Remote Instrumentation Stations:

Progress in the last year

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Boiler Plate

UNAVCO:

A non-profit membership-governed consortium, facilitating geoscience research and education using geodesy. Government funded (NSF, NASA). Has professional staff dedicated to supporting polar research projects.

Status in 2012:

7 years engineering work on remote polar instrumentation technology, including pNSF-MRI project on remote power and comms, completed jointly with IRIS/PASSCAL.

Designs used in ~160 remote polar stations, ~70 in Greenland, ~90 Antarctic

- ~150 GPS stations, ~100 with comms and ~30 with met stations
- ~10 stations with other instrumentation
- ~20 PI projects

Also: UNAVCO PBO group operates 135-station Alaska network (2003-present)

Remote Polar Station Designs

Designed to be versatile and modular

- 12 VDC lead-acid batteries, 200 to 2400 amp-hour banks, long polar life, rechargeable
- 18 VDC lithium backup, 10x power density of lead acid, non rechargeable
- Up to 320W solar charging
- Up to 2 vertical-axis or 1 horizontal-axis wind turbines
- Structural frames configurable for rock, snow, or ice surfaces
- Rapid installation with small teams
    * Nominal GPS station can be installed in one flight
    * 4-5 hours on the ground, 3-person team

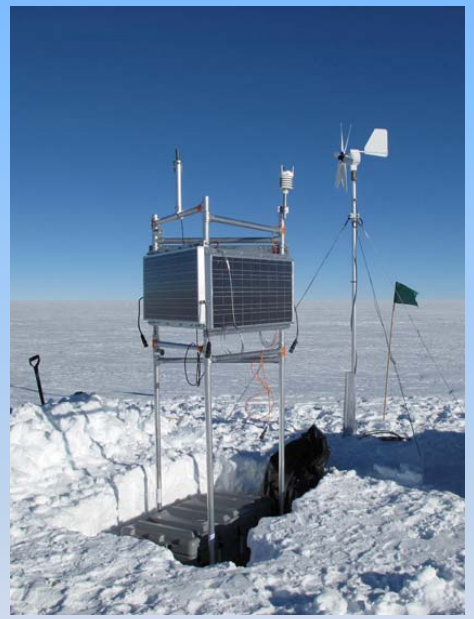
Remote Polar Station Designs

Two basic designs for different environmental regimes:

Continental Margin (high wind, moderate cold, rock surface)

Polar Plateau (low wind, deep cold, snow surface)

Margin system: Lepley Nunatak
- Minimal insulation and heating
- Wind hardened components
- High speed wind turbines



Plateau system: Recovery Lakes
- Highly insulated
- Active heating
- Low speed wind turbine

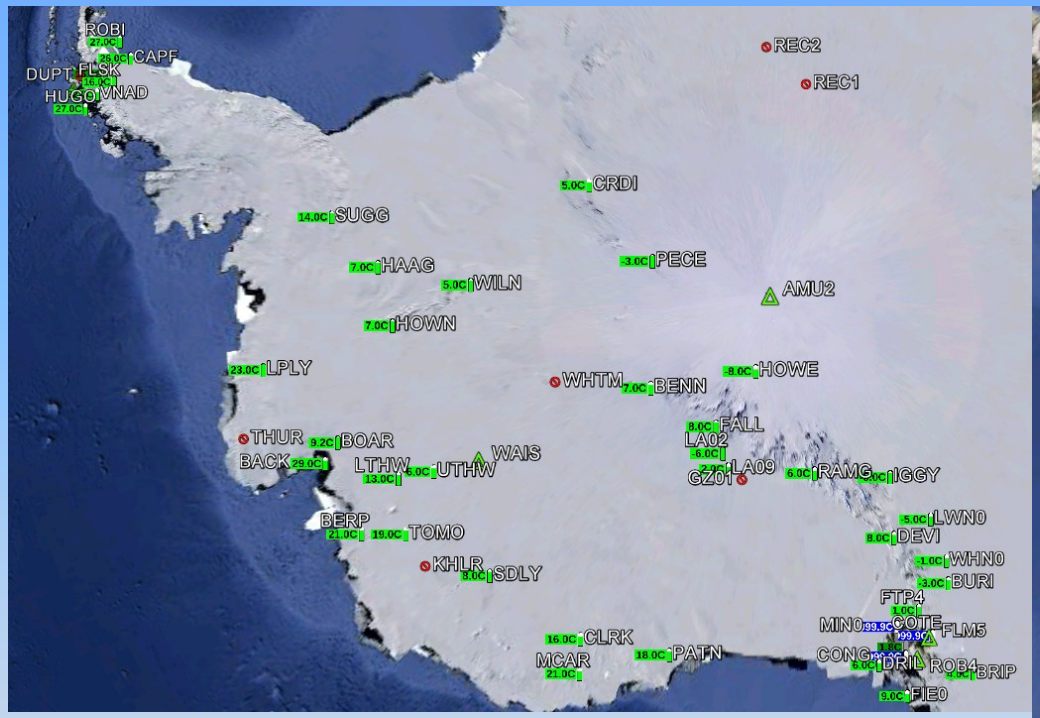
Remote Polar Station Designs

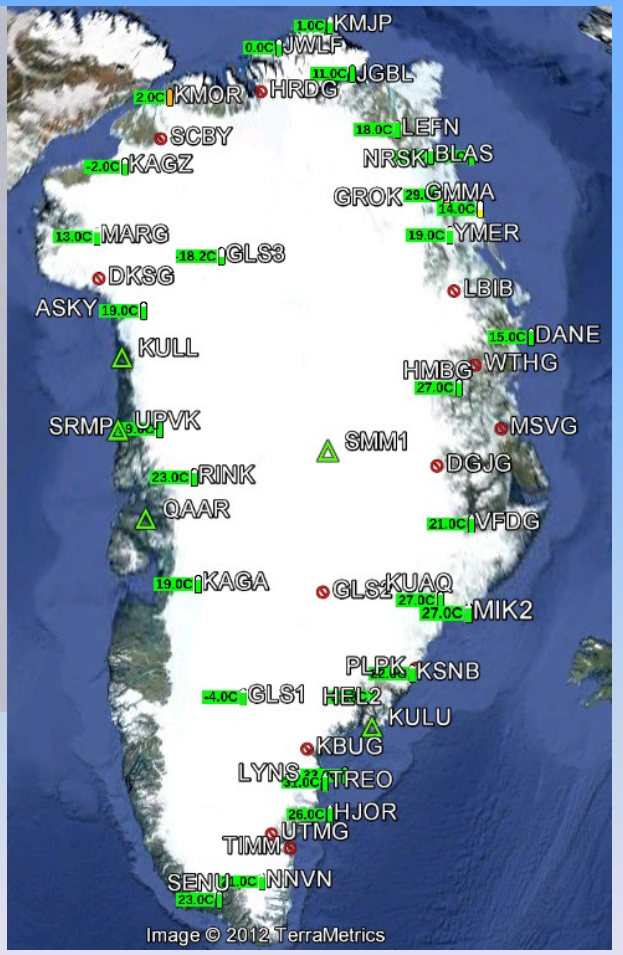
Further cusomization for specific locations, weight requirements, etc.

West Antarctic system: ANDRILL site
- Moderate cold and moderate wind
- “Margin” enclosure and electronics
- “Plateau” snow surface frame

Single-pole system: Greenland Ice Sheet Periphery
- High ablation zone
- Single pole mount, unguyed
- High speed turbine, small enclosure, small panels
- First deployment in 2011, revisit spring 2012

Site Locations (stations with comms)





Antarctica 2005-2012
88% data return, 79% retrieved remotely

Greenland 2007-2012
88% data return, 74% retrieved remotely

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Updates for this Presentation…

Iridium Communications

Wind Turbine Testing

Powering Multidisciplinary Instrumentation

Anti-Static Measures

Polar Bear Protection

GPS Receiver Update

Iridium Communications

Dial-up Operation with Dual Modems

- Reliability of newer 9522B modems is improved vs. older models, but failures still too frequent
  * Hardware failures, aggrivated due to cold
  * Serial communications = tweaky, static sensitive, prone to hangups / failures

- Since 2011, now installing two modems at most remote sites for redundancy
  * Our GPS has two serial ports – put them to use
  * Primary and secondary modems powered 50% of time, same draw as one modem on 100%
  * Secondary modem and SIM are tested, then SIM is deactivated to save $
  * If primary modem fails or gets hung up, can remotely reactivate secondary SIM
  * Many examples so far where this has restored our communications

- This is a band aid, but effective.

Iridium Communications

Experience with Beam Communications Hardware

- Beam Communications RST-600 vs. NAL Research A3LA-X
  * Both are 9522B-based modems, support dial-up, SBD, RUDICS etc.
  * Different form factors, but functional drop-in replacements for each other
  * A3LA-X has more OEM modifications, while RST-600 is basically an Iridium 9522B modem with a custom bracket and cable (is this good or bad?)
  * RST-600 price is slightly higher

- One RST-600 evaluated in 2011
  * Passed cold testing to -40C
  * Modem was sent to field as a backup, but not installed. Damaged during return transit.

- 12 more RST-600 purchased for Greenland 2012
  * So far 4 of 4 have passed cold test. 4 of 4 A3LA-X have also passed.
  * With dual-modem arrangement, will see direct performance comparison with A3LA-X

Iridium Communications

Beam RST-600

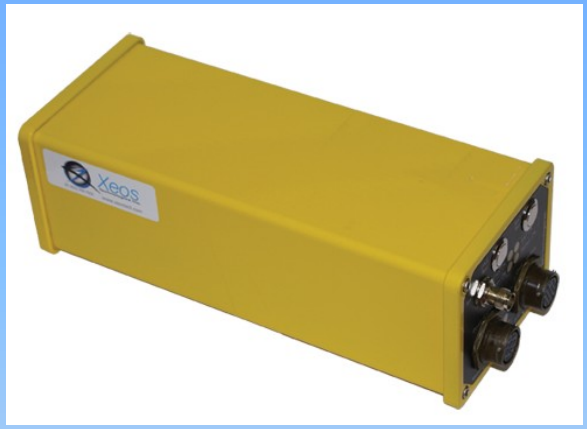
NAL A3LA-X

Iridium Communications

Xeos XI-100 Modem

- Original SBD-only version developed by Xeos Technologies and PASSCAL. Field proven.
- New RUDICS-capable version, developed by Xeos, PASSCAL, and UNAVCO
- Features:
    * Can connect to generic Ethernet devices at remote site
    * Uses Iridium SBD + RUDICS to maximize throughput with absolute minimum power draw
    * Active internal heating, switched relay output, ethernet + serial communications
    * Xeos software: IP tunnel manager application
- Alpha RUDICS development completed 2011
    * Hardware, firmware, software development. Delivery of prototypes.
    * Testing at UNAVCO. Successful year-round deployment at McMurdo.
    * Higher throughput, increased reliability demonstrated
- Beta development continuing 2012-13
    * 8 devices now installed at remote stations (2 more in Greenland summer 2012)
    * 7 modems are working; problem at remaining station is unknown (modem? power? SIM?)
    * Minor software / firmware modifications ongoing

Iridium Communications



Xeos XI-100 Modem

XI-100 on GPS electronics board installed
at Pine Island Glacier station BOAR

[Xeos Tunnel Application Web Interface]

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Iridium Communications

Additions to the long list of things "you just have to know" to use Iridium…

- Data modems must be "whitelisted" to operate within the DOD network.
  * When ordering modems, specifically request whitelisting on the order
- Can occasionally fix connection problems by deleting SBD / RUDICS provisioning at Iridium then re-enabling the exact same provisioning (!)
- UNAVCO had two SBD+RUDICS provisioned cards which would not complete their first registration using a data modem. But we placed these cards in a phone handset and they registered immediately.
  * From Gary Ferentchak and Dan Wagster (Lockheed): The first registration involves a more extended process within Iridium than subsequent registrations.
  * Should be possible with a data modem, but not sure what if any AT commands are needed
- "Quiet" mode exists on Iridium RUDICS server, can be toggled on and off. This suppresses certain messages which may affect user scripts which trigger on these messages.

Iridium Communications

New 9523 Data Transceiver

- Replaces 9522B products, which will be obsoleted
- Nominal specs from Iridium for 9523 versus 9522B

	9523	**9522B**
* Size	70 x 36 x 15mm	162 x 81 x 28mm
* Operating temp	-30 to +70C	-30 to +70C
* Avg. power during call	expected <4W (slightly)	4W

- Price expected to be slightly lower than comparable 9522B devices

Wind Turbine Testing

Forgen 500

- Low power vertical axis turbine.
  * Ideal type and style of turbine for low-power polar instrument stations
  * UNAVCO turbine regulation scheme is field proven
    (Flexcharge NC25A regulator and STEP Warmfloor heating pad divert load)
  * Historically, many field successes but also many field failures due to mech. strength issues

- New 3-phase design
  * Increased power output (20W at 40 knots) vs. older single-phase design
  * Has external rectifier box inline with cable
  * We have not tested power output due to personnel time constraints. Plan to evaluate Forgen 500 single phase, 3-phase, Leading Edge LE-V50, WindKinetic beginning this spring.

Wind Turbine Testing

- New side-mount design
  * Top bearing and side U-bracket:
    Directly address the mechanical weak point
  * First deployment of side-mount turbines in
    Greenland 2011 and Antarctica 2011-12
  * High expectations, but no repeat site visits yet
    …so no concrete results on survivability.

Side-Mount Forgen 500

Wind Turbine Testing

Leading Edge LE-v50

- Higher power vertical axis turbine
  - * Larger and heavier than Forgen 500, but higher rated power (50W at 40 knots) and lower $
  - * Has top bearing and side mount bracket.
  - * Extremely robust-looking mechanical design, especially the blades.

- Evaluation unit installed at McMurdo Station
  - * So far so good (but it is only April)
  - * Evaluation unit had major design flaw: generator area protected by thin plastic piece, with large gaps to allow air / debris to flow inside
  - * We modified the unit by attaching a wide piece of sheet metal around the generator area
  - * Leading Edge reports their design has since been improved to better protect the generator

Wind Turbine Testing

Modified LE-v50 installed at McMurdo test site

Newer LE-v50 design with improved generator protection (brochure image)

Wind Turbine Testing

Rutland 910-3

- High power horizontal axis turbine (at least "high power" for UNAVCO world)
    * Furling design to protect from high winds
    * Rated power 140W at 32 knots, decreases thereafter due to furling
    * Used with success by ARRO project and NZ Darwin Glacier project
- Evaluation unit installed at McMurdo Station during 2011
    * Successful operation all winter. Kept battery bank voltage above 12V at all times. (system would have lost power in ~June without the turbine)
    * Turbine examined after winter. Furling mechanism works very well in protecting the turbine from high winds – no mechanical or electrical damage found. Except…
- One bearing was destroyed in late spring; blades turned very roughly afterward.
    * This bearing is on the inner side of the rotor, with one face open to the environment.
    * With head-on winds this bearing is protected, but when the turbine yaws 90º during furling, wind passes directly between turbine body and blades, forcing dirt/grit into bearing

Wind Turbine Testing

Rutland 910-3 Turbine

Side view showing airflow path between body and rotor when furled

Internal view of rotor, showing damaged bearing on exposed face of rotor

Wind Turbine Testing

Rutland 910-3

- Protection of this bearing is the key
    * Interior bearing was not exposed to winds, and was in perfect condition
    * Possible solution: implement concentric ring “labyrinth” seal between rotor and body
- Regulation scheme worked very well.
    * Based on the same Flexcharge NC25A regulator as with lower power turbines
    * Used a network of heating pads as the divert load
- Another Rutland 910-3 fielded for winter 2012
    * Turbine has demonstrated ability to provide consistent wintertime power in moderate to high wind locations, and can allow significant battery weight savings.
    * New unit is powering laser thermometry system at Windless Bight on Ross Ice Shelf
    * With no windblown grit, believe turbine will survive well…
    * PASSCAL is also using 910-3 on Greenland ice sheet winter 2011-12. Results TBD, pending inspections in summer 2012.

Wind Turbine Testing

Aerogen 4

- Non-furling “high power” turbine
  - * Used by UNAVCO on polar plateau (light winds, deep cold)
  - * Very good multi-year operation demonstrated at three plateau sites.
  - * PASSCAL is also using Aerogen 4 on Greenland ice sheet winter 2011-12. Results TBD, pending inspections in summer 2012.
- See previous PTC presentations for more details

Wind Kinetic

- New vertical-axis design from Italy, available commercially spring 2012 (?)
- UNAVCO could not acquire prototype for Antarctic testing this season, but hope to test this spring in the US.

Powering Multidisciplinary Instrumentation

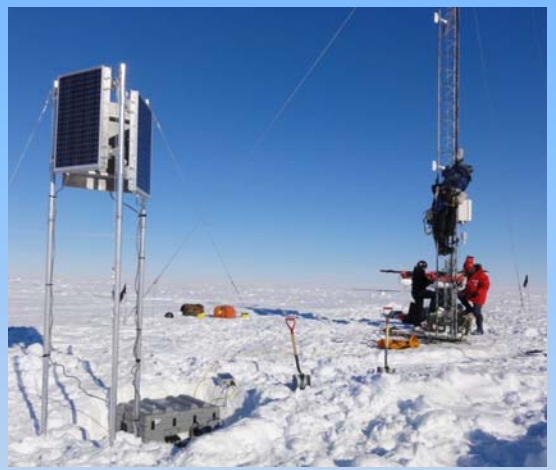
Powering Multidisciplinary Instrumentation

- Can power other geophysical instruments. Currently:
  - * 5 met stations, weather + camera instruments (Holland, Lazzara)
  - * 1 ground ozone station (Avallone / Kalnajs)
  - * 1 laser thermometry “DTS” station (Holland)

- Prototype design at McMurdo: integrated AWS for GPS stations
  - * Collaboration with U. Wisconsin AWS group
  - * Upgrade from Vaisala WXT-520 weather stations currently installed at GPS stations
  - * Pressure, Temp, Humidity, Wind speed / direction, radiation. Campbell CR1000-based.
  - * Integrated power and comms with GPS
  - * Mechanical design to bolt-on to existing stations.

Powering Multidisciplinary Instrumentation

AWS station integrated with GPS, McMurdo



Tall Tower! AWS, Ross Ice Shelf (photo AWS group)

Ground Ozone next to AWS, Marble Point (photo Lars Kalnajs)

Anti-Static Measures

- Many static-related failures seen in past years
  * Key flaws in initial design, did not properly account for static buildup + discharge
  * Fried Iridium modems, GPS receivers = significant data loss
  * Resulted in analysis of system grounds / commons
- Anti-static measures implemented at remote GPS stations
  * Surge protectors on serial, GPS antenna, and Iridium antenna lines
  * Added metal grounding plates to plastic enclosures at RF pass-thru connectors
  * Electronics boards inside grounded anti-static bags
- Results
  * Limitations in polar logistics mean design flaws can persist for years. A handful of stations have still not been upgraded.

  BUT:

  * No static-related GPS receiver failures at upgraded Antarctic GPS sites during winter 2011!

Polar Bear Protection

- Three instances of polar bear damage at two stations
    * Various types of damage, but cabling was the key problem
    * Power system failures and battery damage due caused by broken battery and solar cables
- As opportunity allows, now retrofitting threatened sites
    * Cable exit points from solar panels and battery boxes are better hidden
    * Protecting cables behind rocks and metal conduit
    * Continue to use fox-proof cable conduit at all stations
- Results so far:
    * First station retrofitted in 2010 after two separate attacks, still operational March 2012
    * Second station retrofitted 2011 after attack, still operational March 2012
    * Two other stations retrofitted 2011 to guard against future attacks

- Upcoming electrical design changes to reduce single-point failures
    * All external cables will have individual fault protection (diodes, breakers, etc).
    * One broken cable cannot bring down entire system!

GPS Receiver Update

- Existing GPS receivers are reliable, low power, and versatile.
- Most UNAVCO polar GPS stations use the Trimble NetRS receiver, but now discontinued
- UNAVCO polar now using Trimble NetR9
    * Similar power consumption (as low as ~2.9W w/o antenna)
    * Cold performance is as good as NetRS
    * Few key firmware upgrades still remain to optimize polar performance; waiting on Trimble

- Polar receiver development and testing is behind due to project support commitments, but a high near-term priority for UNAVCO is selecting the next polar receiver. Possibilities:
    * Evaluate existing survey-grade receivers and select optimum model?
    * Solicit manufacturers to produce specific device?
    * Very low-power OEM boards– build around these?

Last Slide – Question for PTC Group

- Lead-acid battery replacement schedule for remote polar stations?
  * Logistics costs for battery replacement are high, so need to get most from existing batteries before replacement…**BUT:**
  * To maximize data return, must replace batteries BEFORE they fail
  * We will develop a comprehensive battery testing and replacement plan for long-term UNAVCO-supported networks (e.g. POLENET).

- Key question: what is curve for Loss of Capacity vs. Time for lead-acid gel cells under "typical" remote polar usage?
  * For sites where batteries have been treated nicely (no overcharging or over-discharging), our state of health data so far (< 5 years) shows little or no battery degradation
  * Causes of premature battery failure are not of interest (we have acquired sufficient data on this topic). We don't need statistics on murders, but on age-related deaths…
  *** Is there a critical point beyond which capacity loss accelerates?**
  *** Lots of anecdotal evidence out there, but need empirical data!**

Contact

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