Building Polar Instrumentation

Successes, Failures, and Lessons Learned

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Background

The scientific value of long-term, continuous GPS datasets has been recognized for more many years. For example:

- Tectonic velocities require 3+ years data for full confidence in results. Accuracy has direct implications for ice sheet and climate studies.
- Continuously tracking *GLOBAL* stations are critical for maintaining spatial reference frames and the GPS system itself.

Status of polar GPS in 2006:

- "Campaign" studies regularly performed but temporary, summer only e.g. WAGN, glaciology projects
- Many permanent networks built around the world, but polar coverage still very sparse. ~15 permanent stations continent-wide.
- Significant technical hurdles remained to achieve a reliable, deployable system to meet polar technical, environmental, and logistical demands.

However…advancements made in GPS and comms technology, with development by polar research projects (e.g. TAMDEF, VLNDEF, MEVO), meant it was now possible to envision a year-round GPS system to allow building of polar networks.

Background

2006: UNAVCO and PASSCAL facilities awarded a community-backed joint 3-year NSF “MRI” project to develop power and communications systems for polar GPS and seismic instruments. Other broader goals:

- Develop platform suitable for other instruments
- Thorough documentation, publicly available
- Create and maintain equipment pools for use by community

2009: All project technical goals and milestones met.
For more details, technical info, intermediate progress: UNAVCO presentations from previous conferences are online at PTC website.

2010: 150+ continuous stations w/comms. Large and small networks:
POLENET Antarctica GPS and seismic, POLENET Greenland GPS
AGAP Antarctica seismic, Erebus-TOMO Antarctica seismic
LARISSA + Pine Island Glacier + Recovery Lakes + Whillans Ice Stream Antarctica GPS

Background

- For polar systems, 1-year design cycles are typical. But remote instrumentation can effectively involve 2 year cycles. E.g. first design fielded early 2007 in Antarctica, significant improvements not fielded until late 2008.

- Historically, technology development often done in parallel with science, often not an optimal process. UNAVCO-PASSCAL MRI project was funded as technology development only (with science guidance), many scientific systems were still built with alpha and beta systems. Double edged sword…

Negative: alpha/beta designs used for science

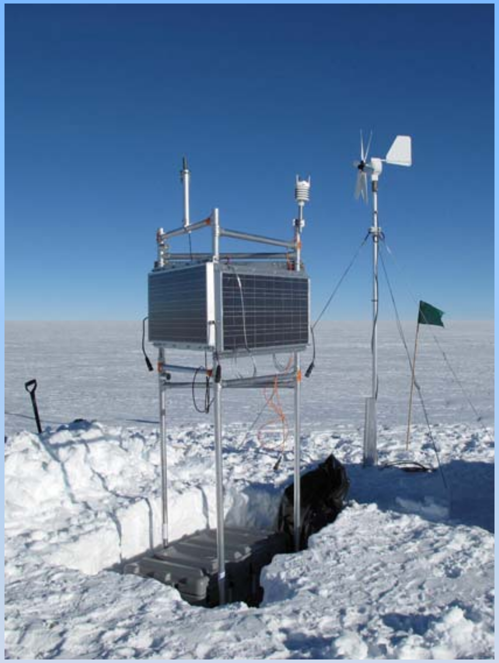
Positive: but more systems deployed and statistical info about performance obtained more quickly.

With this in mind, on to some problems…

Background

Two basic system designs: Continental Margin and Polar Plateau.

"Hybrid" setup for West Antarctica (margin system with plateau frame)



Margin system West Antarctic system Plateau System

MACZ KHLR REC1

Mt. Erebus Kohler Glacier Recovery Lakes

Problems, Solutions, Lessons

<u>Wind Turbine: Forgen 500</u>: One or two at high-wind sites, as needed

Problem: No regulation initially for simplicity sake. Initial tests with very low power turbines showed no regulation needed even at "windy" Antarctic sites (e.g. Minna Bluff). However, destructive overcharging at very windiest sites (Iggy Ridge, Pecora Escarpment)

Solution: Flexcharge wind regulator in parallel with Flexcharge solar regulator. Wind divert load is STEP Warmfloor heat pads: rugged, self- regulating, with large heat dissipation area w/o hot spots. Divert load resistance sized to (roughly) match effective battery resistance at high wind.

Not good…

Lesson: ***Robust turbine regulation everywhere.***

Problems, Solutions, Lessons

Wind Turbine: Forgen 500

Problem: Significant percentage broken during Antarctic winter.
Failure analyses = bearing seize, torsion failure of threaded shafts.

Solution: Use "AGO-spec" bearings (C3 clearance, LG68 lubricant). Solid shaft design to come. Note: manufacturer has improved bearings but above parts are polar-proven.

Lesson: ***For windy polar sites, survivability not efficiency is most important.*** Strong components, good bearings. Our opinions: small, vertical-axis turbines are best choice for most low-power, remote polar instrumentation. Wind is most useful where size/weight restrictions on solar+battery size.

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Problems, Solutions, Lessons

Wind Turbine: Aero4gen: One per site at low-wind (plateau) locations

Problem: Yaw motion sticky in extreme cold

Solution: Remove water seal ring and use silicone to seal cable exit point.

Note: also use AGO-spec bearings like Forgen 500

Lesson: ***For plateau, low-wind startup in extreme cold is everything!*** Cold test turbines if possible. Several factors contribute to rotational friction, and turbine rotation as-built can be much higher than with its individual bearings.

Aero4gen at South Pole April 2009 (photo Robert Furhmann)

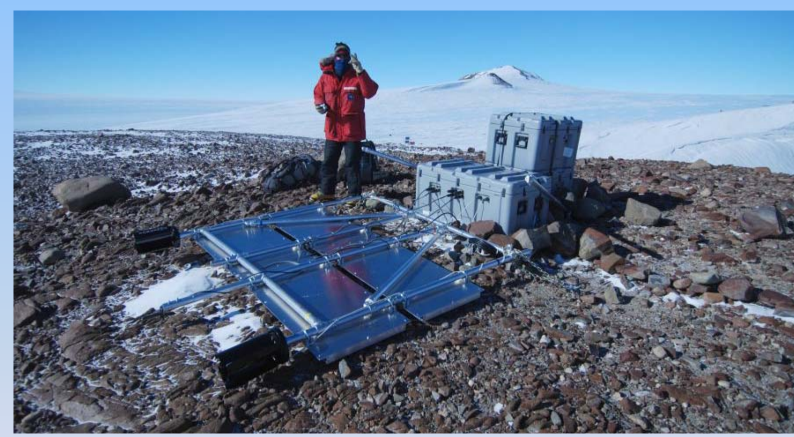
Problems, Solutions, Lessons

Mechanical Structure

Problem: Three (of ~75) structural frames failed under wind loading. Analysis of original hinge fittings slipped through the cracks.

Solution: Revise design to include stronger fittings. Also retrofit existing stations with new fittings (very tedious).

not good =>



Lesson: ***When in doubt, make it stout.*** The effort required to build something strong, and back it up with engineering analysis, are worth it when compared to the hassle and cost of making it right later.

Problems, Solutions, Lessons

Installation

Problem: Field blunders. Examples: auxiliary battery banks disconnected, mis-wiring batteries (i.e. sparks), GPS antenna not connected.

Solution: Minimize field wiring required. Minimize mechanical assembly required at field site. Have a well-thought-out plan before heading to field.

Lesson: ***Comprehensive checklists and log sheets.*** Especially at altitude!

Problem: Inefficient field installation. Too much time needed, assembly and test steps not well-thought out, field team not trained adequately.

Solution: Examine design from top to bottom. Many small changes in design add up to surprising time savings for installation. Optimize deployment procedure with set sequence and well-understood tasking for field team members. Importance of training and practice prior to field season cannot be overstated, but is very often neglected.

Lesson: ***Antarctica is not a good place for on-the-job training.*** Needing one extra flight to finish a job is a big deal (if you can even get that flight).

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Problems, Solutions, Lessons

<u>Electrical and Electronics</u>

Problem: Electrical problems due to faulty connectors. Examples: bad GPS cable crimp at Brimstone Peak, but luck held for 2 years. Mt. Erebus repeater had 4-month power failure due to loose wire. Several battery connections missing due to bad crimps.

Solution: Manual pull test and electrical continuity test for all cables.

Lesson: ***"90% of all electrical problems are cables, and 90% of all cable problems are connectors"***

- *anonymous*

Problem: Cold failures and "infant mortality" with electronics. Examples: Pine Island Glacier Iridium modem dysfunction, and Hugo Island timer circuit failure.

Solution: Rigorous cold chamber testing and "burn-in" testing with electronics boards before deployment. Logsheets and records.

Lesson: ***Lack of proper testing means higher risk of failure.*** Funding cycles and logistical constraints can handcuff testing, but ultimately you pay.

Problems, Solutions, Lessons

Communications

Problem: Several (~10) Iridium modems found with similar failure modes in field. This type of failure was attributed to static susceptibility, and grounding problems were identified in 2009 which we believe were the root cause.

Solution: Ensure all RF shields and DC grounds are cleanly tied together. Use static surge suppression devices in serial lines.

Lesson: ***Earth grounds are tenuous at our sites: dry bedrock & dry snow.***

With high winds, blowing snow, low humidity, static is a major issue and must be carefully addressed in system design.

Problems, Solutions, Lessons

Communications

Problem: Iridium hardware is by far the weak link in our system, still too many failures. Example: 7 Arctic/Antarctic sites stopped answering calls in last 2 months, 6 of which have grounding improvements.

Not a SIM de-registration problem.

UNAVCO operation: modem-modem dial-up (not best mode), mostly with A3LA-SA and -MPT (less reliable than -I, -X unknown)

Solution (partial): Rigorous cold culling and burn-in testing to eliminate marginal hardware prior to deployment.

Solution (partial): Initiate technology development project with Xeos. Operate with SBD+RUDICS modes (DOD). Heat oscillator. Build system around the board from the 9522B modem.

Lesson: ***It's doable, but difficulties do exist in achieving reliable operation of remote Iridium systems, especially in polar regions.***

Reliability and QC even when warm	Call drops
Mysteries within Iridium system	Static sensitivity
Cold performance of stock hardware	Correct programming and options

Other Successes

<u>Adaptability of power/comms platform</u>

- One radio repeater: Mt. Erebus
- One tide gauge: Cape Roberts w/LINZ
- Three AWS: Ross Ice Shelf w/U. Wisconsin, Pine Is. Glacier and Helheim w/New York U.

<u>Corrosion resistance</u>

- Often overlooked in structural design
- Polar regions generally not as severe as other locations
- Aluminum structures with zinc-plated iron/steel fasteners have been used with good success at general polar locations.
- Volcanic plume is another matter. Station MACZ has suffered over past 3 years and needs a structural rebuild in 2010-11 (above pic).

Other Successes

Fasteners:

- Use 5/16” zinc-plated steel grade 5 fasteners: strong and cheap.
- Nylon-insert locknuts used everywhere. Very few loosened nuts observed after years of service (possibly not fully tightened during installation).
- Same size fasteners minimize assembly time and tools required in the field.

Anchoring:

- On rock (windiest) sites, use battery weight to partially anchor frame. Then use quick-set rock bolts and chains to fully restrain system. Anchor stakes occasionally used for sketchy surfaces.
- Snow surfaces: simple aluminum snow anchors and quick-install wire rope with Gripple tensioners.
- No sites yet where anchoring impossible, and no anchors failed yet.

Other Successes

Wind turbine survivability:

Forgen 500: Examples of power provided by two Forgen 500's at windy Antarctic sites during wintertime:

- Pine Is. Glacier (75S): continuous winter data with 10 batteries. Forgens = 9 batteries equiv.
- Minna Bluff (78S): continuous winter data with 10 batteries. Forgens = 11 batteries equiv.
- Iggy Ridge (83S): continuous winter data with 9 batteries. Forgens = 14 batteries equiv.
- Whillans Ice Stream (85S): 1 month winter outage with 10 batteries. Forgens = 10 batteries

Aero4gen: Well suited for Antarctic plateau applications

- Three plateau sites with 1 turbine + 10 or 6 lead-acid + 0 or 10 lithium backup. 82, 83, and 90 south latitude
- Wind turbines have powered GPS systems, kept all electronics above -35C, kept battery voltage above 12V during plateau winter. Without turbine these sites need 23-28 batteries to survive winter; with turbines, 6 batteries are enough and lithium backup has not been used.
- At south pole, Aero4gen observed to spin at -90F and 10 knots wind.

Other Successes

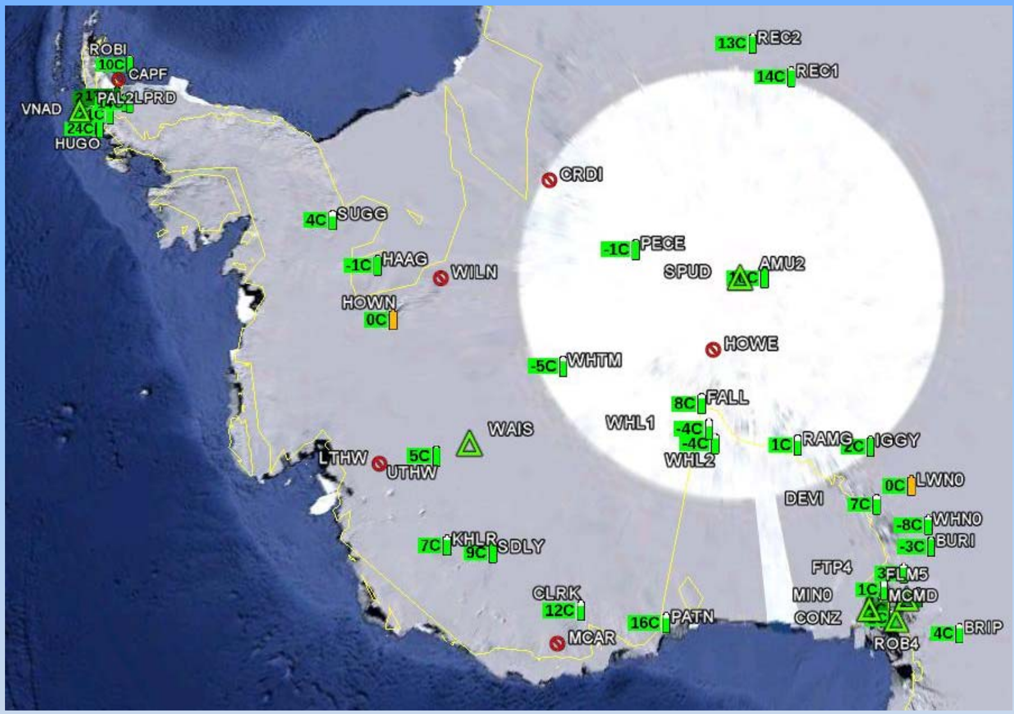
Solar Panels:

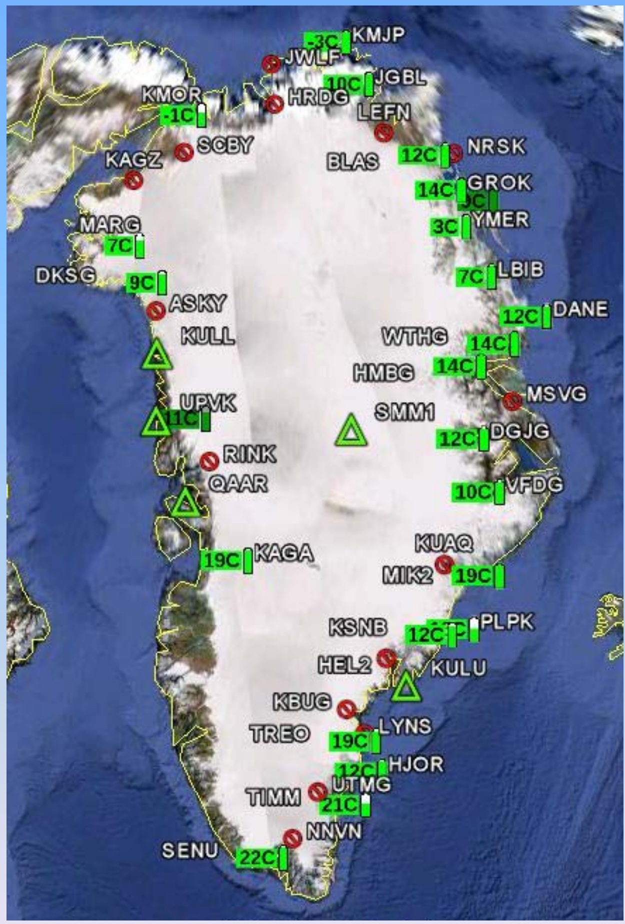
- 80W panels hardened with auxiliary backing and rugged cable. 150+ panels installed at windy polar locations.
- Excellent survivability. Only two panels broken, by flying rocks on front face (Mount Patterson).

Communications:

- Iridium: problematic but overall many success stories. Year-round GPS data retrieval demonstrated at many sites covering entire range of polar conditions.
- Point to point: FreeWave / Intuicom 900 MHz radios are extremely reliable and a real no-brainer for point-to-point applications, with or without repeaters. Serial and ethernet interfaces.

Site Locations





Google earth status and SOH plots:
www.unavco.org/polartechnology

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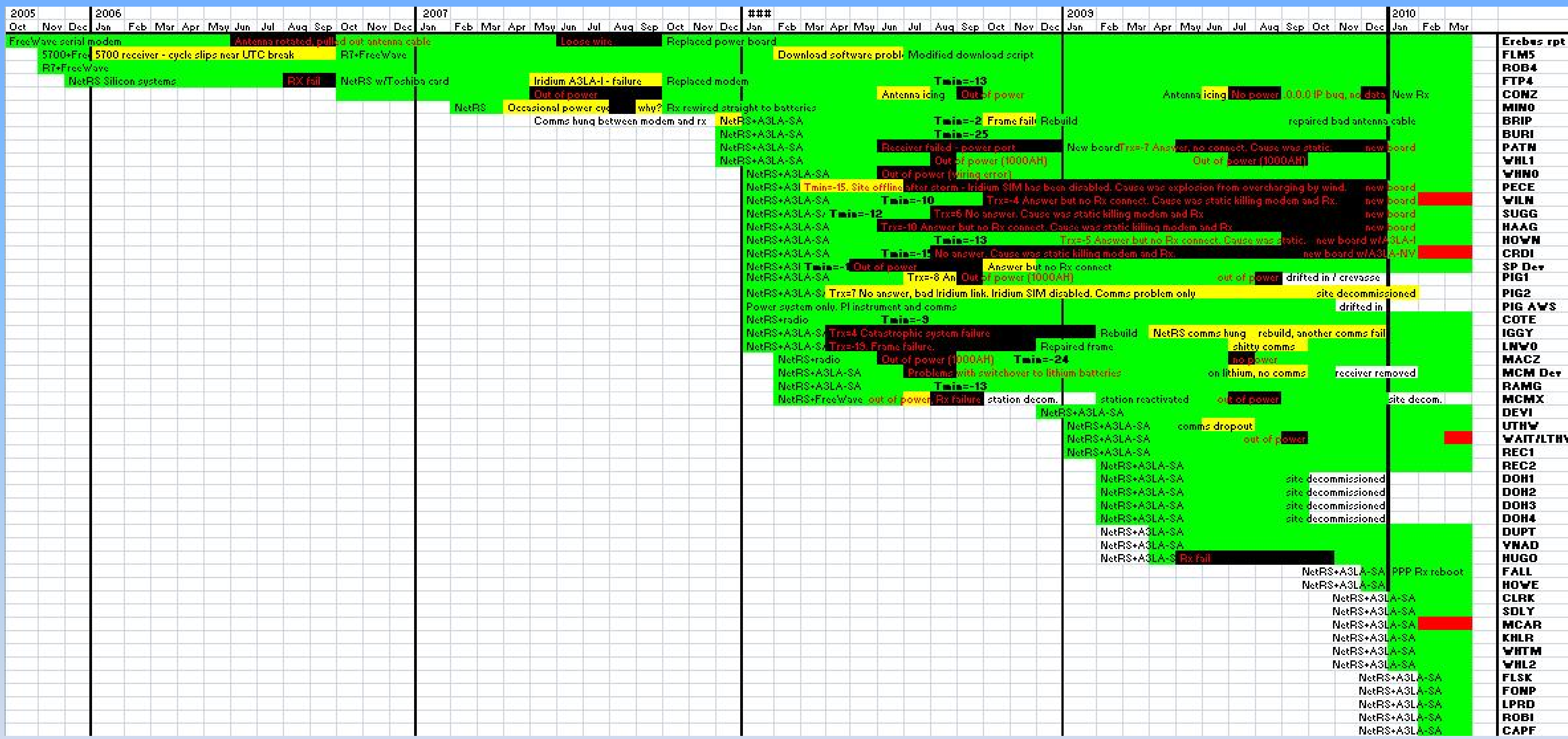
Overall Performance: Antarctica 2005-2010



Green = data retrieved remotely

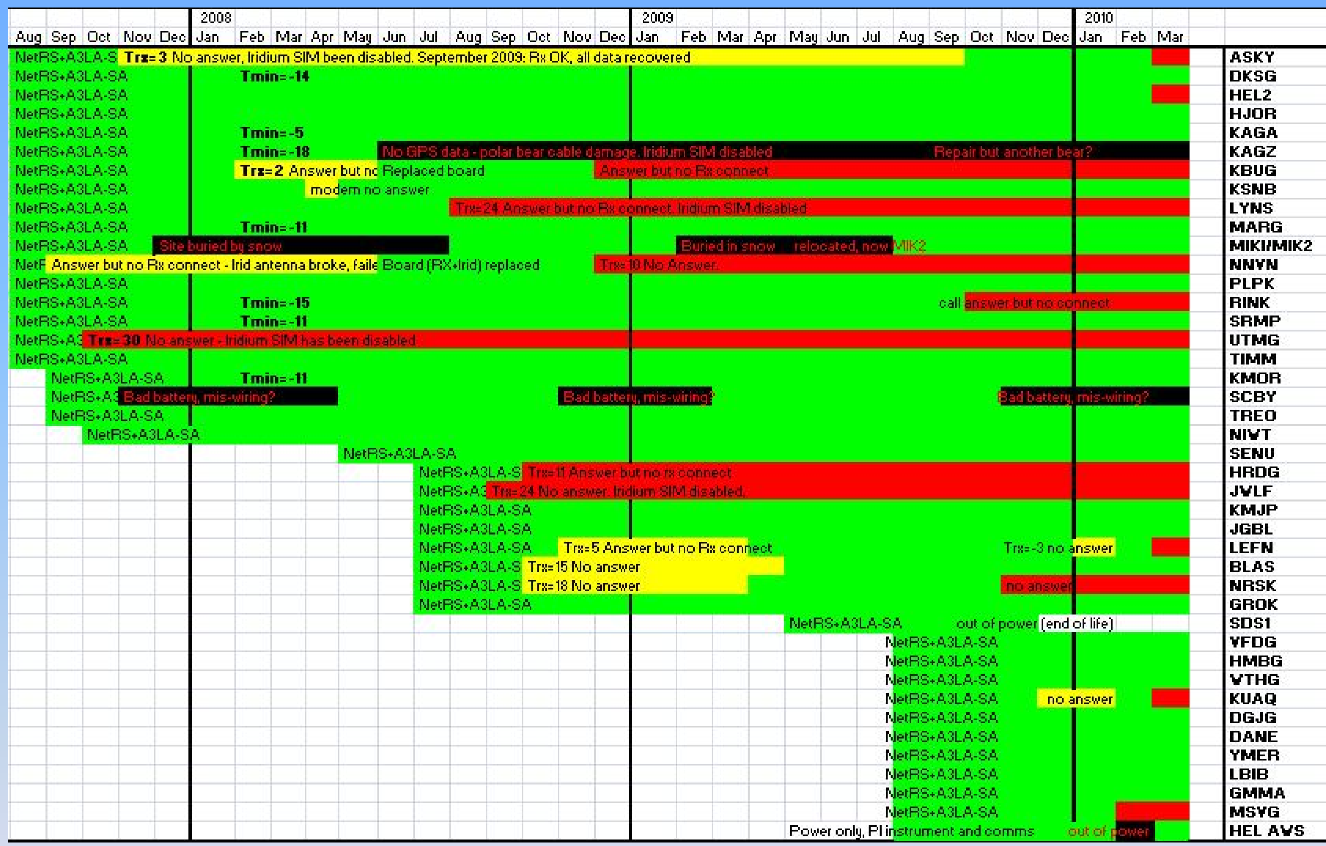
Yellow = data retrieved on-site

Red = status unknown (no comms)

Black = data lost

Overall: 82% data retrieved (76% remotely). 1% more may still be retrieved (83% o'all).

Overall Performance: Greenland 2007-2010



Green = data retrieved remotely **Yellow** = data retrieved on-site

Red = status unknown (no comms) **Black** = data lost

Overall: 80% data retrieved (74% remotely). 15% more may still be retrieved (95% o'all).

Contact

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