collaboration with complementary surveys of the Pine Island Embayment proposed by D.G. Vaughan and A.M. Smith

Gordon Hamilton/U. Maine Mass balance and accumulation rates. Our interest is in understanding patterns of ice thickness change in the Pine Island and Thwaites glacier catchments. Radar altimetry work by Wingham et al. suggests large values of dH/dt . These results need to be confirmed. Ground-based measurements using precise GPS surveys are one way to do this. We are also interested in spatial (and temporal) variations in snow accumulation rates because of

their importance in mass balance work. A series of firn cores linked by GPR/GPS profiling is a promising method for mapping catchment scale accumulation rate patterns.

US ITASE traverses in 2001-2002 and 2002-2003 will visit portions of the Pine Island and Thwaites glacier catchments. The work described above is one of the traverse activities.

Terry Hughes/U. Maine In July I discussed with Bob Thomas a project that he and I could do together which seemed to interest him. It would be a study of the calving mechanism for Pine Island and Thwaites Glaciers. The study would begin on Pine Island Glacier, since it has a smoother surface, known basal melting rate and grounding-line retreat rate, and surface velocities. It also drains the lowest ice divide (1200 m above sea level) in West Antarctica, in conjunction with Rutford Ice Stream. Hence a study of the effect on ice-divide lowering due to an unbuttressed and fully buttressed ice stream on each flank is attractive.

We would study the Reeh (1968) mechanism of ice-shelf calving caused by arching and downwarping near the calving front. On the assumption that bottom crevasses form at the grounding line, and perhaps beneath the known bit transverse surface crevasses upstream behind the grounding line, these crevasses should be lines of weakness that are transported to the calving front and reactivated by Reeh bending.

We would do radar sounding and radar or laser profiling from a low-flying aircraft along flightlines from the calving front to beyond the large transverse crevasses. These data would locate surface and bottom crevasses, map Reeh arching and downwarping near the calving front, locate shallow surface troughs above bottom crevasses where high longitudinal strain rates are "necking" the floating part of Pine Island Glacier, and map the grounding zone by elevation changes associated with tidal changes. After these maps were produced, surface studies would be conducted across "lines of weakness" as future lines of calving. Surface studies would include those that Thomas did on the Ross Ice Shelf (strain rates, temperatures, pit studies, etc.).

Christina Hulbe/NASA-GSFC Bedrock topography is an important input to ice sheet numerical models. At present, models are limited by lack of data and poor resolution in several key areas-the Pine Island/Thwaites Glacier catchment among them. Bedrock elevation changes significantly over short distances, creating basal troughs that guide ice flow. Those troughs are not well resolved in

existing data sets, making accurate 2 or 3-dimensional modeling of ice flow difficult, if not impossible. Given the importance of the PIG/Thwaites region to the mass balance of the WAIS, the suggested airborne geophysical campaign should be included in future field seasons. The resulting data will be immediately useful for numerical modelers.

Robert Jacobel/St. Olafs College I am interested in proposing ground-based radar in conjunction with shallow cores and other glaciological field measurements. Internal stratigraphy from the radar would connect measurements made in core studies at sties along a traverse.

S. Jacobs & M. Visbeck/LDEO Circumpolar Deep Water and the West Antarctic Ice Sheet

We have been given the green light by NSF/OPP on a proposal bearing the above name, with fieldwork currently scheduled for the Amundsen Sea in February-March 2000 aboard the NB Palmer. The primary objective of this work is to evaluate the role of Circumpolar Deep Water (CDW) in the attrition of the West Antarctic Ice Sheet. Prior ocean measurements have shown that the basal melt rate of the floating portion of Pine Island Glacier exceeds 10 m/yr, more than 50 times the reported melt rates of the Ross and Filchner-Ronne Ice Shelves (Jacobs et al 1996; Jenkins et al 1997; Hellmer et al 1998). Even higher rates for this deep-rooted glacier have since been inferred from satellite interferometry (Rignot 1998). This attrition appears to result in part from the presence of 'warm' CDW on the continental shelf in the SE Pacific sector, but melt rates of the Thwaites and other glaciers in this region are unknown.

We would map the water masses and sea floor of the Amundsen shelf in sufficient detail to define the routes of CDW access to the continental ice, the locations of meltwater outflows, and the westward evolution of CDW influence. We would use bottom-moored arrays to obtain time series data, and CTD-mounted acoustic doppler instruments to profile the thermohaline and current field. The in-situ data would be utilized to estimate melting rates and validate numerical models of the sub-ice circulation. Collaborating programs are anticipated, including tracer water chemistry, and bottom coring and seismic work to document the deglaciation history of this region. Given sufficient geophysical interest, gravity and magnetic lines could be run across the continental shelf and slope. Other cooperative ventures that would be highly desirable include repeated cruises in subsequent years to retrieve long-term moorings, and detailed sea ice work for operational support

and scientific analyses. If ship-based helicopters were available, that would allow the placement of Automatic Weather Stations, sea ice reconnaissance, and radar/seismic work on the floating glaciers to better define their underlying cavities.

Tom Kellogg/U. Maine Objective: The principal objective is to document to deglaciation history of the Amundsen Sea shelf (WAIS priority research goal H2: Bindshadler, 1996).

1. Collection of additional bathymetric data, and collation of the available data into a form usable by other investigators: This is necessary to establish correct locations of coastlines and islands and to determine the extent and orientation of major glacial troughs (former ice streams channels). Is there a trough fronting Thwaites Glacier? Does it joint with the Pine Island Trough? Are the troughs foredeepened, with shallow sills at the shelf break? Where are former pinning points located, which could serve as temporary grounding line positions, or sites of former local ice caps during deglaciation, etc. Bathymetric information will make it possible to select coring locations along specific flowlines, and hence to track grounding line and calving margin retreat from the shelf break to the present positions.

2. Sediment coring: Cores available now cover only a limited area in the easternmost Amundsen Sea. Needed is coverage of the entire area. Coring efforts should be concentrated along glacial troughs, to document timing of deglaciation (grounding line and calving margin retreat) and between troughs to sample the diamicton. Sedimentologic analyses of the diamicton will reveal its origin (is it a till?). Micropaleontology can tell much about the nature of the surface waters overlying coring sites during deposition of postglacial sandy muds. ¹⁴C dating of carbonate shells or particulate organic carbon are needed to document ages of glacial retreat.

3. Marine Geophysics (esp. Seismic): Needed are multichannel (ideal) or single channel seismic lines, especially along and across troughs, to establish extent and thickness of sediment units (and to aid in selecting coring sites). Seismic data can also reveal information about the nature of the glacial bed (submarine moraines, flutes, grooves, till tongues, former grounding line positions, etc.).

4. Physical oceanographic processes in the Amundsen Sea: Of particular importance are verification that shelf water is not forming here, a more accurate quantification of basal melting rates under the PIG ice shelf, and determination of oceanographic interactions with Thwaites Glacier. Meteorologic-oceanographic

linkages and interactions also need work to quantify what are now mostly qualitative relationships. A complete understanding of the complex factors involved in Amundsen Sea glacial history also requires collection of glaciologic, glacial geologic, and meteorologic data from the area and adjacent West Antarctica and the Southern Ocean (e.g., WAIS research areas C1 and C2).

NOTE: Because of the heavy ice cover in the Amundsen Sea, any cruise to this region entails considerable risk that goals will not be met or that the planned field program will be only partially successful. One way to reduce this risk is by employing a vessel designed for work in heavy ice. This means use of Coast Guard icebreakers. An additional advantage here is that the icebreakers routinely carry helicopters which can be of considerable assistance in locating leads in the pack ice, and can also carry scientists from the ship to geologic/glaciologic sites of interest along the ship's track (e.g., such studies might include measuring the maximum elevation on islands, examining glacial deposits on islands and ice free coastlines, studying moraines on inland mountains within helicopter range, and establishing short-term field camps for glaciologic research). While the cruise should be devoted primarily to marine geology and geophysics and oceanography programs, interested scientists in other fields should be accommodated if possible so that the maximum amount of data is obtained from what is likely to be one of the few opportunities every for most scientists to visit this remote area.

**Craig Lingle, Keith Echelmeyer, Elena Suleimani/Univ. of Alaska, Fairbanks
Ron Kwok, Eric Rignot/JPL** The proposed program will involve fieldwork, focussing on use of aircraft laser altimetry for measurement of surface elevation profiles and airborne deep-ice sounding radar for measurements of ice thickness. 'SOAR' will be employed for both.

The program will also involve use of SAR interferometry for measurement of surface velocities, with INSAR also employed to measure detailed surface topography, to the extent this is permitted by multiple repeat image pairs for differential INSAR.

Numerical modeling will be employed, in conjunction with the above, for simulation of the deformational contribution to INSAR-measured surface velocities, etc. (See abstract on opposite side of this page.)

Abstract

[The mass balance of Antarctic snow catchment areas has traditionally been estimated by summing the total mass input from accumulation, and comparing that quantity to the total mass outflow across grounding lines. On a local scale;

say, at a given point on the ice sheet, an equivalent procedure would be to estimate the time rate-of-change of the ice thickness by taking the difference between the surface accumulation rate and the horizontal divergence of the ice flux averaged through the depth.

Accurate measurement of surface velocities with spaceborne radar interferometry (INSAR) has made it possible, in principle, to estimate the rate-of-change of the ice-sheet thickness on a local scale, in regions where the orbital coverage of ERS and RADARSAT have yielded SAR image-pairs suitable for this technique. Such areas include the Thwaites and Pine Island glacier catchment areas north of lat. 79S (approximately), where the ERS-1 and -2 Tandem Mission yielded image pairs with one-day time separation suitable for measurement of relatively fast-flowing ice. The Thwaites and Pine Island glaciers are of interest in conjunction with the question of the stability of the West Antarctic ice sheet.

A three-dimensional numerical ice-flow model will be used to compute the depth-dependent deformational component of the surface velocity field. The depth-dependent total velocities, including contributions from basal sliding (if any), will be computed by using this result in conjunction with INSAR-derived surface velocities. Use of a nested grid will be investigated for improved model resolution over the Thwaites and Pine Island glaciers. The resulting depth-dependent velocity profiles will be employed to estimate the horizontal divergence of the ice flux and hence the time rate-of-change of thickness, using the continuity equation. The preliminary results will be presented, including an assessment of errors caused by uncertainties in the gridded accumulation rates and airborne radar-derived ice thicknesses, both of which are required as model input.]

Baerbel K. Lucchitta and Christine E. Rosanova/USGS Baerbel K. Lucchitta and Christine E. Rosanova plan to continue their work on velocity measurements on the Pine Island and Thwaites glaciers. The method is by feature tracking on ERS, Radarsat, and Landsat images. One of the goals is to substantiate whether the Thwaites Glacier has indeed been accelerating. Another is to monitor possible future velocity changes. The data will be available for possible calibration of and cross-checking with interferometry measurements of velocities, and for mass balance studies once the bedrock configurations will be known.

Joe McConnell/Desert Research Institute (in collaboration with Rob Arthern) Accumulation variability and its impact on altimetry-based estimates of mass balance. Our interest is in understanding how the temporal and spatial vari-

ability in snow accumulation (and associated changes in near-surface density) affects ice sheet elevation and so altimetry-based estimates of ice sheet mass balance. We have been doing similar work in the high-elevation regions of Greenland where we found very close agreement between observed changes in ice-sheet elevation and modeled elevation change driven by ice-core measurements of contemporaneous snow accumulation (Nature, Aug 24, 2000). These results suggest that reliable interpretation of altimetry data will require full understanding of the actual snow accumulation over the region. Field efforts would include detailed measurements of snow accumulation from widely distributed shallow firn cores (analyzed in the lab using continuous flow chemical analyses and an ice-core melter). Modeling and interpretation would be highly collaborative, involving meteorologists, ice dynamics modelers, remote sensors and others.

Ross Powell/N. III. U. Sedimentary processes both up-stream (grounding zones) and down-stream of a grounding line are important variables to quantify in order to constrain flow dynamics and ice stream behavior and also sub-ice-shelf processes. However, no direct measurements of any of these processes have been made. Research programs using submersible remotely operated vehicles (ROVs) and subglacial and sea floor sampling (including coring) are needed in order to evaluate grounding line and up-stream subglacial processes of WAIS glaciers like Pine Island and Thwaites, as well as for determining sub-WAIS source sediment and evaluating past ice sheet behavior. Data collected in such studies can: (1) document physical and geotechnical properties of subglacial till up-stream from and at ice stream grounding-lines to evaluate down stream areas of ice streams that have had their bed characteristics evaluated farther up-stream; (2) provide a continuum along flow lines to tightly constrain the influence of bed character to flow velocity and sediment supply to grounding-line depositional systems, including the effect grounding-line areas may have on determining transient behavior of ice streams; (3) provide ground truth for geophysical models of subglacial and grounding line sedimentary processes including sediment deformation and sediment geometry; (4) quantitatively and qualitatively document physical and chemical processes for evaluating the interaction between sedimentary grounding-line systems and grounding-line movement relating to ice sheet and ice shelf stability; (5) provide ground truth for sedimentological models of grounding-line systems inferred from the stratigraphic record; (6) be used to construct glacial marine environment models for interpreting sedimentary records on the Antarctic continental shelf of various ages, including the last retreat; (7) provide ground truth

for geophysical and oceanographic models of sub-ice-shelf circulation and freezing/melting patterns and processes, including tidal pumping and tidal influence on periodic grounding line movements over a possible grounding zone; (8) determine the sources (and their character) of sediment under WAIS and perhaps evaluate past fluctuations of the WAIS using sediment mineral and fossil content.

Eric Rignot/JPL Remote sensing data reveal high bottom melt rates on the floating part of Pine Island Glacier and Thwaites Glacier. They also show that these glaciers are experiencing grounding line retreat. We would seek to analyze to-be-collected ice sounding radar data over the floating portion of these glaciers and in particular at the junction ice-ocean, combined with interferometric sar observations, to determine the spatial variations in bottom melting of the ice shelf, and study how oceanic tides and ice thinning interact with the rough glacier bed at the grounding line to produce grounding line migration. We would seek to study this latter aspect combining sar data with an elastic plate modelling of the ice shelf. These data would provide important insights into the ice shelf and grounding line stability in this region.

Ice sounding data presumably to be collected by JPL radar on-board Blankenship's geophysical airborne platform *Ed note: airborne work is a subject of discussion at this meeting.*

Andy Smith/BAS Pine Island Glacier Drainage Basin

I would like to express my support and interest in the proposed research collaboration in the Pine Island Glacier region of West Antarctica. This is an important, yet poorly studied region of the West Antarctic Ice Sheet and attempts to improve our knowledge of the area are long overdue. If the chance were to arise, I would be keen to conduct ground-based geophysical surveys in key areas of the drainage basin. Recent results from SAR interferograms (Wisconsin), airborne radar flights (BAS) and basin analyses (BAS) have already highlighted a complex pattern of streaming flow and interesting basal conditions. Ground based seismic surveys are already proven as a valuable glaciological tool for studying basal and sub-glacial conditions. I would welcome the opportunity to conduct seismic and short-pulse radar surveys in the region. High-resolution seismic reflection can tell us much about the subglacial conditions and their influence on ice flow, whilst refraction surveys can image deeper structure and indicate geological correlations with the ice flow regime. Short-pulse radar surveys can show any non-steady state in the surface mass-balance in the region. Ideally, I would hope that the ground surveys

could be a collaborative project with (at least) Sridhar Anandkrishnan. Support for a small field party could be sought from either US NSF or BAS logistics - or some combination of the two. If the current US/BAS proposal is successful, then one option would be to support the ground seismic party at the same time as the airborne surveys. Otherwise it might be necessary to consider conducting the seismic acquisition at a later date.

Matt Spencer/Penn State Given the recent papers by E.R. Rignot and D.J. Wingham, I'd like to examine the role of firn densification on mass balance determinations throughout the catchment. We know the grounding line has apparently retreated some 5 km during the period of study by Rignot; we also know Wingham's radar-measured elevation change is most pronounced over the area; but we don't know whether these two studies, suggestive though they are, require the mass balance to actually be negative. The near-surface of an ice sheet affords considerable elevation change by way of firn densification dynamics.

I propose a study of the state of firn desification over the catchment in order to determine whether the region's surface is in steady state. Pit studies alone may be sufficient to preclude this, though a few short cores would be ideal.

Mark Stenoien and Charlie Bentley/U. Wisconsin Stenoien, Mark D. and Charles R. Bentley, CATCHMENT OF PINE ISLAND GLACIER, ANTARCTICA: VELOCITIES AND MASS BALANCE FROM INSAR MEASUREMENTS, *J. Geophys. Res.*, in press.

Abstract

We have mapped the catchment region of Pine Island Glacier, Antarctica, using ERS-1 and ERS-2 radar altimetry and SAR interferometry. The radar altimeter data were converted to a digital elevation model (DEM) using a unique algorithm we developed that corrects for slopes and grids the surface-elevation estimates in a single step. We used the DEM and precise (post-processed) orbital ephemerides to generate terrain-corrected and geolocated complex radar imagery. Interferometric pairs on both ascending and descending orbits, corrected by means of the DEM, yielded components of ice-surface motion in the radar look direction. Where possible, we combined velocity components from ascending and descending tracks to produce vector velocities; elsewhere the velocity was calculated by assuming the direction of motion is downslope.

The velocity map reveals a system of tributaries that channel ice from the basin-like catchment area into the fast-flowing downstream trunk of Pine Island

Glacier. None of the tributaries shows a clear onset region. Instead, the ice speed gradually increases, along with a gradual decrease in driving stress, along each tributary. We combined the velocity data with sparse information on ice thicknesses and snow accumulation rates to calculate an approximate mass balance. We find that the region is in balance within an uncertainty of about 30% of the total mass throughput.

Michael Studinger and Robin Bell/LDGO We would like to express our interest in the joint US/UK Pine Island Glacier initiative by contributing a study on the influence of tectonic related structures on drainage patterns in the catchment area. The Pine Island Glacier catchment region differs from the Siple Coast region by the relative orientation between the tectonic fabric and direction of dominant ice flow. While ice flow and extension related tectonic fabrics are oriented parallel for the Siple Coast ice streams and the West Antarctic rift system, the anticipated drainage and geologic structures are oriented almost perpendicular to each other in the Pine Island catchment area. This makes the Pine Island region a unique test area.

Pine Island Bay is located above a crustal boundary separating two terranes with distinctive geological evolution: the Thurston Island crustal block in the east and Marie Byrd Land in the west both forming the Mesozoic Pacific convergent margin of the Gondwana supercontinent. During the Cretaceous a sudden change from subduction to extension occurred along the margin. Intrusion of Tertiary alkaline volcanic rocks has been proposed to be the result of a mantle plume beneath Marie Byrd Land. The anticipated extensional structures associated with rifting (e.g., linear sediment-filled basins), the imprint of the proposed mantle plume, and the location and nature of the crustal boundary are only poorly known due to the ice cover. We believe that including the subglacial geology in the science goals of the proposed program would strengthen it and make it a more comprehensive earth science initiative.

The proposed initiative will strongly depend on a comprehensive airborne geophysical survey for which many potential investigators have already expressed their interest. This data set will provide basic constraints for further work of many participants, and will be used by a broad group of investigators within the proposed research collaboration. Most of the expressed interest focuses on the laser altimetry and ice penetrating radar. We are interested in contributing to the analysis of the potential field data for geologic and tectonic questions related to ice sheet dynamics. The tectonic structures anticipated within the tectonic framework

can be detected with advanced analysis of potential field data. Three-dimensional source depth estimations such as multiple-source Euler deconvolution and power spectral analysis are useful tools in obtaining structural information on the subsurface geology from gravity and magnetic data. Werner deconvolution of magnetic data could be used to constrain magmatic intrusion in the crust.

Ed Waddington, Charlie Raymond and Twit Conway/U. Wash We support the proposed research in the Pine Island Glacier region because of its importance for understanding the drainage of ice from the West Antarctic Ice Sheet. Our main contribution would be to use well-proven, ground-based radar and GPS techniques to examine the present and past flow history of the ridge between the Thwaites and Pine Island Glaciers (Ridge PIT). Stratigraphy in stable areas between ice streams provide the best opportunities for examining past history of flow. Studies on other inter-stream ridges have revealed considerable information about the controls and history of adjacent ice stream activity. Our choice of specific targets for these high-resolution, ground-based studies would be guided by the results of airborne-radar.

Mike Willis, Byrd Polar Research Center, USGS Investigating crustal motion in the PIG area with GPS.

Tectonics: West Antarctica is composed of several micro-plates. The PIG occupies "a narrow but profound depression" (Dalziel and Elliot 1982), interpreted to be the junction of the Thurston Island/Eights Coast crustal block and the Marie Byrd Land crustal block. There are no predicted motions over this junction but a GPS campaign could be initiated to measure any(lack of) motion between these crustal units.

There are reports of active volcanism in the Hudson Mountains, immediately to the east of the PIG. Additionally to the west of the Thwaites Glacier is Mount Takahe a volcano that is also probably active (Le Masurier, 1987). In addition to active areas there are a large number of volcanoes of recent origin. These would be worth investigating in terms of both structural mapping and petrographic studies.

Reconnaissance mapping using high resolution satellite imagery when it is available through the clouds could be used for mapping the structural trends of the area.

Glaciology: According to radar altimetry the annual variability in the snowfall in the PIG area is large. With such a large variation it may not be possible to use altimetry to measure the mass changes of the glaciers over a short time scale. GPS

measurements of bedrock motion can filter out interannual changes in the ice mass and with 3-4 years of measurements it should be possible to measure the elastic response of the lithosphere to ice sheet mass change at selected nunatak sites.

Geodesy: Additionally from GPS measurements we will be able to extract ocean tides, improve the map control for the area and provide a framework for other geodetic work while fulfilling the SCAR directives towards densifying the geodetic infrastructure of Antarctica.