Autonomous Polar Observing Systems Workshop

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Looking Forward

There is no shortage of ambitious ideas for future research from the polar science community. However costs, especially logistics, will always be a limiting factor….a basic conflict facing those funding, supporting, and performing polar research.

Technology is the key to making it happen.

Although recent advances in polar instrumentation have allowed PI's to collect unprecedented datasets, these systems can be better and can do more.

Continue to push the technological envelope…

- Robust, fieldworthy, well-integrated hardware, installed rapidly.
- Reliable, lightweight, year-round power generation and storage.
- Improved remote communications: bandwidth, cold performance.
- Modular, adaptable platforms for co-located multidisciplinary instruments.

Technology Development

- Polar environments are unforgiving on poorly-designed hardware. The development of high-quality, field-worthy systems to collect data used for science is an *engineering* task.

- Technical expertise among support contractors, facilities, and science groups, is considerable. Open sharing of technical information is invaluable.

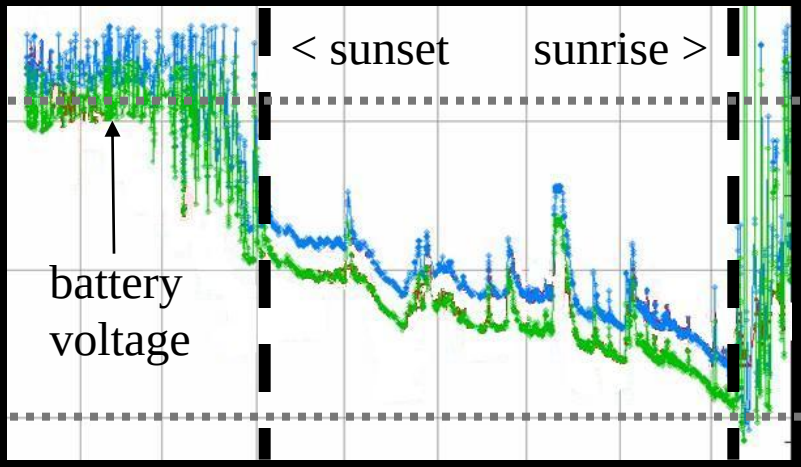
- Polar Technology Conference…a good forum for this exchange. Held in the spring. 2011 location TBD. www.polartechnologyconference.org

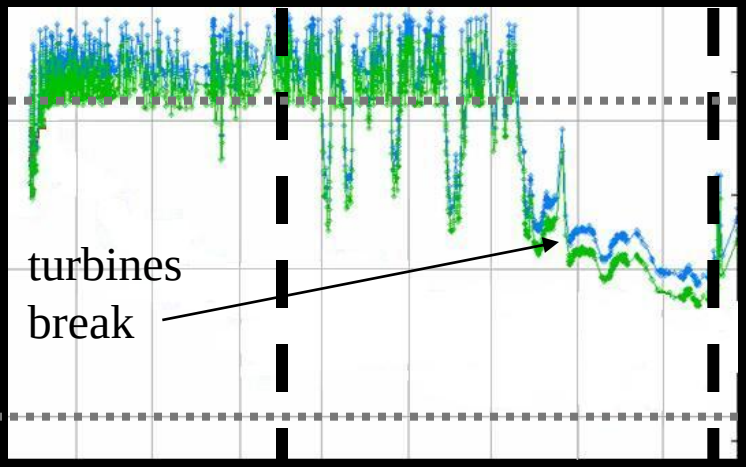
- UNAVCO and IRIS/PASSCAL have developed proven, adaptable, and well-documented systems for the ≤ 5 Watt power range. In our ongoing technical development we are focusing on following technologies…

Micro-Wind Power Generation

Forgen 500: supplemental winter power at extreme wind sites

Small vertical-axis design is the ideal wind turbine format for low-power systems at high wind locations. These turbines essentially replace many heavy batteries.





Success…

Whillans IS GPS (Tulaczyk): 85ºS

Without turbines, system dies in June. With turbines, system runs all winter. Two 15 lb turbines = 1000 lb. batteries!

Failure…

Pecora Escarpment GPS (Wilson): 86ºS

Turbines kept batteries charged into winter but broke in July (system continued to run on battery power).

Micro-Wind Power Generation

Forgen 500: design improvements

- Forgen 500 used by many polar research programs (e.g. BAS). Many examples of success under extreme polar conditions. BUT: survivability not good enough!

- UNAVCO: design improvements with mfg:
  - More robust cabling
  - Improved low-temperature bearings (same spec as AGO turbines)
  - Strengthened shaft (new for 2010-11)
  - Top bearing now also available

- Winter 2011: expect improved reliability.

Micro-Wind Power Generation

Aerogen 4: higher power turbine for low winds + extreme cold

- Higher power horizontal-axis turbine:
  - Battery charging AND heat for electronics.
  - Robust combined solar + wind regulation scheme for Forgen and Aerogen turbines
- Three GPS stations on Polar Plateau
  - 2 at Recovery Lakes (Scambos). Only six lead-acid batteries each + lithium backup. (US-Norway traverse = space/weight limited)
  - Both stations running well after nearly 2 years. Lithium backup batteries not used yet!
  - South Pole testbed also running nearly 2 years
- Proven solution on Polar Plateau…but can it survive higher-wind polar sites? Testing in Antarctica (BAS) and alpine site (UNAVCO)

Micro-Wind Power Generation

Rutland 910-3: higher power turbine for extreme wind sites?

Rutland 910-3 turbine

- Similar power output to Aerogen, but furling design turns turbine away from high winds.
- Survivability demonstrated at Darwin Glacier (Antarctica New Zealand) and ARRO projects. Darwin = blue ice!
- Will be tested winter 2011 at UNAVCO McMurdo test station.
- Could enable a lightweight (~1000 lb) installation of a higher-power (10-20W) instrument suite at extreme wind sites.

Iridium…using it in a better way

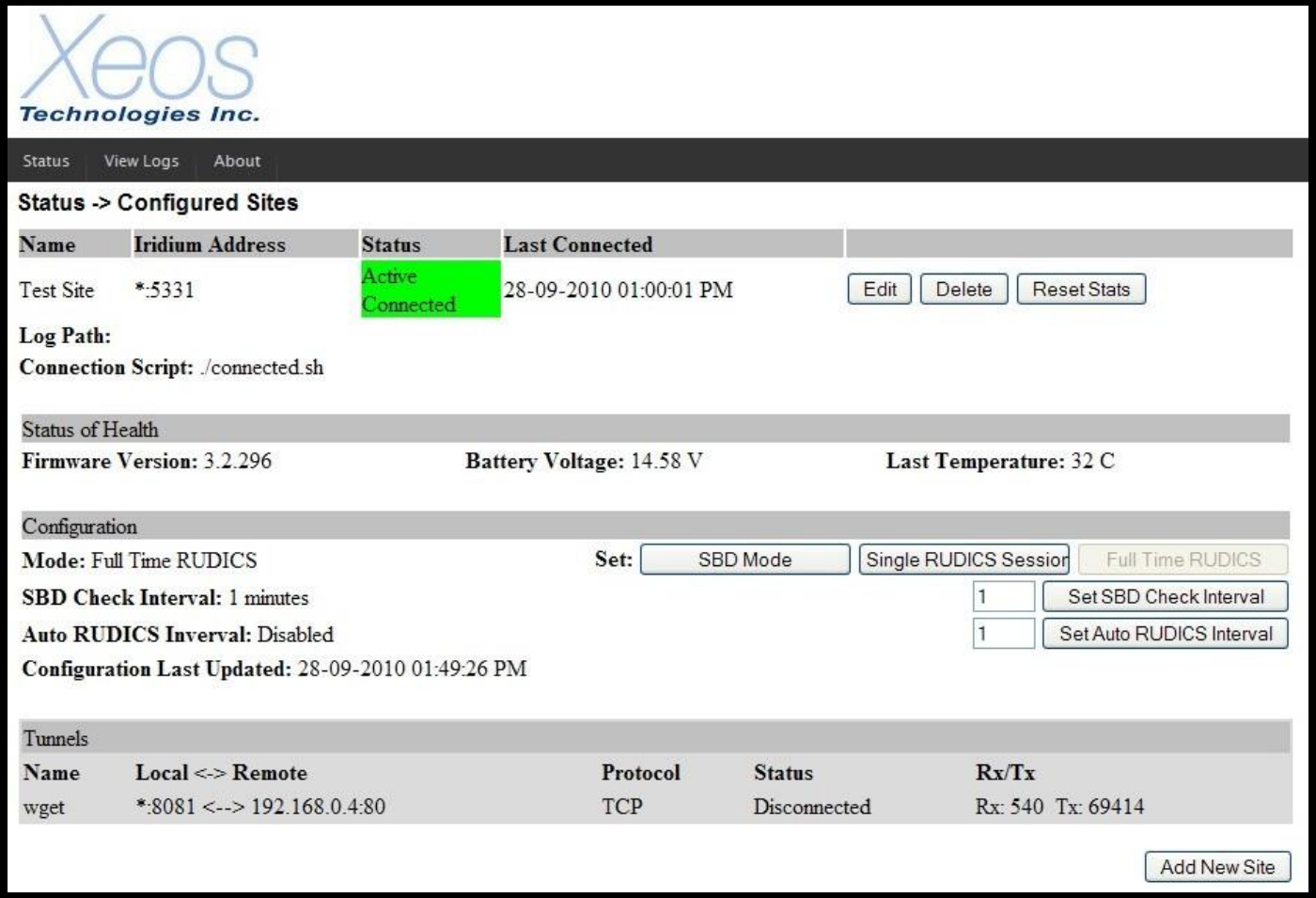
Cold-rated RUDICS modems from Xeos

Xeos XI-100
(Phase I model)

- Iridium is only communications option for many polar applications, but off-the-shelf Iridium products are not highly reliable in polar use.
- Phase I completed: Xeos/PASSCAL
  - Heating of critical component (oscillator)
  - Internal status updates
  - Can communicate to mulitple remote devices
  - ON/OFF power switching to remote devices
  - Proven success across Antarctica
- Phase II ongoing: Xeos/PASSCAL/UNAVCO
  - Internet connection to any remote IP device
  - RUDICS: better call reliability, 20MB/day +
  - prototype field testing at McMurdo winter 2011
- These are commercial products!

Iridium…using it in a better way

Cold-rated RUDICS modems from Xeos

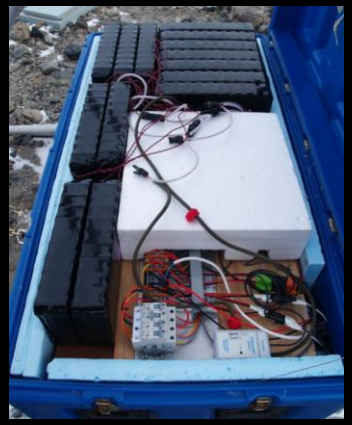


- Xeos "tunnel" application with intuitive web interface
- Immediately scalable up to dozens of remote sites; communicates with multiple remote devices.
- Multiple operating modes

Lighter Batteries

Non-rechargeable Lithium Thionyl Chloride cells

Tadiran TLP93101/E/L



GPS w/lead acid + lithium backup

- Developed by IRIS/PASSCAL and Tadiran
  - Very high power density:
    one 12 lb pack = 140 lbs of lead-acid
  - Excellent cold performance: 55% capacity at -50C
- Lightweight wintertime power
  - Summer w/ lead-acid + solar, winter w/ lithium:
    field-demonstrated for many seismic, a few GPS
  - Two year-round seismic sites in 1 flight!
  - Can make the difference between deploying a system or staying home…

BUT…

- Expensive at ~$1100/pack, non-rechargeable

Lighter Batteries

Rechargeable: Lithium Iron Phosphate cells

On the plus side (red wire):

- Significant weight savings:
  - 75% less weight for same useable AH capacity
- Long cycle life: lithium Cells rated for:
  - 3000+ cycles at 70% discharge depth
- Safe design: extremely stable chemistry eliminates thermal runaway
- Fast, efficient Charging:
  - 99% efficiency (charge in vs. charge out), no absorption/acceptance phase
- Discharge down to -30C, recharge at 0C.
  - Strategy is to heat batteries before charging.
  - In reality, limits can be pushed…but how far? An optimization exercise.

Lighter Batteries

Rechargeable: Lithium Iron Phosphate cells

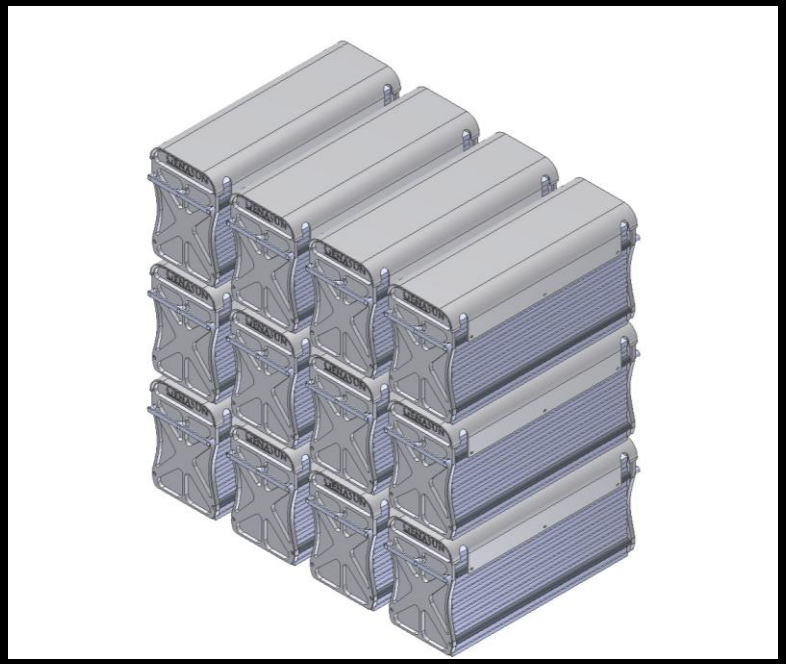
On the minus side (black wire):

- High self discharge
- Costly, and requires smart charge controller. Trade off for weight is more complex and expensive system
- Requires fully integrated power system and charge controller. Batteries and power management system are tuned set.

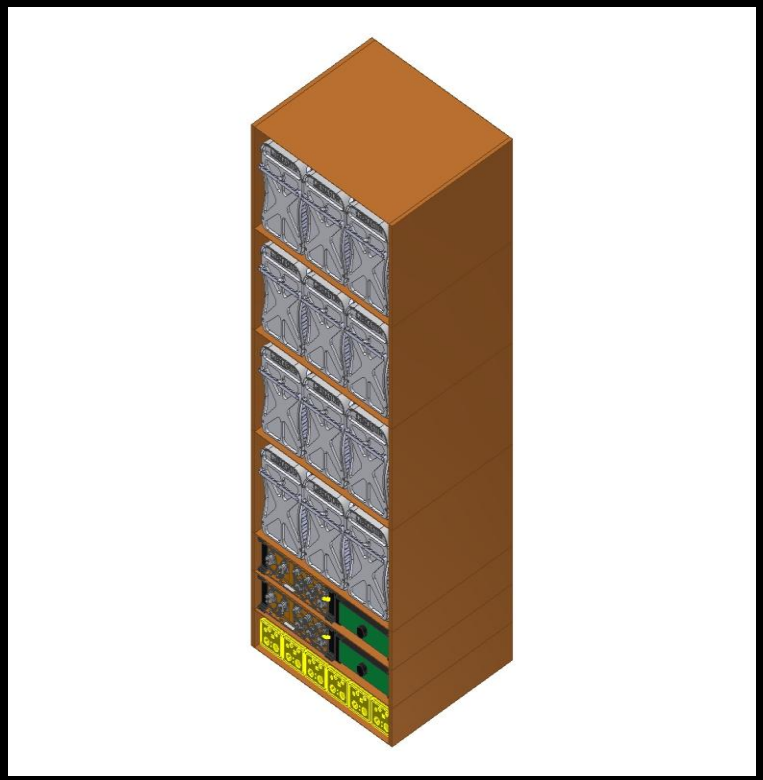
Example battery deployments…

Rechargeable: Lithium Iron Phosphate cells

Large 12-cell array
H 30” x W 35” x D 25”



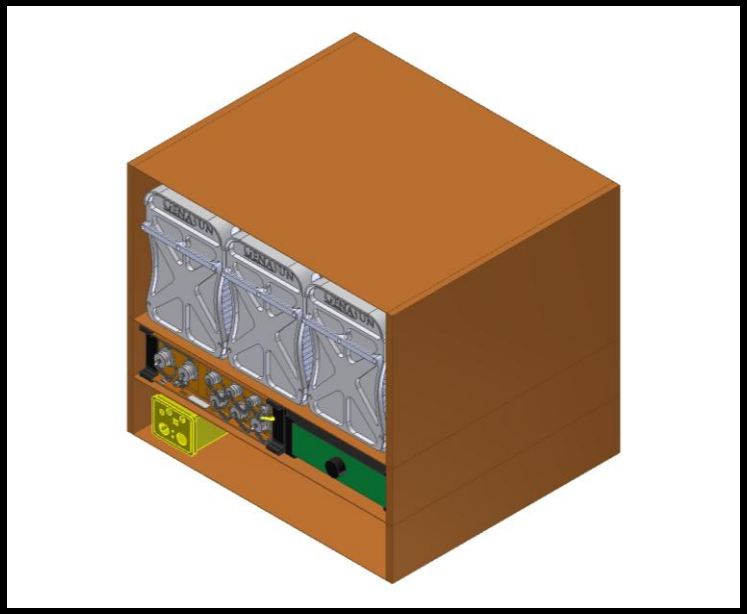
Multi-instrument system rack



Example small POLENET Seismic System

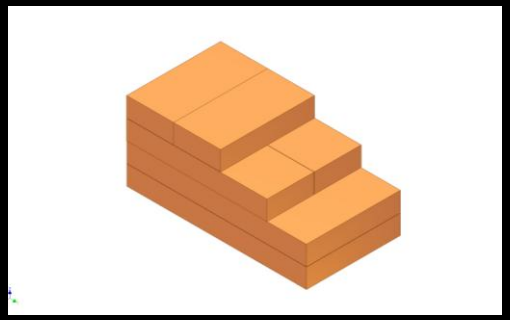
with lithium iron-phosphate batteries

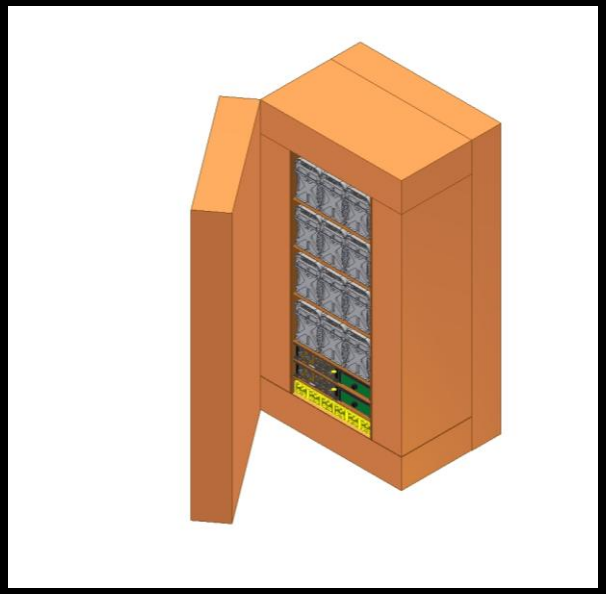
- 11KWH capacity. For 2 watt load = 180 days autonomy.
  - ~125kg = ½ weight of existing system
  - ~$15K
  - Rack inside dimensions H: 24.5”W: 28”D: 24”
  - Flat foam enclosure reduces weight further…



Rugged High Efficiency Enclosure

thick foam material slabs that ship flat

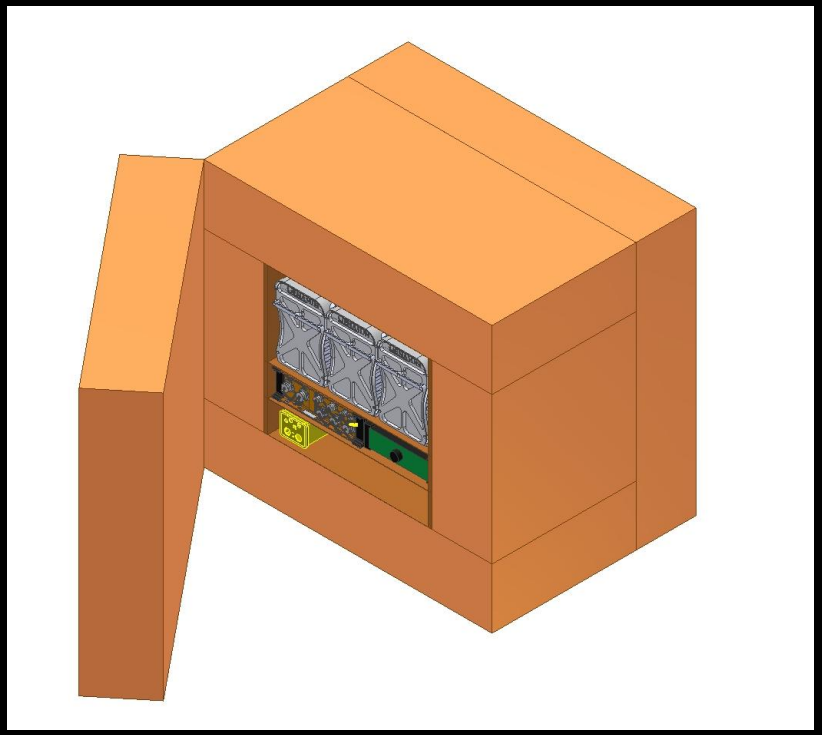




- Vacuum insulation panels:
  - Used w/good success by PASSCAL and UNAVCO
  - Expensive, imprecise tolerances
  - Fragility = often (very) short lifetimes

- Skinned slabs of extruded polystrene or EPS foam
  - In reality, stacked foam is much closer to the rated net “R-value” than rugged vacuum panels!
  - Light weight
  - Inexpensive. Vacuum panels are expensive.
  - Easily manufactured. Vacuum panels = tedious!
  - Relatively robust…a pin prick won’t kill them
  - 10” thickness per side is a good starting point

Example of a small POLENET enclosure



H: 44.5”
W: 48” 10” walls
D: 44”

Multiplexed Iridium field device

- Leverage others development of multiplexing coding and RUDICS (SRI / RPSC / U. Kansas). Need small field rugged enclosure.
- Cycle modems on and off depending on job or season for power savings
- Adds some redundancy
- Iridium OpenPort – can NSF secure a similar cost agreement?
- Using industry partner for development results in commercially available product for purchase.
- Diverse instruments can share a common, higher-bandwidth comms platform
- Could be 2-5 internal modems
- Might require a new way to contract for airtime or bandwidth?

Multi-instrument Platforms

Co-located sensors: lowered logistics, increased science data

Integrated station with geodetic GPS and three-axis seismic

- GPS and seismic integrated station
  - Complimentary instruments
  - Combined station with single power and communications system deployed for 2 years at McMurdo
- GPS: alter ego as an ionospheric probe
  - It is feasible to collect high-rate GPS data at existing stations and retrieve data snippets of interest via Iridium
  - Exploring collaboration with space physics groups

Multi-instrument Platforms

Beyond GPS and seismic devices…

- Meteorology at GPS stations: many uses for this data
  - Improving weather models and forecasting
  - Real-time observations for flight planning
  - Water vapor measurements

- Weather station integration with GPS is an incremental step

  - ~20 POLENET sites in Antarctica already equipped with basic met station Vaisala WXT520. Data retrieved, archived, and made available by UNAVCO.
  - Good survivability, inexpensive, but it has limitations.

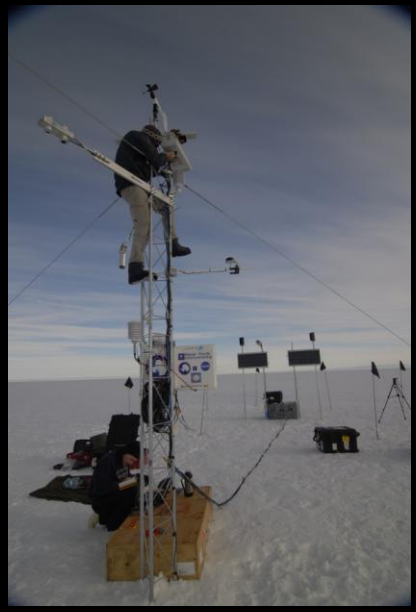
- Develop a research-quality “add-on” weather station
  - UNAVCO / PASSCAL collaboration with Wisconsin AWS group in 2011
  - Field prototypes in 2011, including Antarctic demonstration

Multi-instrument Platforms

Beyond GPS and seismic devices…

< Greenland basal
sliding project (Harper)

Environmental observatory >
Pine Island Glacier (Holland)



What is needed for low-power (≤5 watt) multi-instrument sites?

- Reliable, modular, adaptable power and communications systems….DONE
- Straightforward design, rapidly installable by PI science groups…... DONE
- At present, delivering a lightweight power and communications platform for low-power instrumentation is not a redesign. It is an integration exercise.
- To support higher power instruments with a similar size + weight system, our approach is to pursue more powerful wind turbines and more advanced batteries…