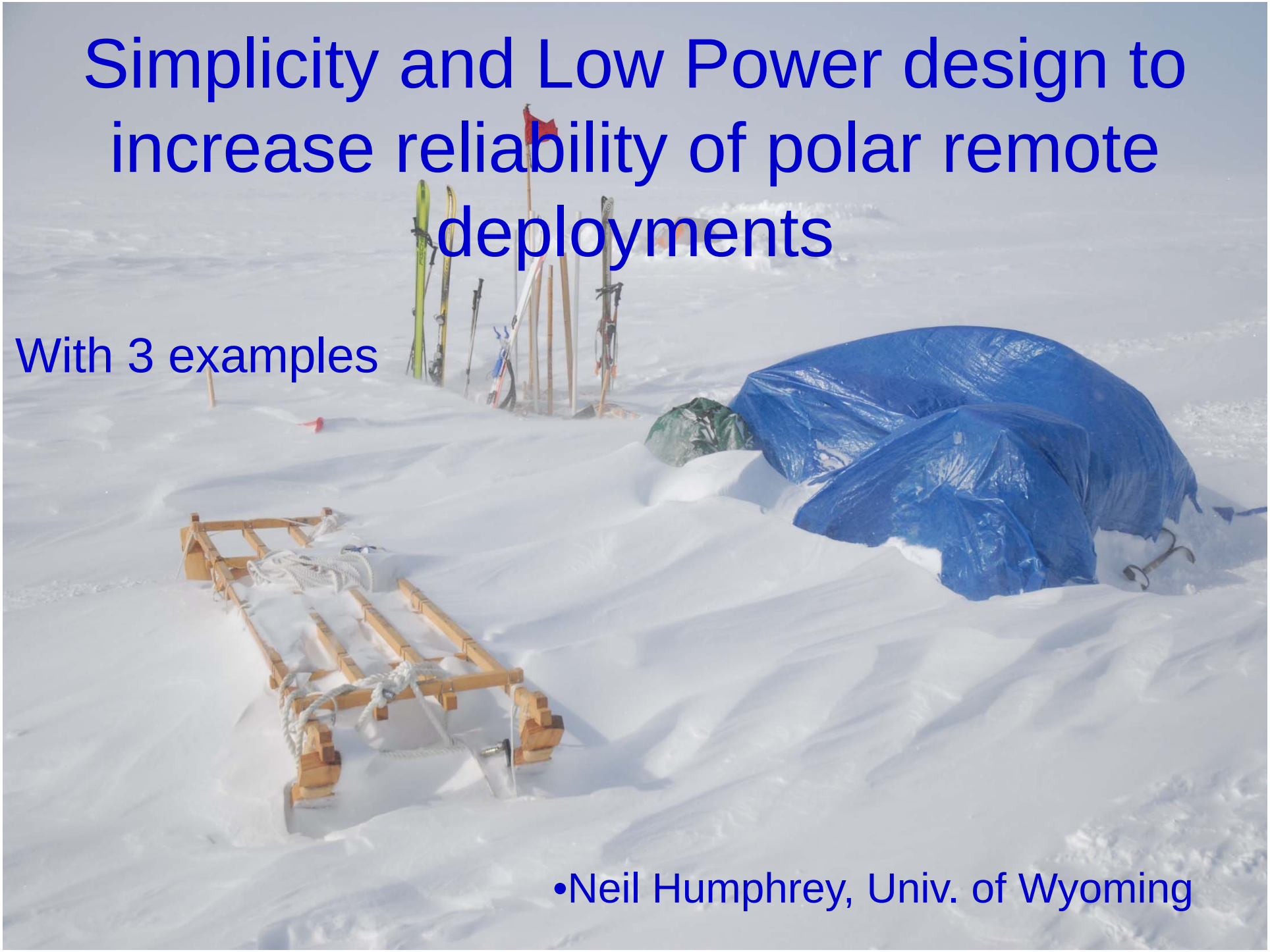
Simplicity and Low Power design to increase reliability of polar remote deployments



With 3 examples

•Neil Humphrey, Univ. of Wyoming

Most common failure modes

- Power loss
- Miss-match between sensors and controllers/loggers
- Water/ moisture in a complex setup

- In addition, logistics can make or break a project

- If you are lucky enough to have a Herc, most of what I am saying can be ignored


C-GWBU

- Tired of large bulky heavy logistics draining systems that didn't work.
- We decided we would go with our own systems that probably wouldn't work, but would be a lot simpler, lighter, smaller and cheaper.

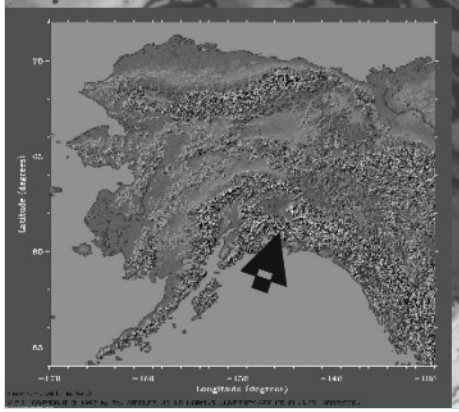
Focus on 3 low power installations

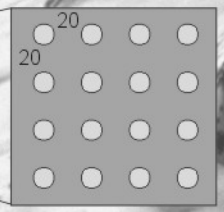
- Dataloggers, simple, stripped down and customized for deployment
- Remote logging Radar
- Downhole (Borehole) Instrumentation

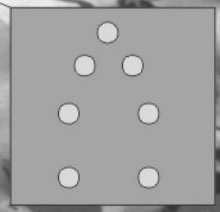
First a little history/motivation

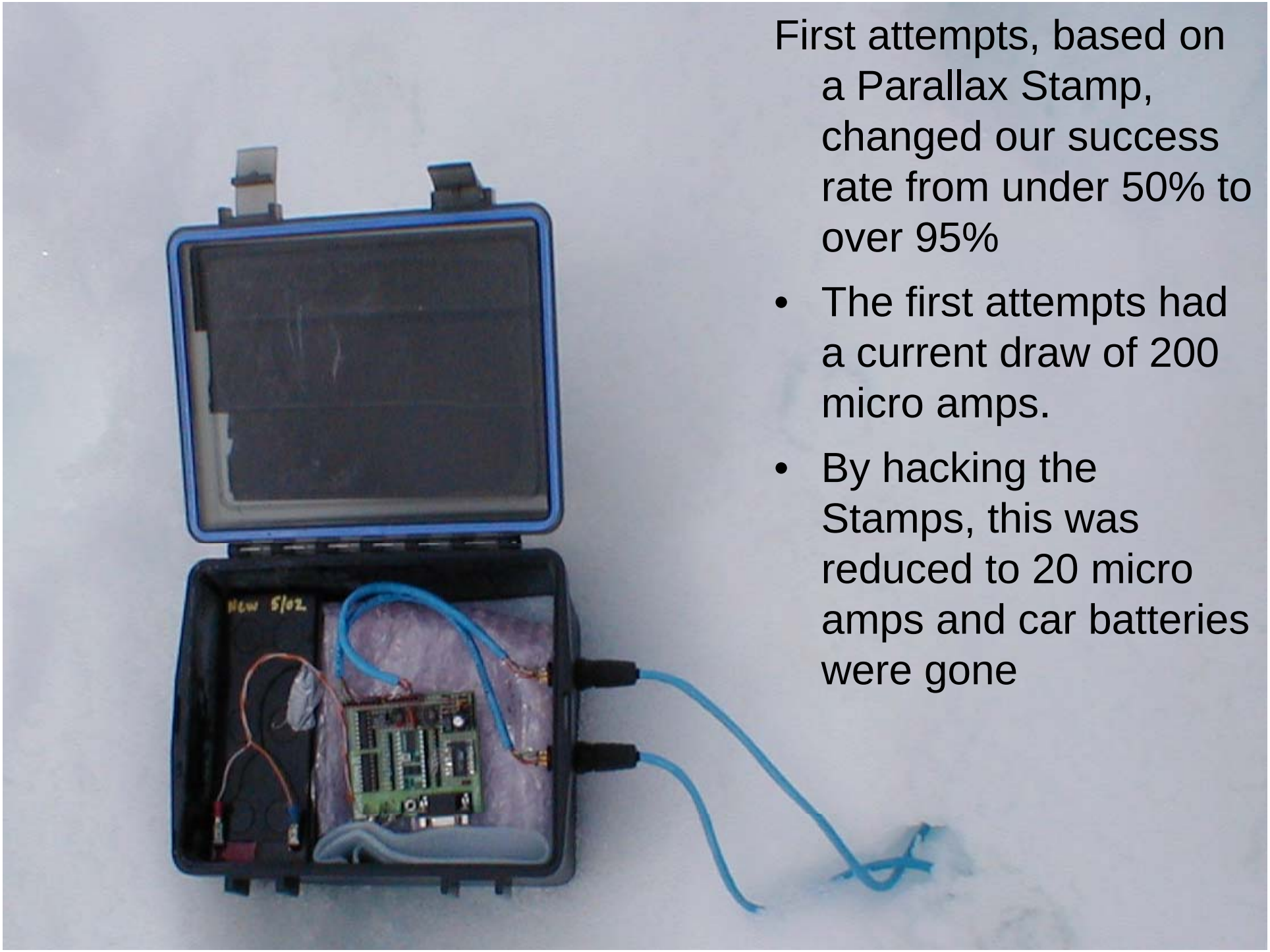
2002-2006
Glacier bed instrumented at 51 locations

-150-200 m thick
- hard bed
- temperate



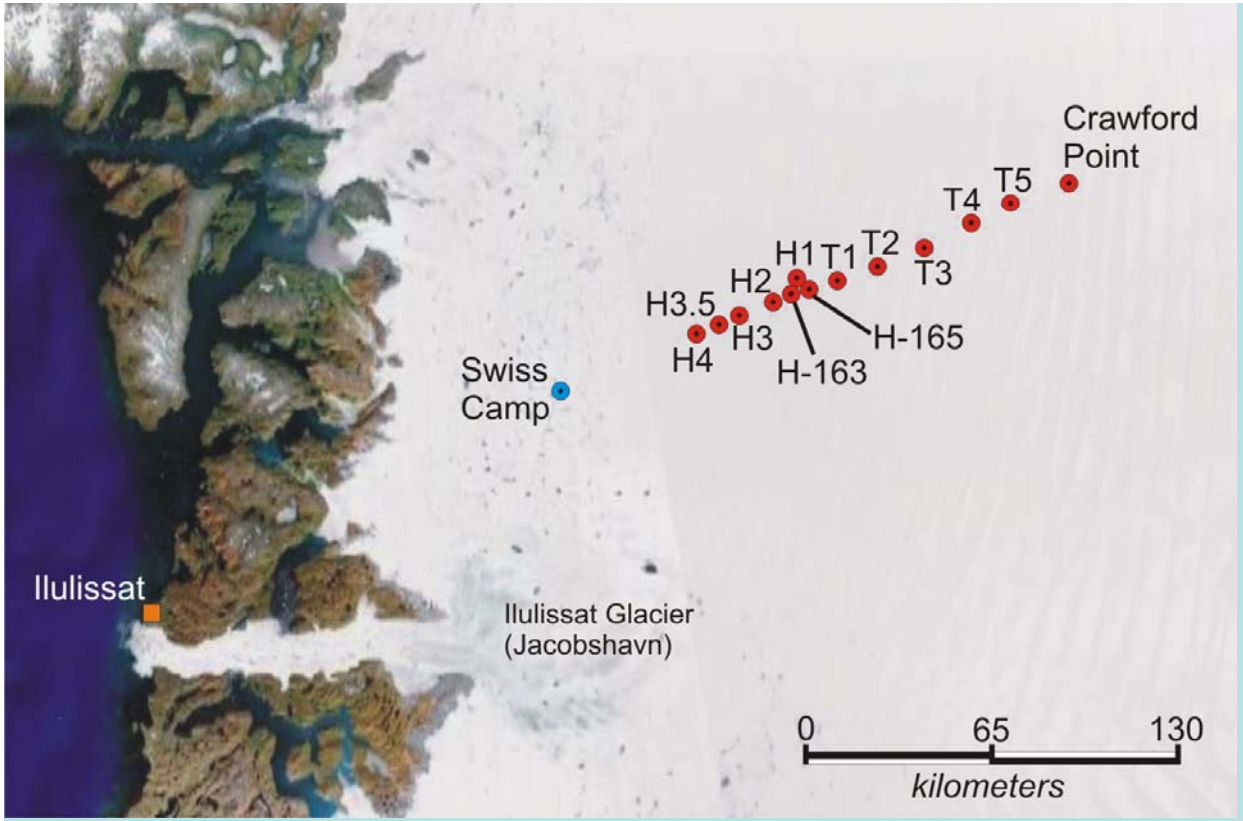


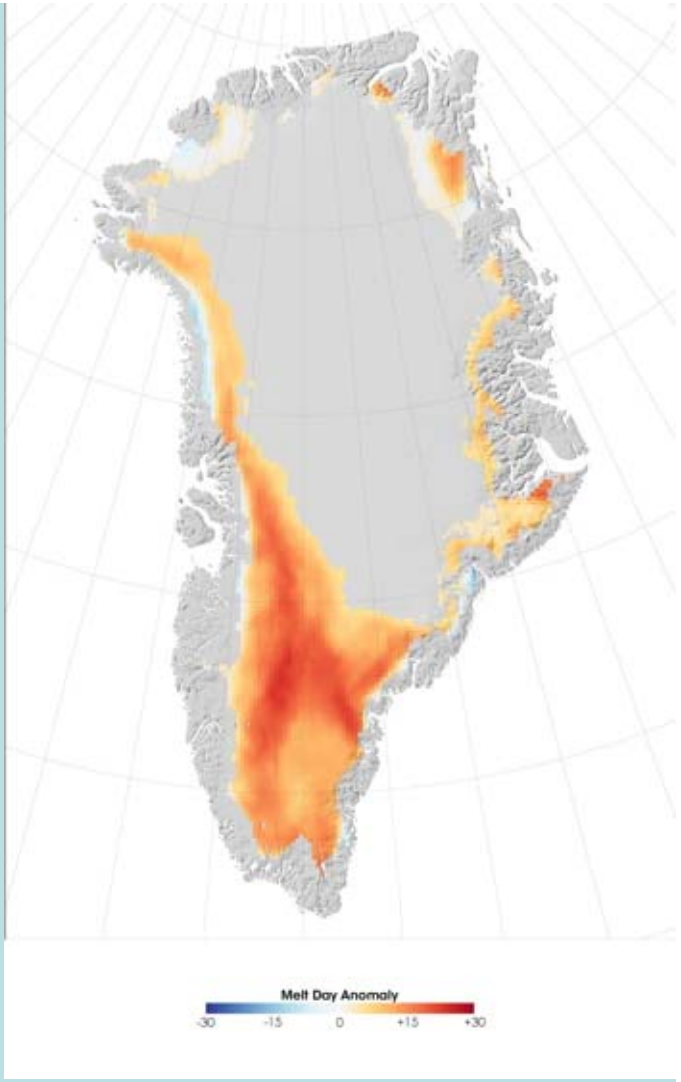




First attempts, based on a Parallax Stamp, changed our success rate from under 50% to over 95%

- The first attempts had a current draw of 200 micro amps.
- By hacking the Stamps, this was reduced to 20 micro amps and car batteries were gone



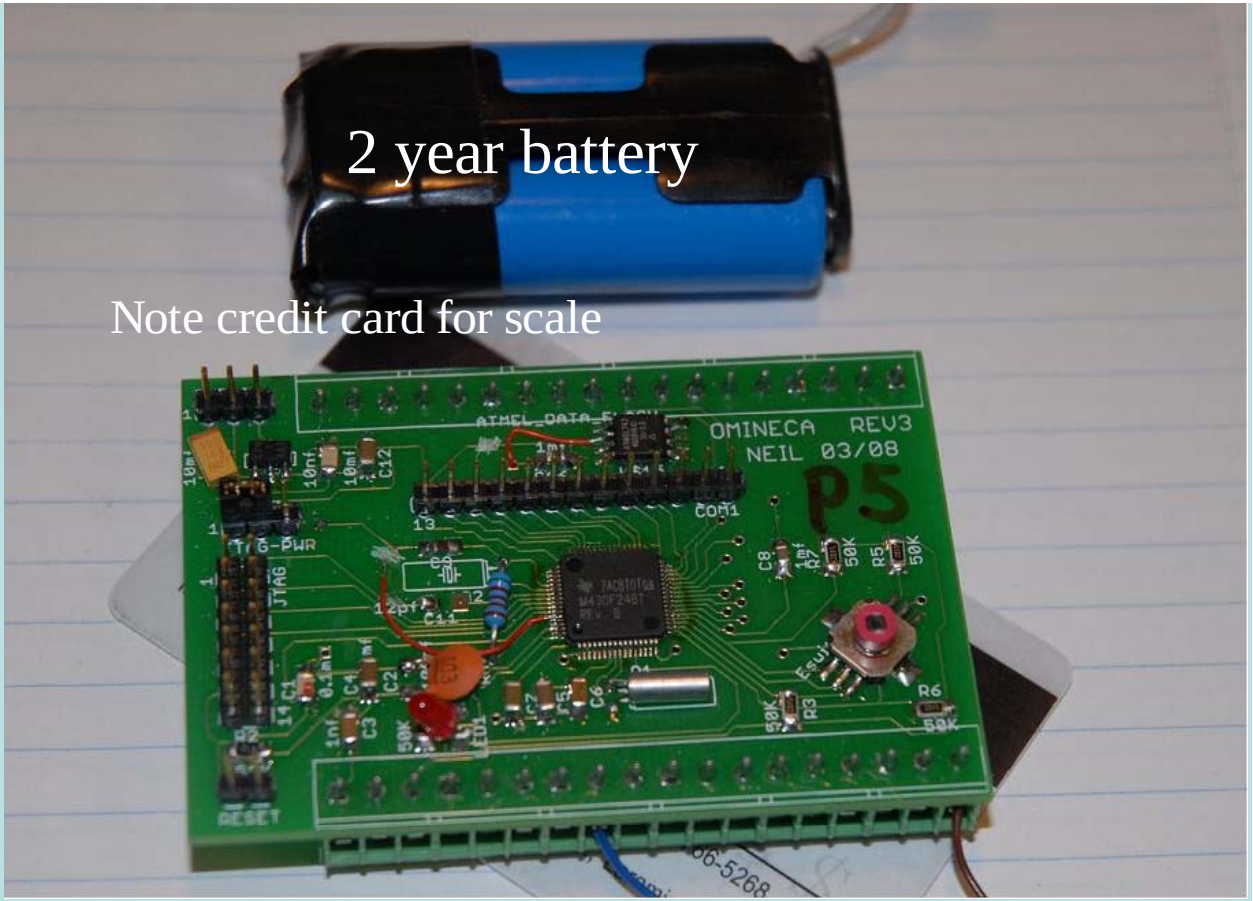


Two traverses, 2007 and 2008

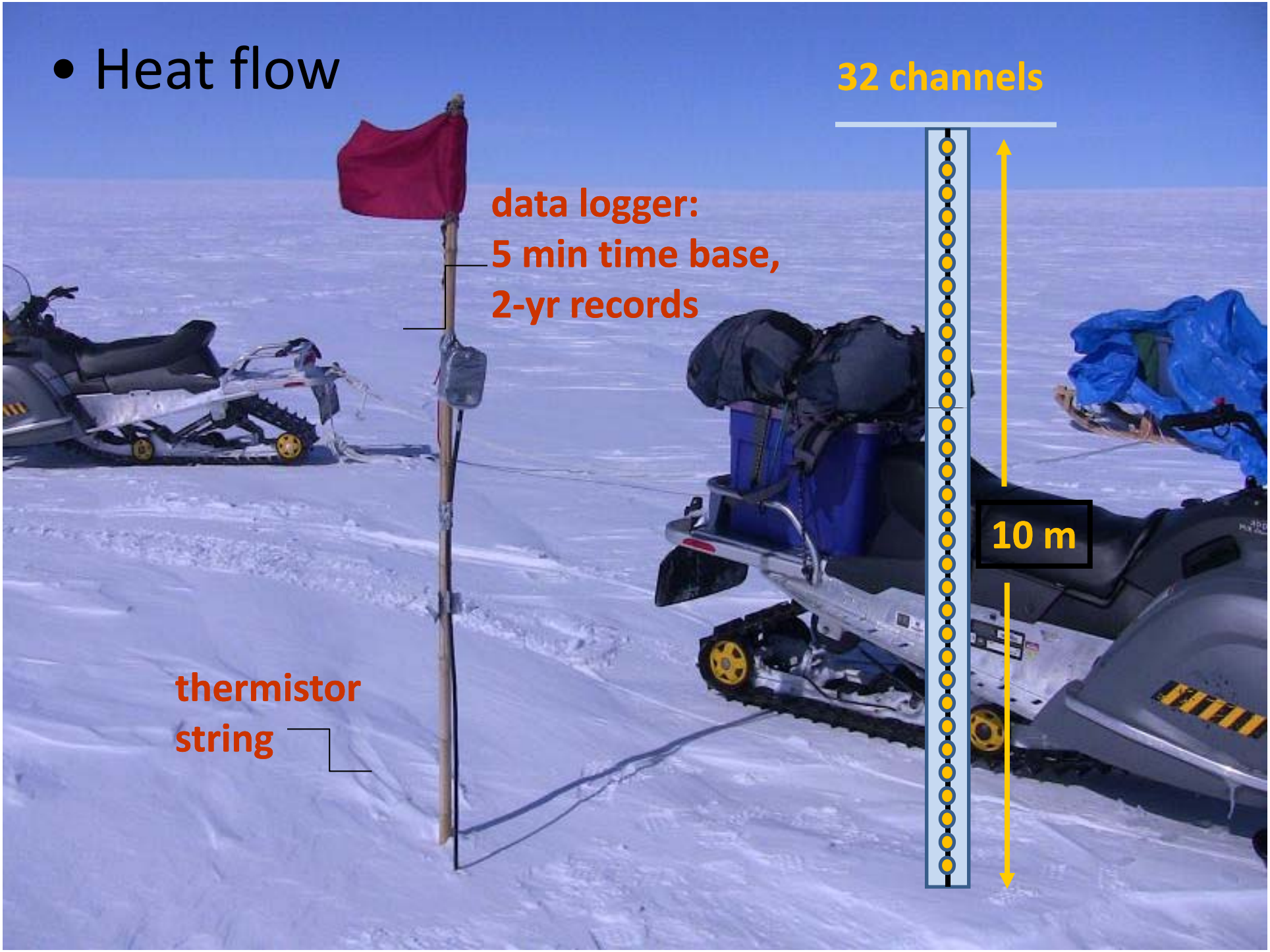
14 sites, some with multiple boreholes.

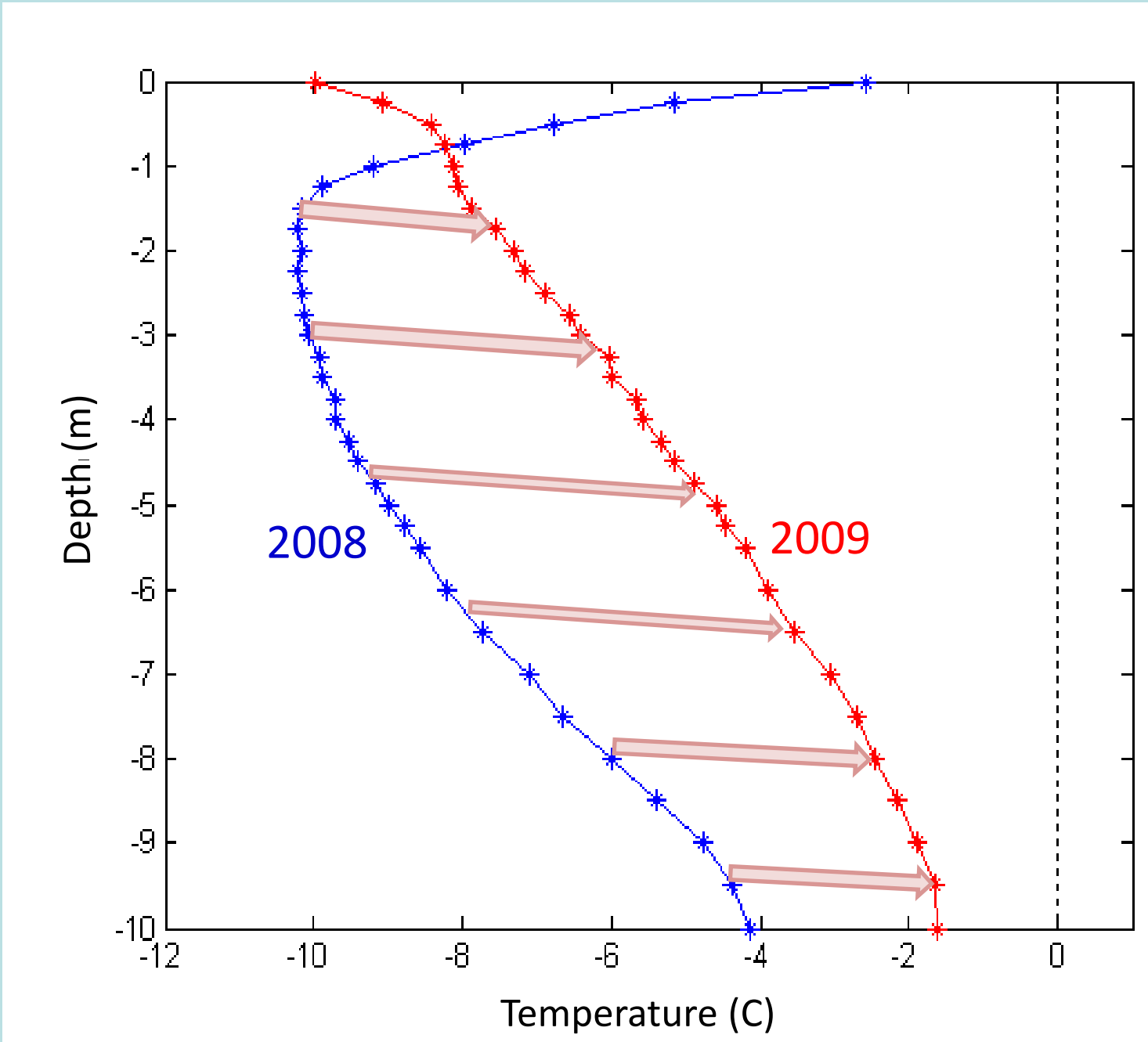
Each site has as a minimum:

- 10m temperature string (32 thermistors) continuous recording.
- Density/stratigraphy profiles.
- GPR survey

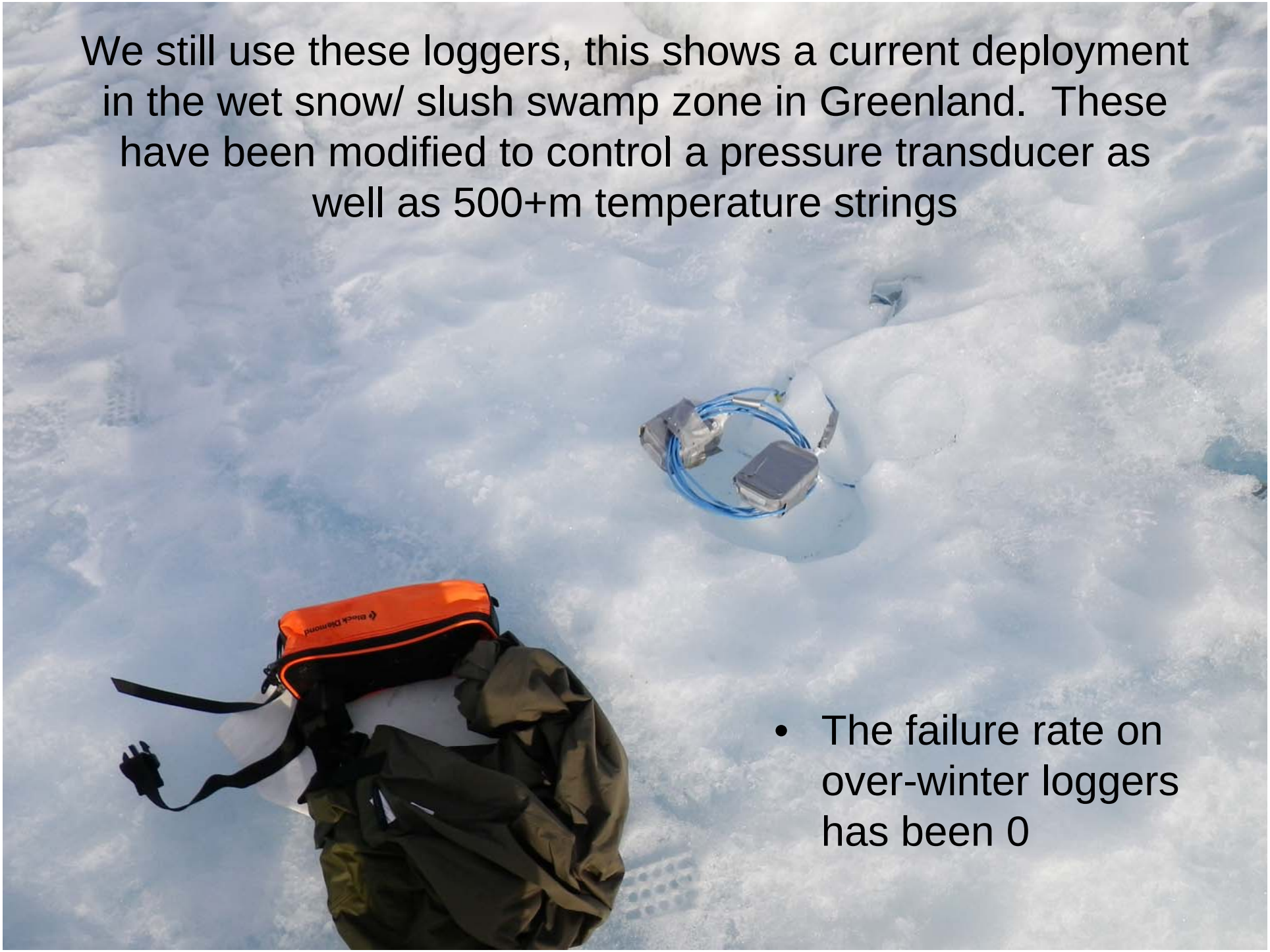


- 32 channels, 12 bit resolution
- Drives external LCD display
- Joystick user programming
- Power consumption, 4microWatts
- Memory 8MB or SD card
- Cost about $100

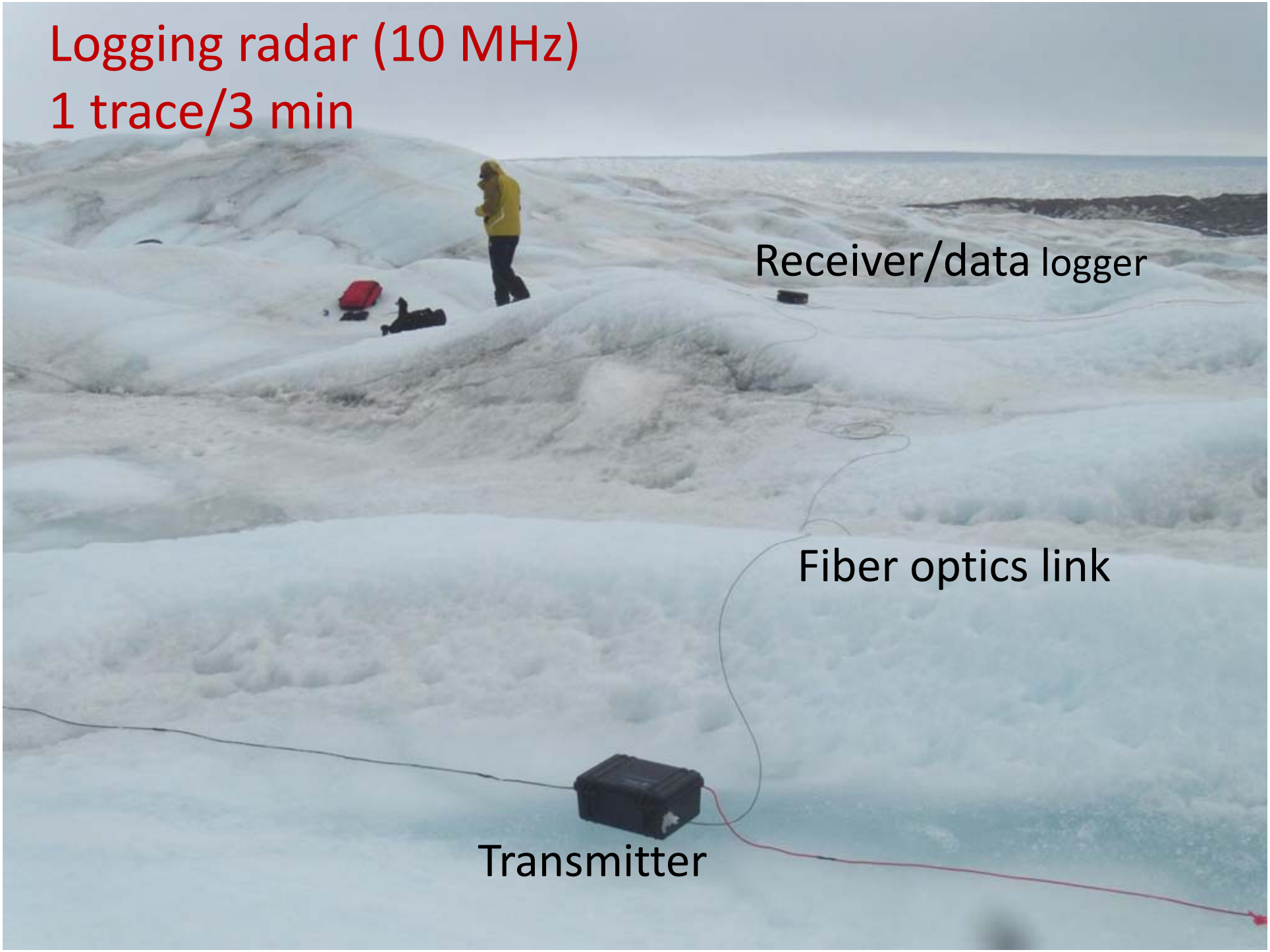

• Heat flow
32 channels
data logger:
5 min time base,
2-yr records
10 m
thermistor
string

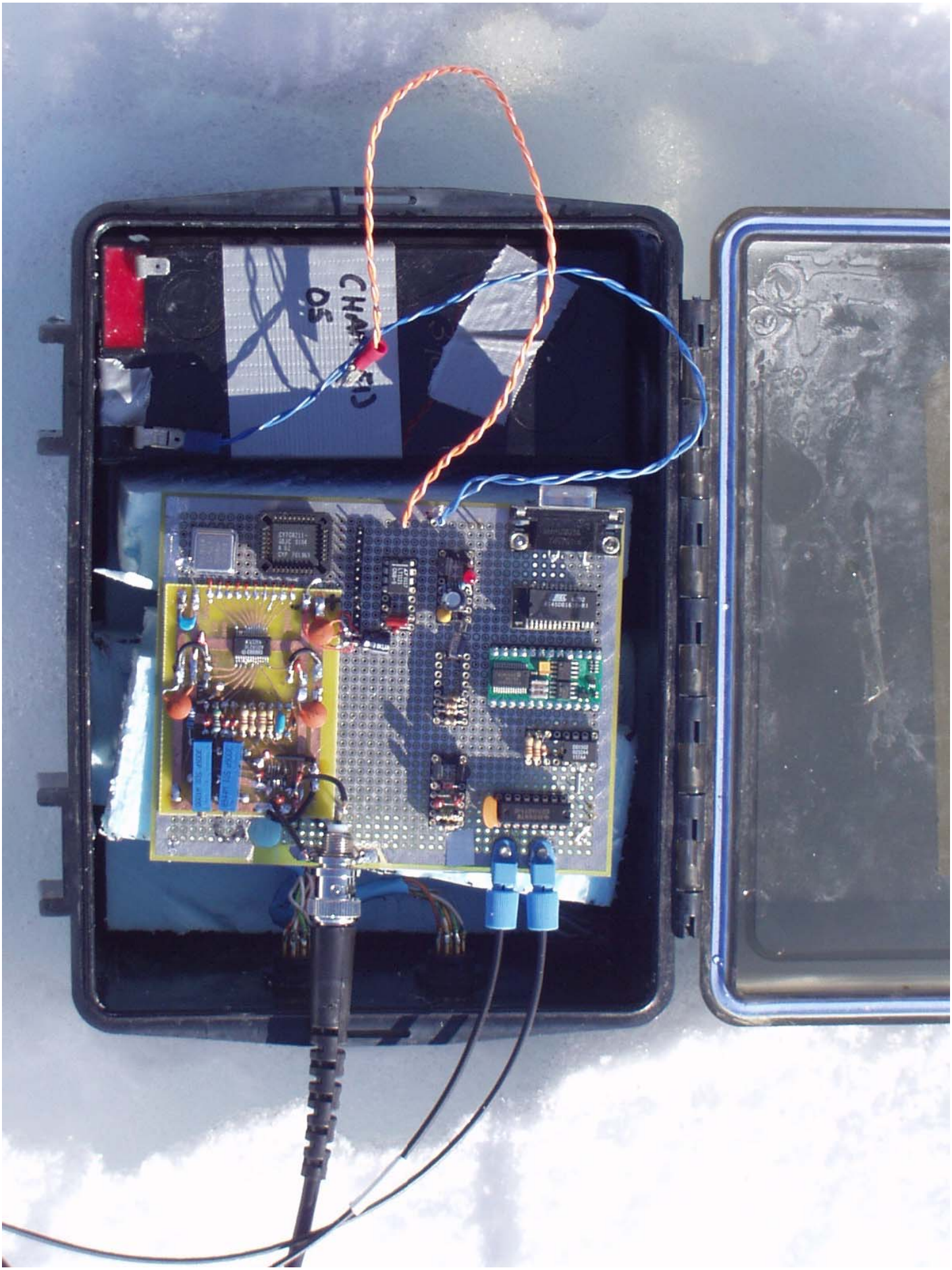

0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-12
-10
-8
-6
-4
-2
0
Depth (m)
Temperature (C)
2008
2009

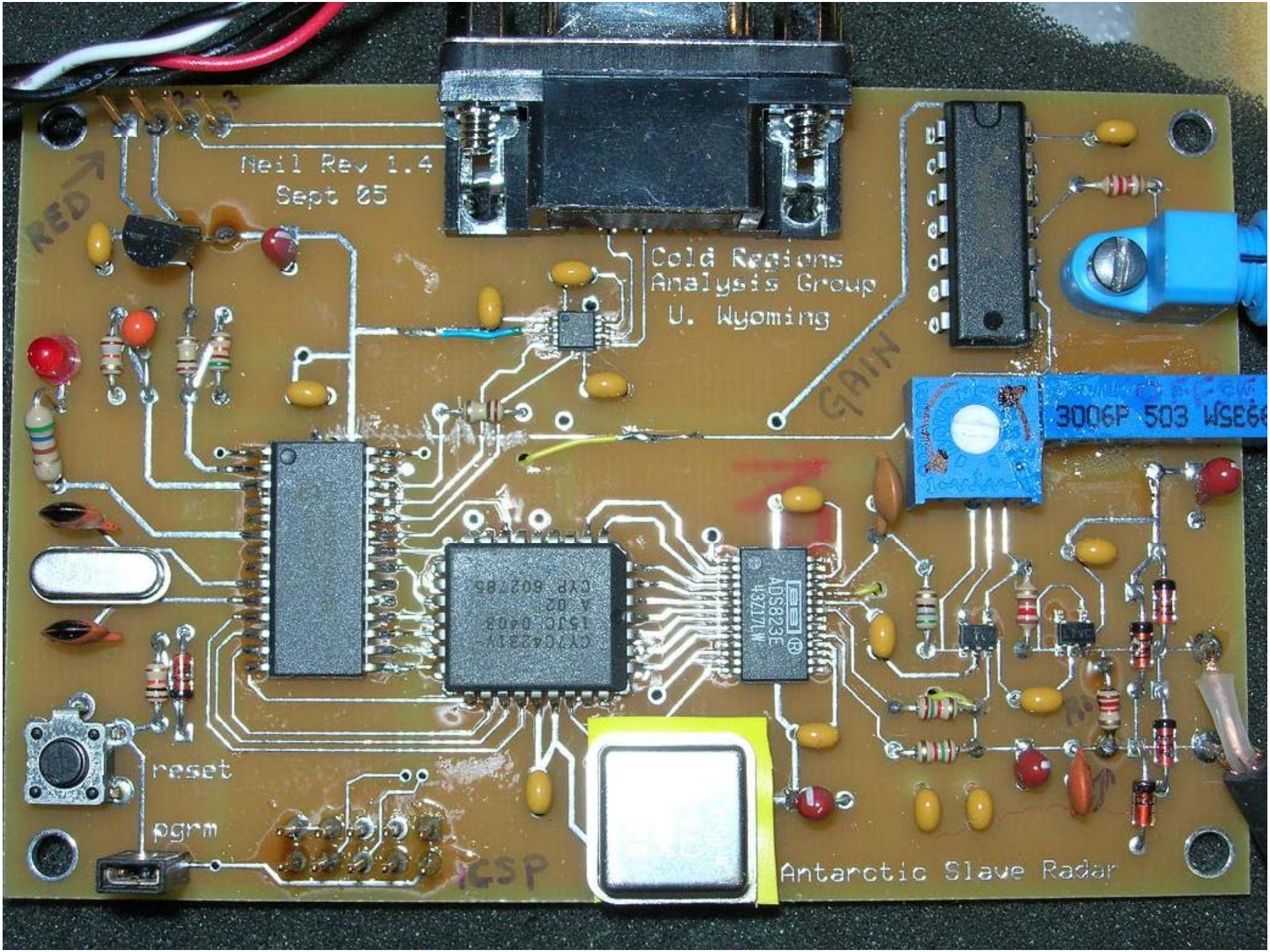
We still use these loggers, this shows a current deployment in the wet snow/ slush swamp zone in Greenland. These have been modified to control a pressure transducer as well as 500+m temperature strings

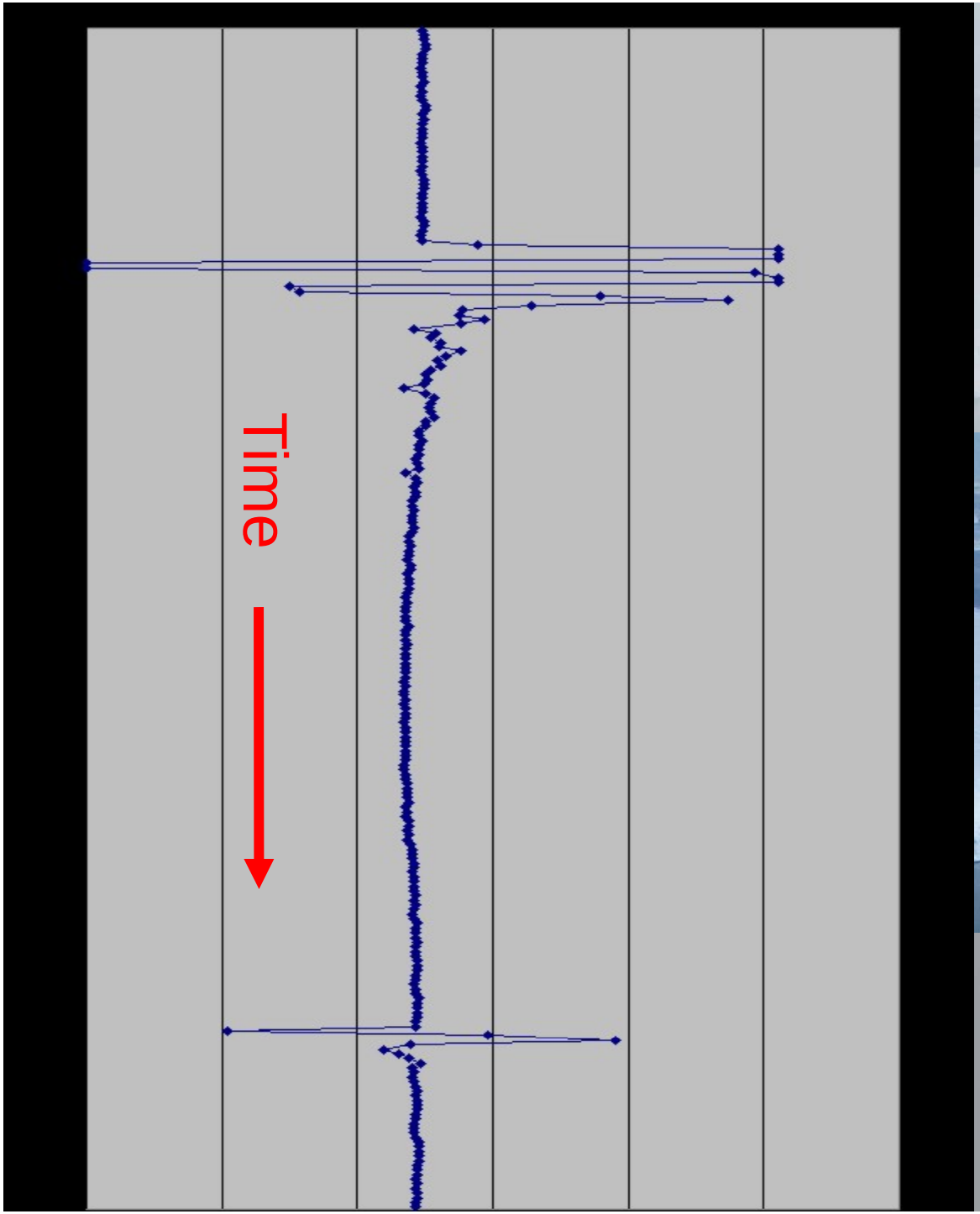


- The failure rate on over-winter loggers has been 0


Logging radar (10 MHz)
1 trace/3 min
Receiver/data logger
Fiber optics link
Transmitter



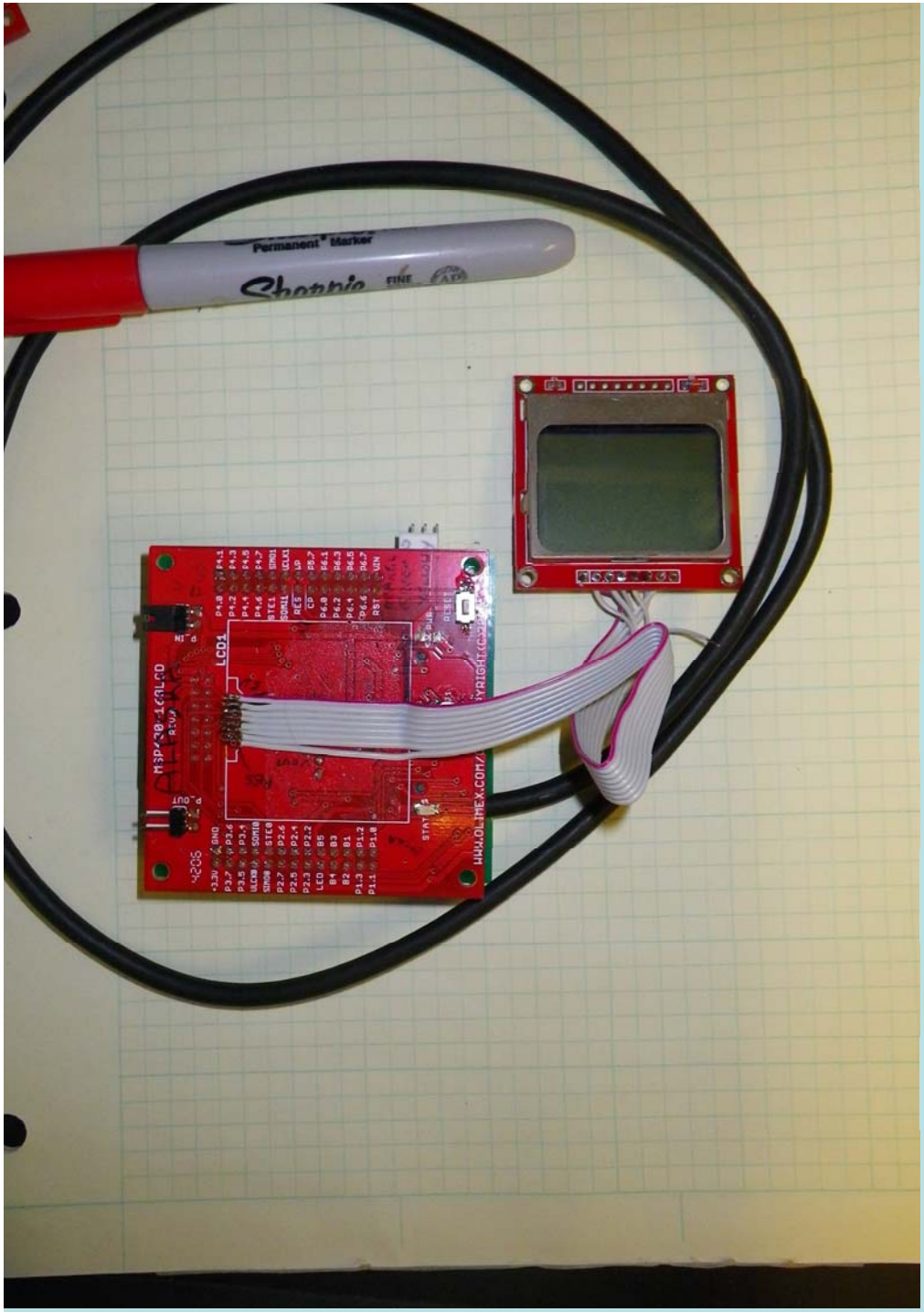

Neil Rev 1.4
Sept 05
RED
Cold Regions
Analysis Group
U. Wyoming
GAIN
3006P 503
reset
pgrm
Antarctic Slave Radar



Iceberg Radar

Surface Radar Pulse (airwave)

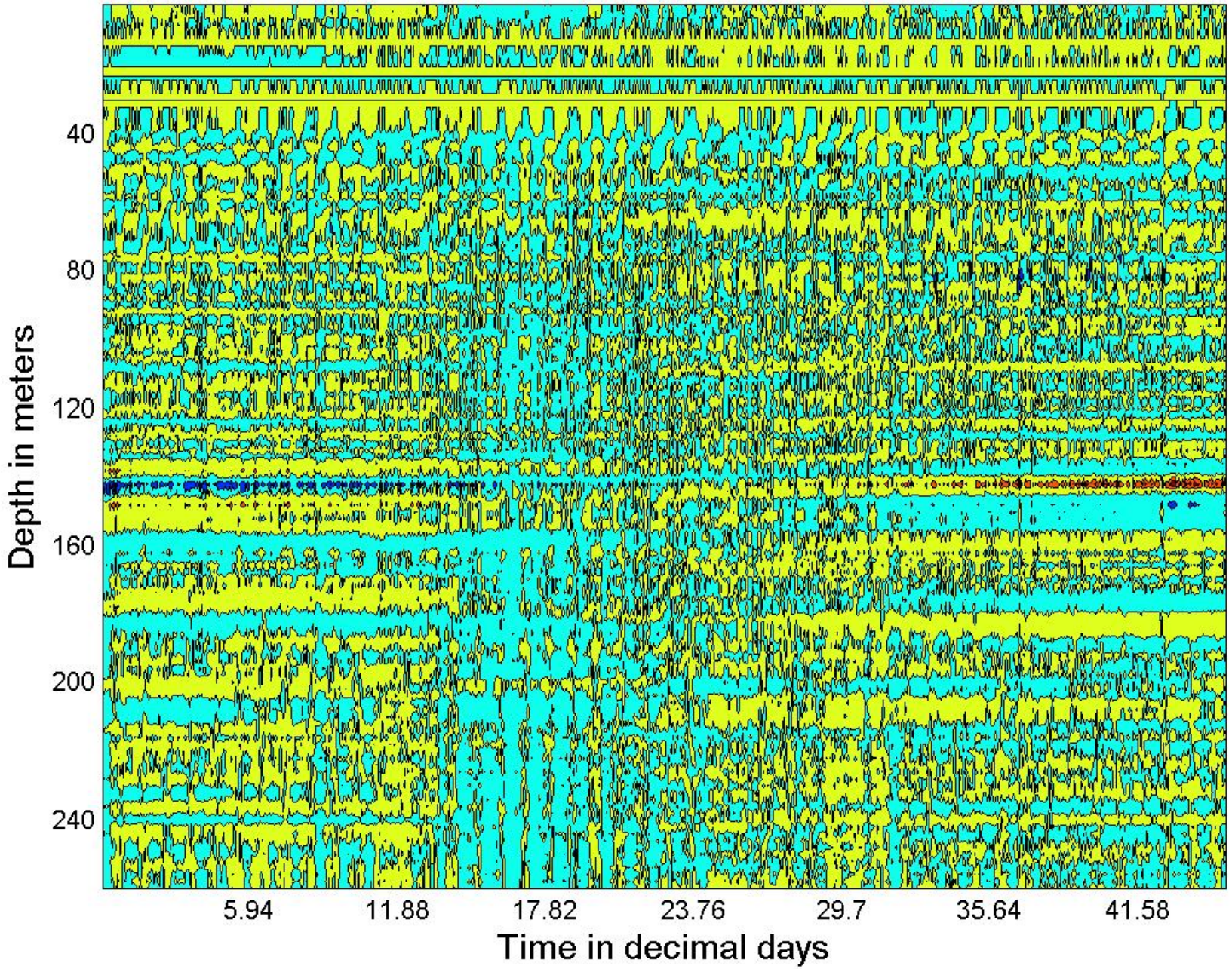
Reflection from sea-water under berg



The current version of the radar has been reduced to only 2 chips and includes a graphic display to observe traces in the field.

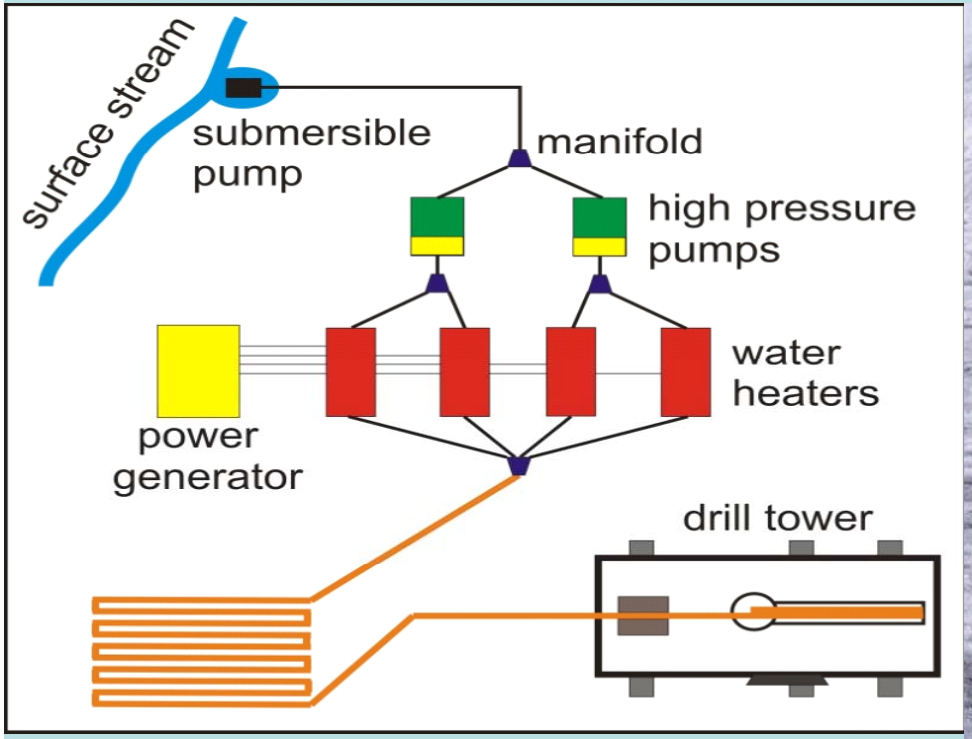
Power consumption is minimized by using short power windows. This has logged successfully for 1 year on a 5 amp-hr battery.

Monitoring Radar over time, Bench Glacier Summer 05



Borehole instrumentation

The new drill can make lots of holes.
What is needed is a low cost temperature, pressure and inclinometer string using low cost wire.
We need about 10 1-2000m strings.

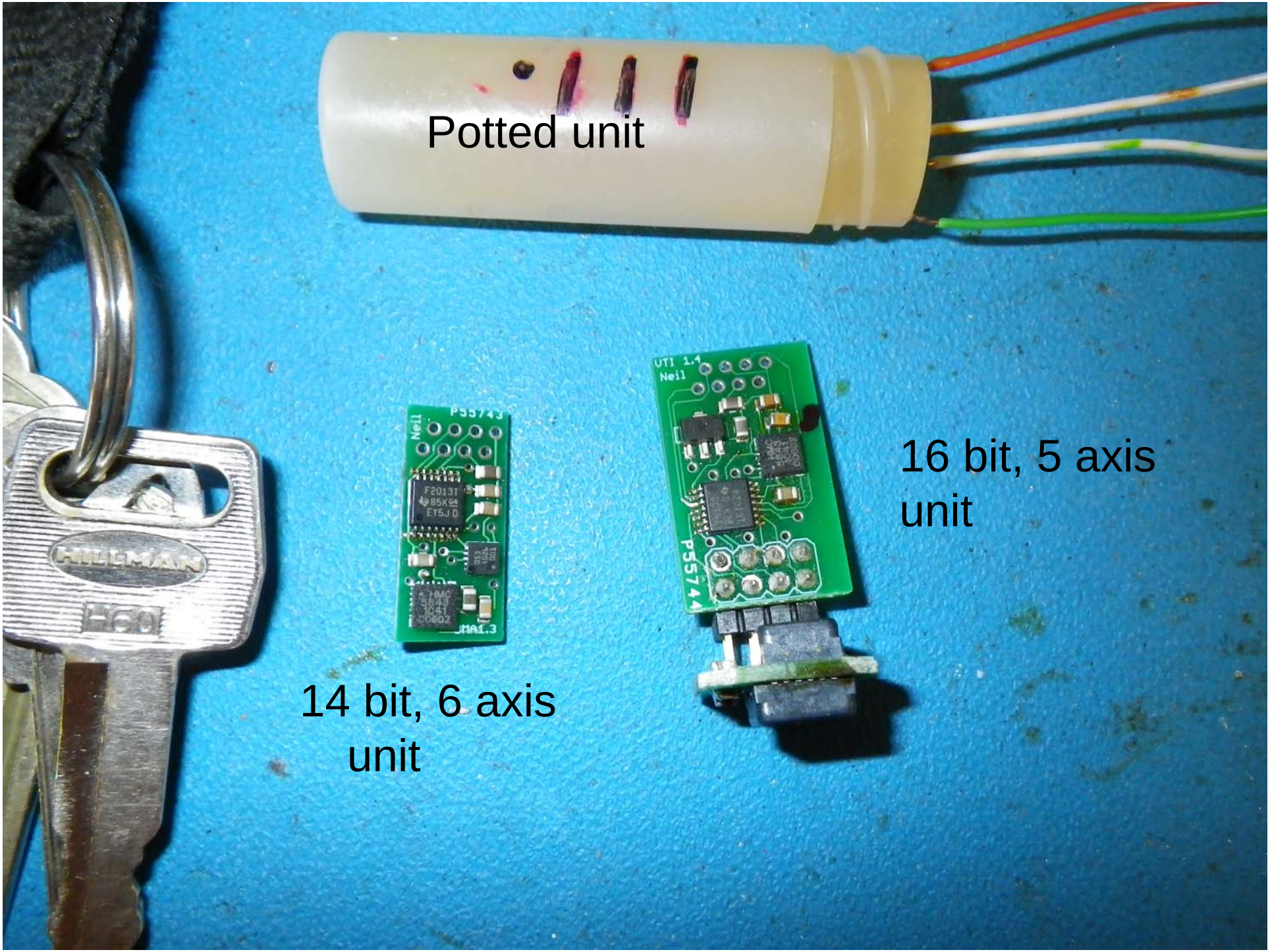


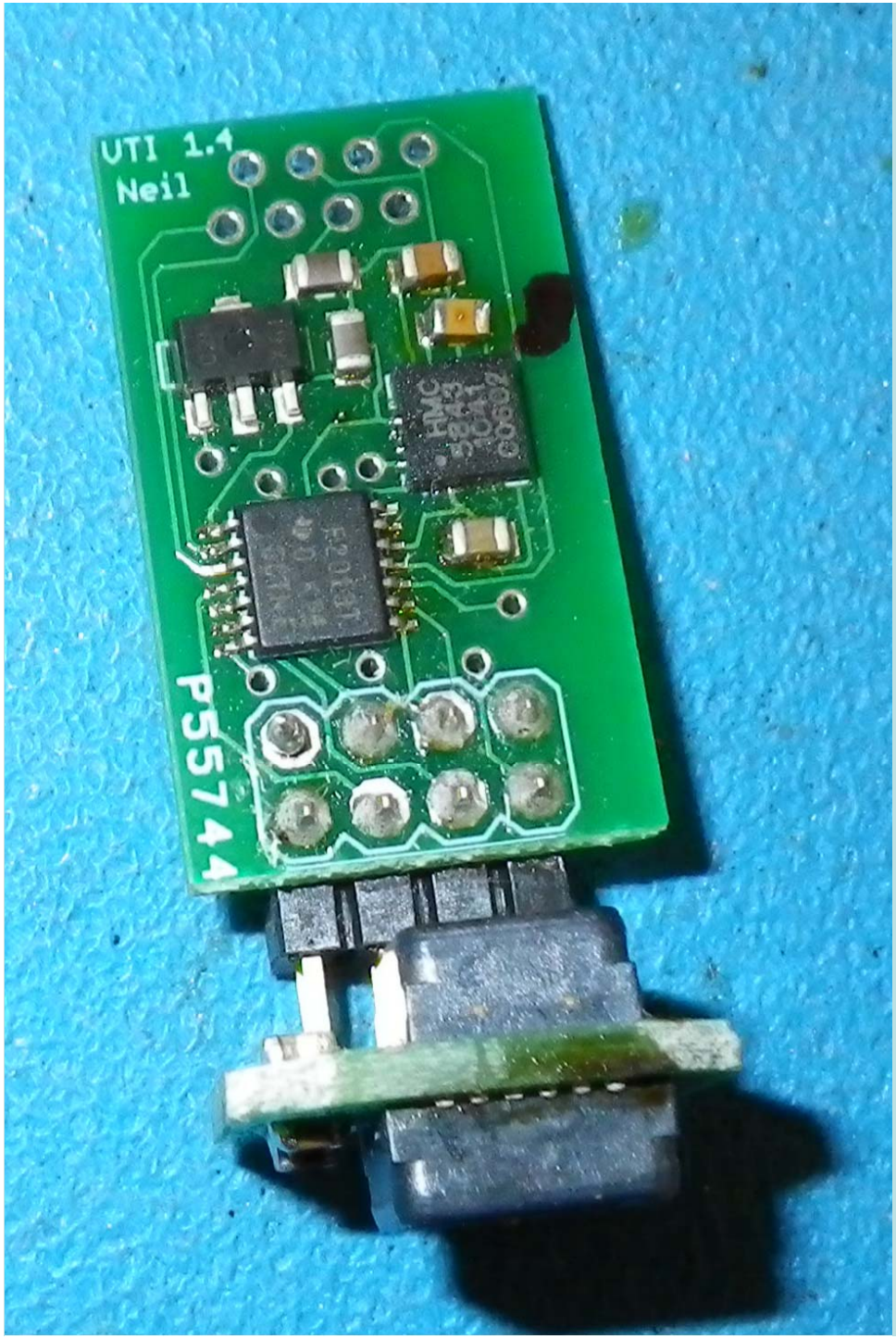
The design criteria:

- Low cost sensors and wire
- Ability to put hundreds of sensors on a single string
- Temperature, inclination and azimuth (+ pressure)

Our solution:

- Cat5e wire, 8 conductor, ~90 ohm per 1000m
- Intelligent sensors that can listen for their address while consuming 100 nano-amps
- Operate and process using ½ micro amp
- Peak surge power of 1/2 milli-amp to start the high power inclinometer chips
- Inclinometer resolution 30secs, azimuth 1-2 degs, temperature 1/100th of a degree
- A 2nd design which uses ½ micro amp in standby, and 5 milli-amps surge, gives 10sec tilt resolution


Potted unit
14 bit, 6 axis unit
16 bit, 5 axis unit



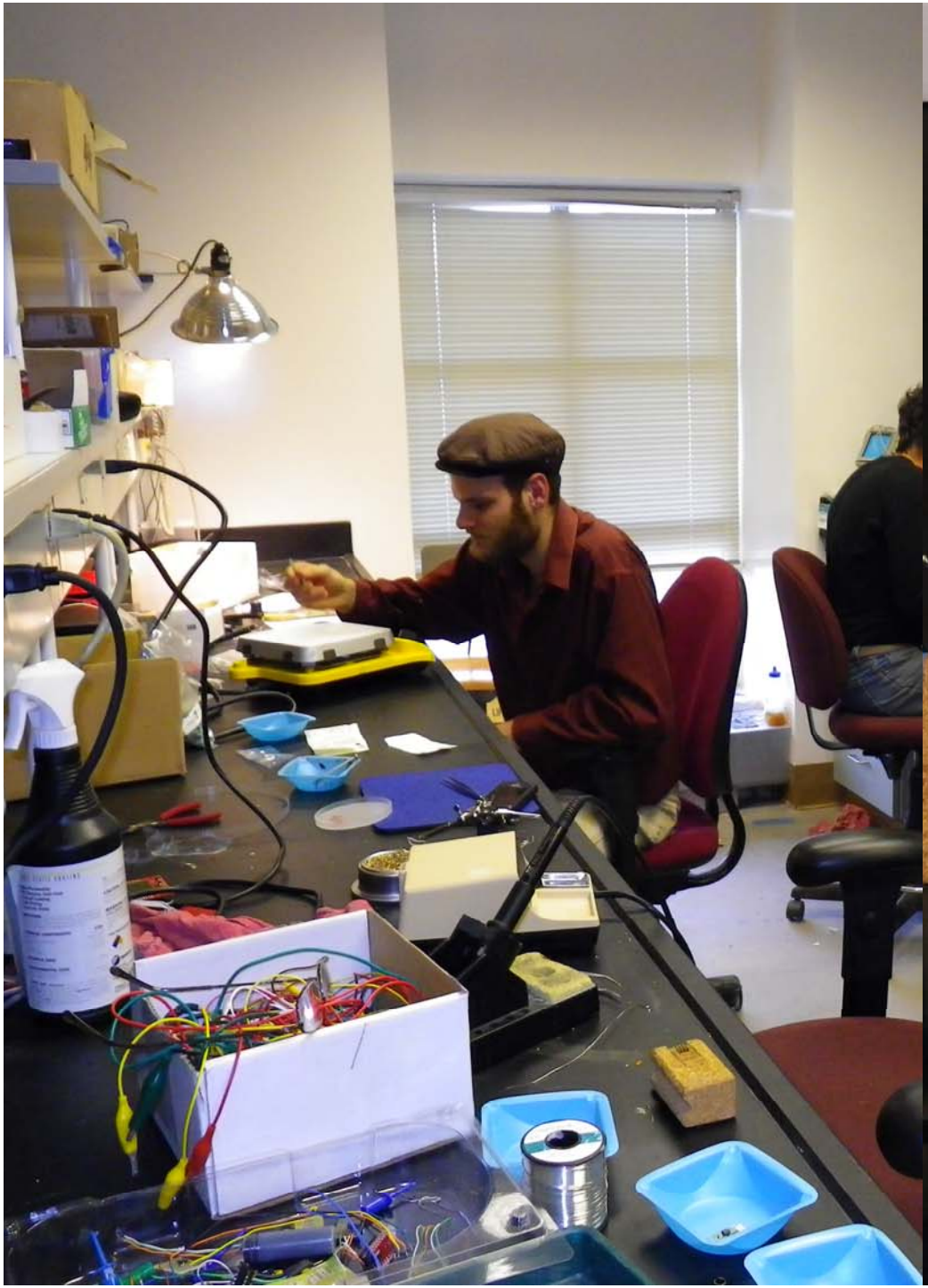
Components for the high power/ high resolution unit

- Voltage regulator
- HMC5843 3-axis magnetic field sensor
- MSP430F2013 microcontroller with 16 bit ADC for temperature
- 2 VTI 16 bit 1 axis inclinometers

The micro controller uses I2C protocol for the magnetic sensor, SPI protocol for the inclinometer and uses a 4 wire SPI-like, 10 baud

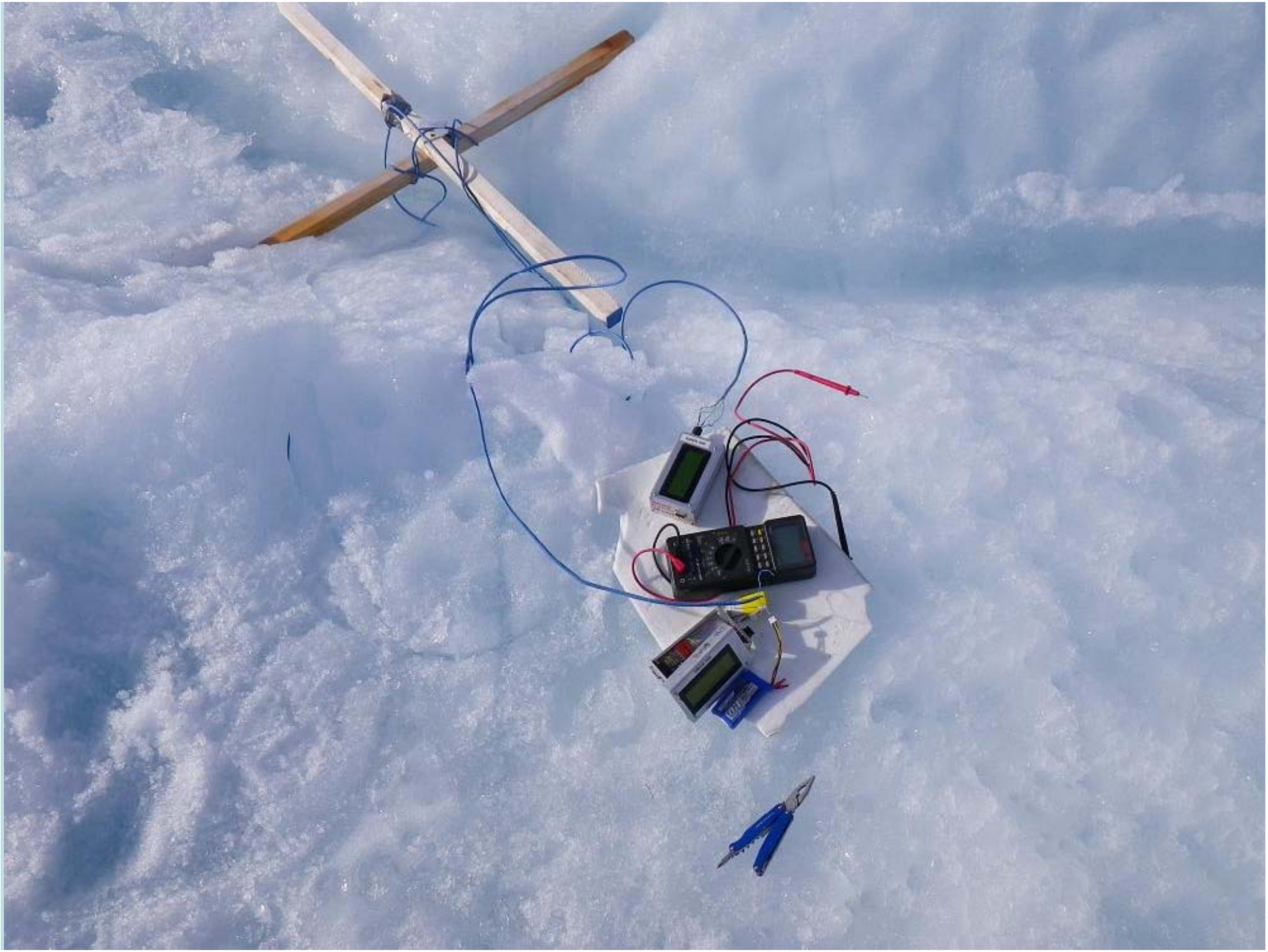
The crux of the low power downhole design is similar to the our other designs, but power and size constraints are more extreme. The only chip which remains powered is the micro-controller which is operated at a few hundred hertz while waiting to be addressed. This limits the bandwidth on the string so that it takes several seconds to download any given sensor.

Surface logging is done with a small MSP430 based unit.



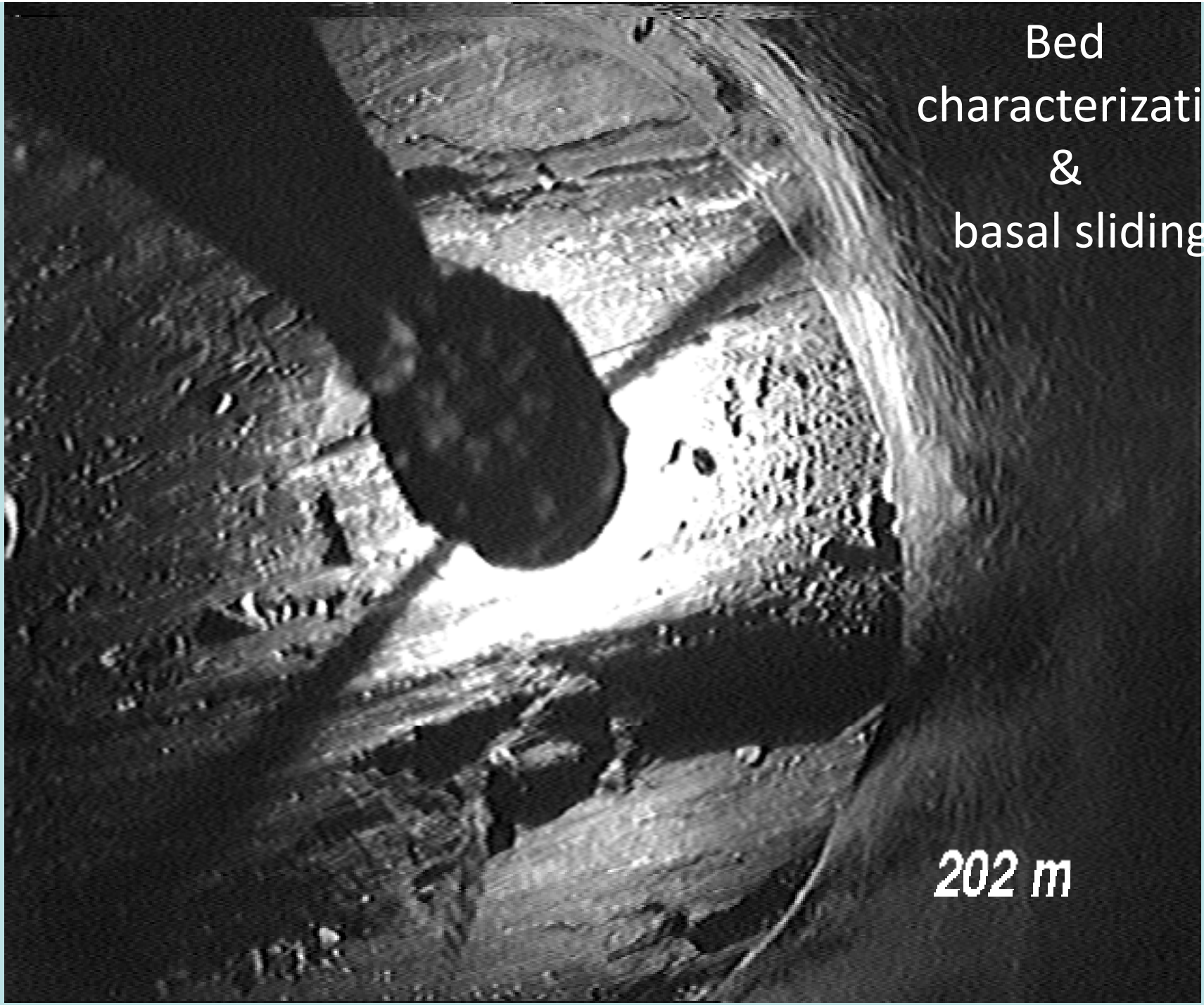
Some final ideas:

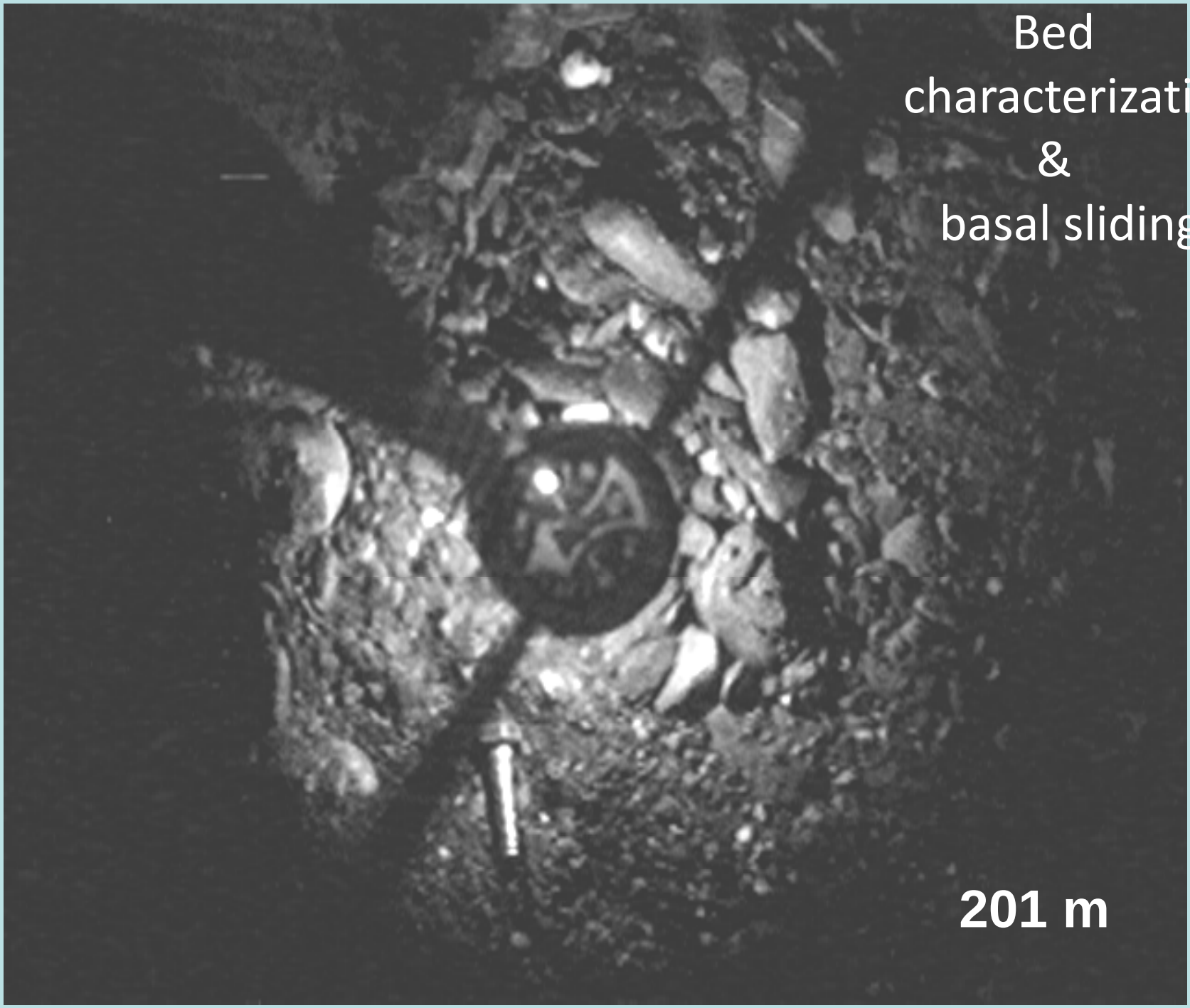
- Reducing power, size, and complexity has a multiplicative effect on the science bottom line
- Reliability is increased dramatically
- Logistics costs associated with sensors are almost eliminated
- The amount of junk (especially batteries) left on the ice is greatly reduced
- Modern consumer electronics allows for easy design of purpose built sensors and loggers
- Basically it is more bang for the buck




NEIL @
UNYO.EDU
IDM LOGGER


FILM
400
25
exp.


Bed
characterization
&
basal sliding
202 m


Bed
characterization
&
basal sliding
201 m