A New Telemetry Module Based on Iridium SBD

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The 2012-2013 AGO Field Season

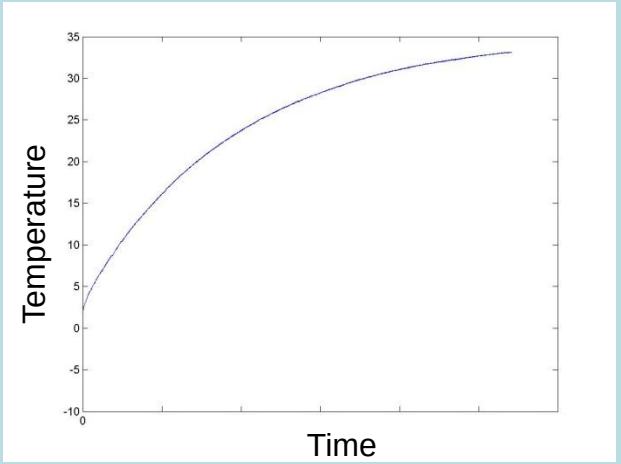
- Five Telemetry modules fabricated
- Four units deployed on the Ice at remote sites starting Dec 2012
- One unit has failed for unknown reasons
- Three remaining units working as expected

Basic capabilities

- 32 channels of analog data – voltage range and input impedance can be configured by the user
- 8 channels of temperature measurement
- 4 channels of digital input; one digital timer; all opto-isolated
- Two latching relays that can be controlled from stateside
- Input voltage range is 18 to 36 Vdc; nominal draw is around 30 mA but can be much more when the heater turns on or when transmitting
- Used to send housekeeping information or moderate-rate science data
- Entire systems runs on a separate battery so that it can provide a *post mortem* if the main power system fails
- Small patch antenna is more than adequate with good sky visibility

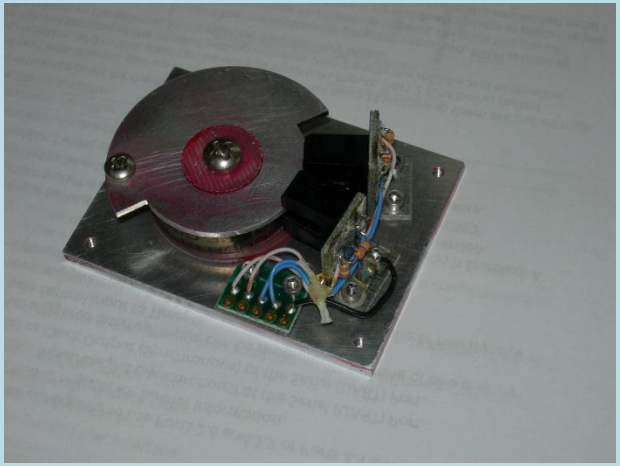
Thermal design

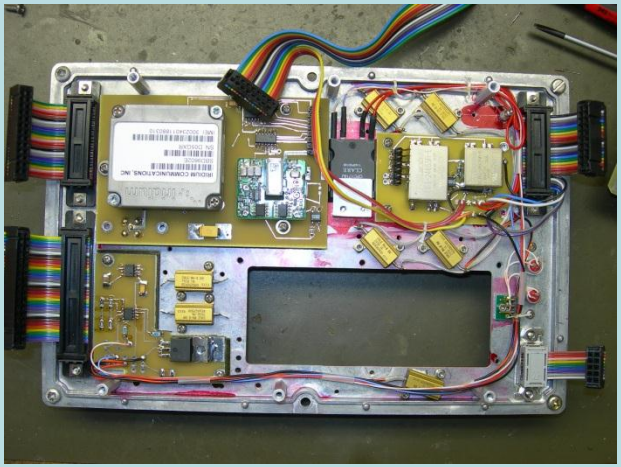
- Electronics package inserted in a plastic Hardigg case
- Pinkboard foam (appx R10) used as insulating blanket
- Use “wedding cake” staggered step to reduce leakage of lid
- Test shows that appx 2 W of heat will put package > 30 °C above ambient
- Shelter can get down to -70 °C, but modem wants warmer than -40 °C, so 30 °C delta is adequate



Thermal design …

- Used LM56 temperature regulator chip as simple controller
- Bang-bang control around a set-point of appx -20 °C
- Experimented with a mechanical thermostat, but eventually went all electronic
- Heater is a bank of 5 W power resistors bolted to lid of enclosure
- Heater circuit tested extensively in a cold chamber
- Approximately ½ W of heat is *not* controlled by the thermostat—serves as a pre-warmer when power is restored after a cold soak





Temperature measurement

- Module can do 8 channels of temp measurement with at least 150 °C range using type K thermocouples
- Earlier design used an LM135 semi-conductor temp transducer – easy to use but insufficient range and not rugged
- Thermocouples are cheap and rugged; the sensitive electronics stays inside the shelter(!)
- Accuracy is appx +/- 3 °C, but this is more than enough
- The Maxim 31855 makes thermocouple management very easy – provides a reference junction, error checking, and a tri-state digital SPI output to a uP; all for about $7 per chip!
- Thermocouple connections to electronics package made with small screw terminals

Money issues

- The 9602a modem costs appx $250
- One-time activation fee of $80
- Monthly recurring charge (mrc) of appx $11, even if not used
- AGO pays appx $60/month for air-time or $120/month for air-time with science data
- Supporting circuitry costs about $75

9602a reliability issues

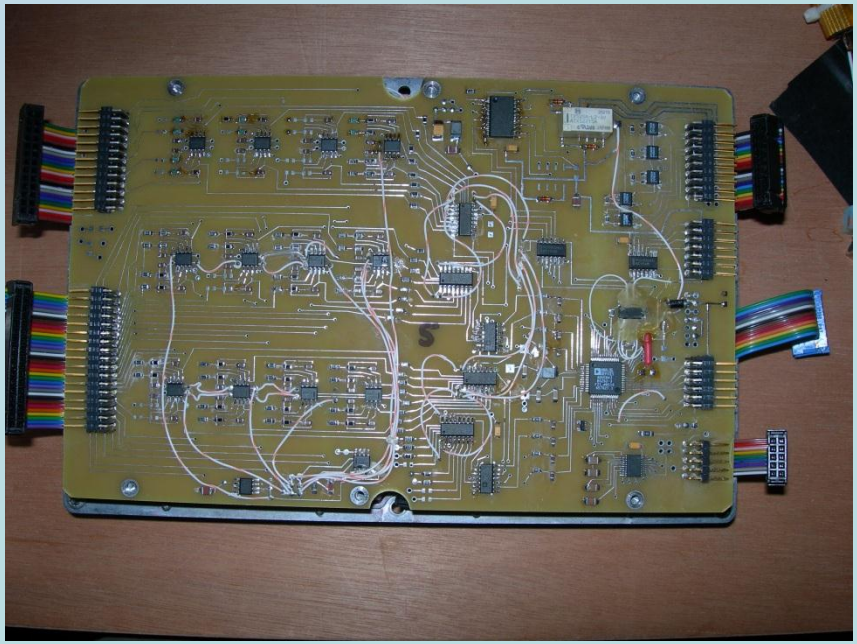
- Good, but not great
- Purchased 5 units for deployment, one failed before being deployed
- Two units on Ice last season, one survived a cold-soak, one did not
- To be fair, units got much colder than their rated -40 °C
- Suggestion: get several 9602a modules and run a cold-soak stateside before deployment
- Failed unit is being returned for failure analysis

Modem interface

- Home-made interface board
- Used Lineage SC003 series DC-DC converter (appx $25) to supply +5 Vdc to the 9602a
- Proper power management (with filtering) is very important
- Must follow strict power-on protocol to avoid latchup
- Note: modem wants +5 power but logic interface is 3.3 V(!)

The micro-processor control

- Used the Analog Devices AD843 uP chip
- Serial port of uP used for firmware load and to communicate with a laptop
- Implemented a “synthetic” serial port by using two logic pins for Rx and Tx; sometimes called *bit banging*
- uP can allow a direct connection between the laptop and the 9602a for debugging, learning, etc.; highly recommended

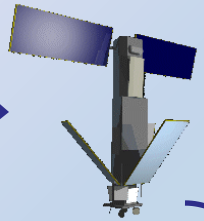


Some ideas

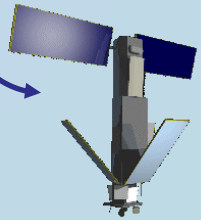
- Can Iridium, LLC provide a software emulator for the 9602a?
  This would allow experimentation without putting a unit on the air.
- Reliability needs work.
  Where are the units actually made and do they all come from the same fabricator?

Monitoring AGOs stateside

antenna



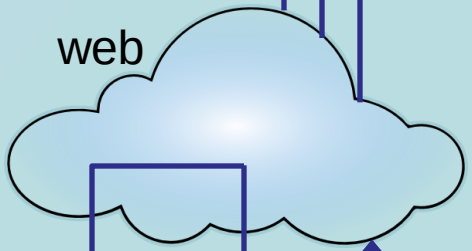
Iridium constellation



end-user

modem

web



IP

microprocessor and sensor feeds

Iridium gateway with SBD network equipment

server, database, and webserver

Advantages of stateside monitoring

Before …

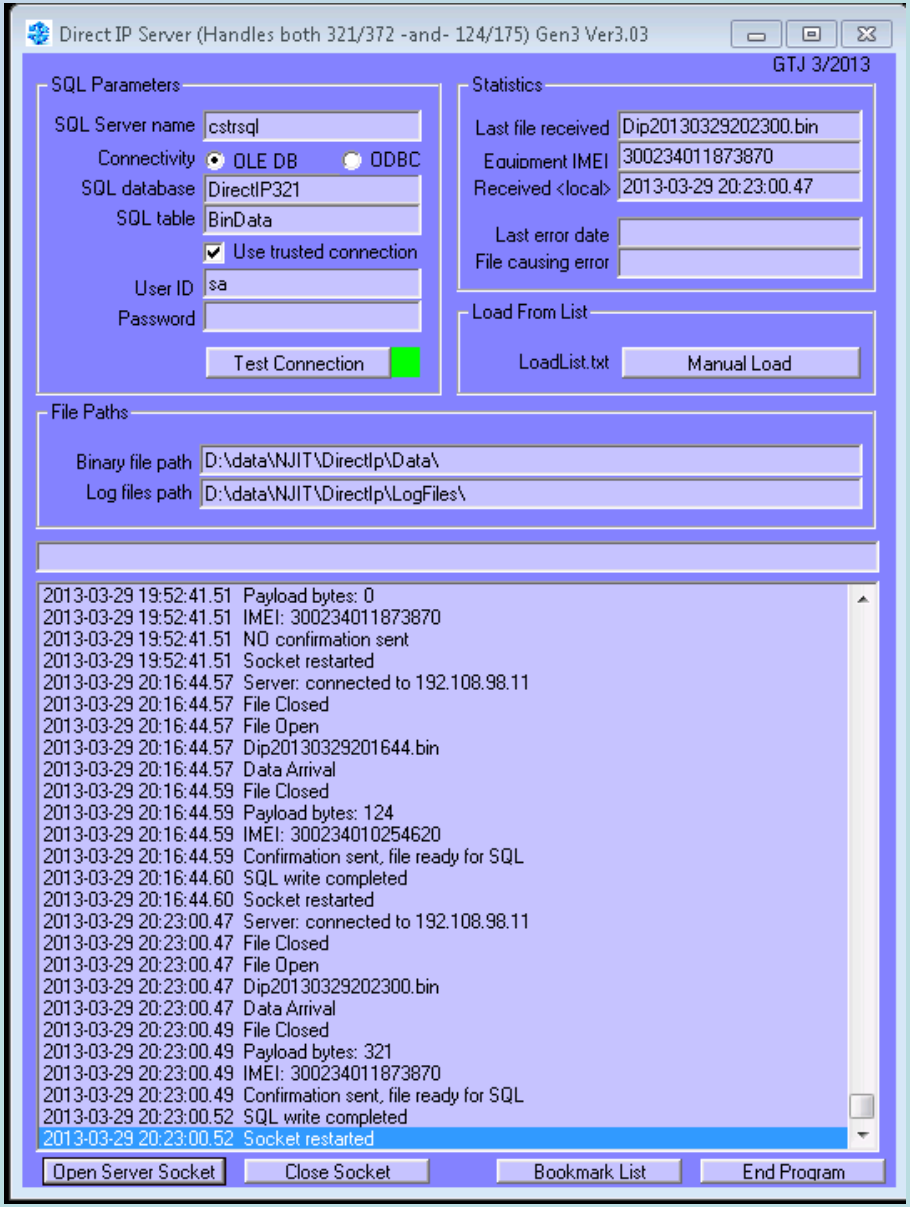
- Deployed equipment, no feedback until returning one or two years later
- Synthetic testing for individual components in cold chamber
- Failure diagnostics can only begin after returning from the ice

Now …

- Near real-time monitoring of power system, instruments, temperature allow us to see how equipment responds in real environmental conditions – long term low temp, wind fall off, recovery after prolong cold soak, etc.
- Diagnosis of failure before field season begins – parts, re-design, etc.
- Science data (AGO 1) from fluxgate updated every half-hour
- Future capability to do limited remote-control

Stateside data management

- Direct IP server runs 24 x 7
- Each modem has unique IMEI, processing different (env + sci)
- Application immediately saves received packet as binary file, only then does it process bytes
- Processed into SQL database, reporting is off of this live data
- If this server is unreachable, retries packet for 12 hours
- Up to 10,000 packets in queue
- Multiple destinations possible; we've added dedicated email, will add a second server site



Stateside data management

Message Size

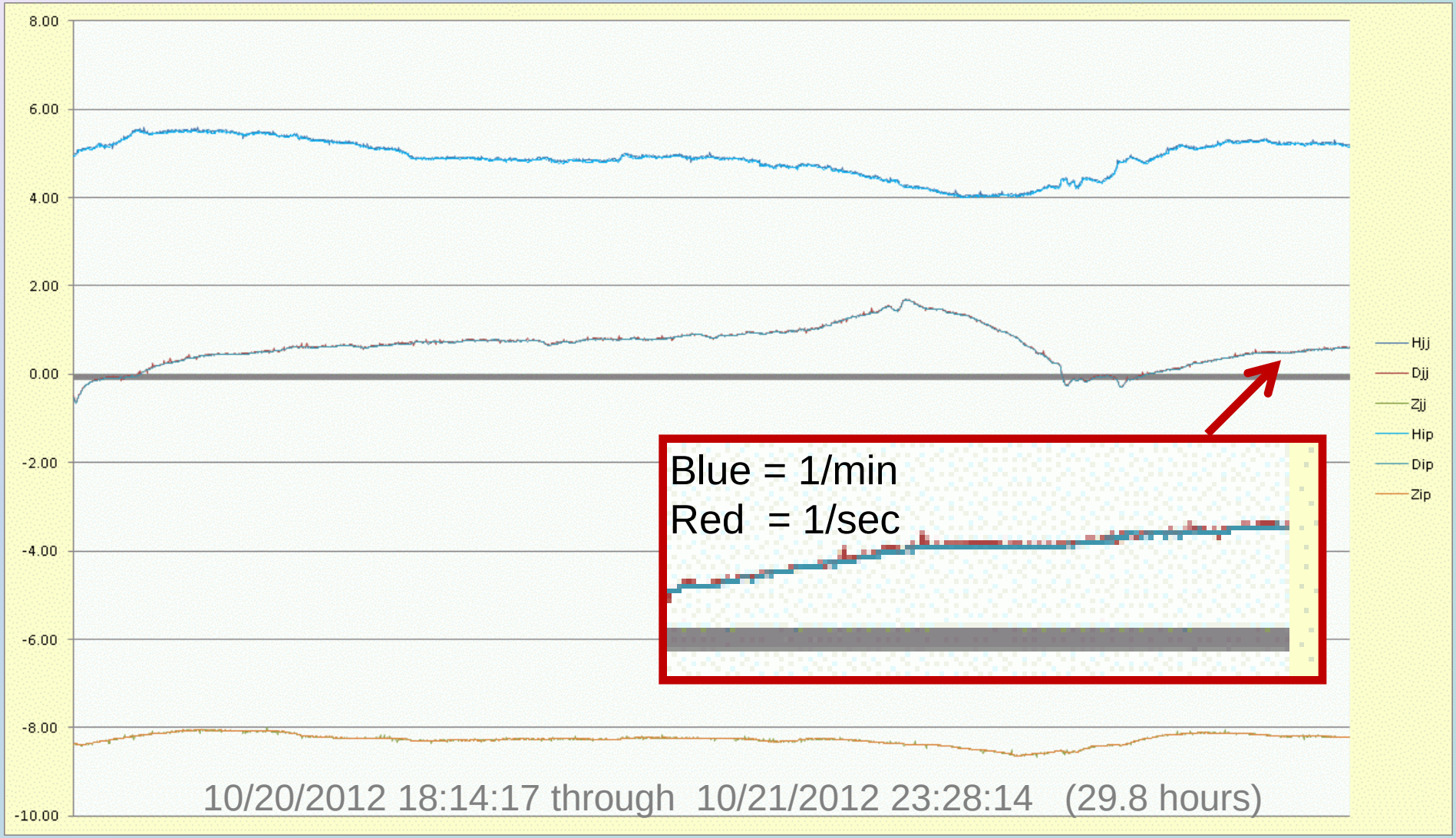
- Maximum 9602 Modem Originated (MO) message size is 340 bytes
- Messages are always delivered in order, can split long messages at the source and piece them together at the server end

Robust Reception

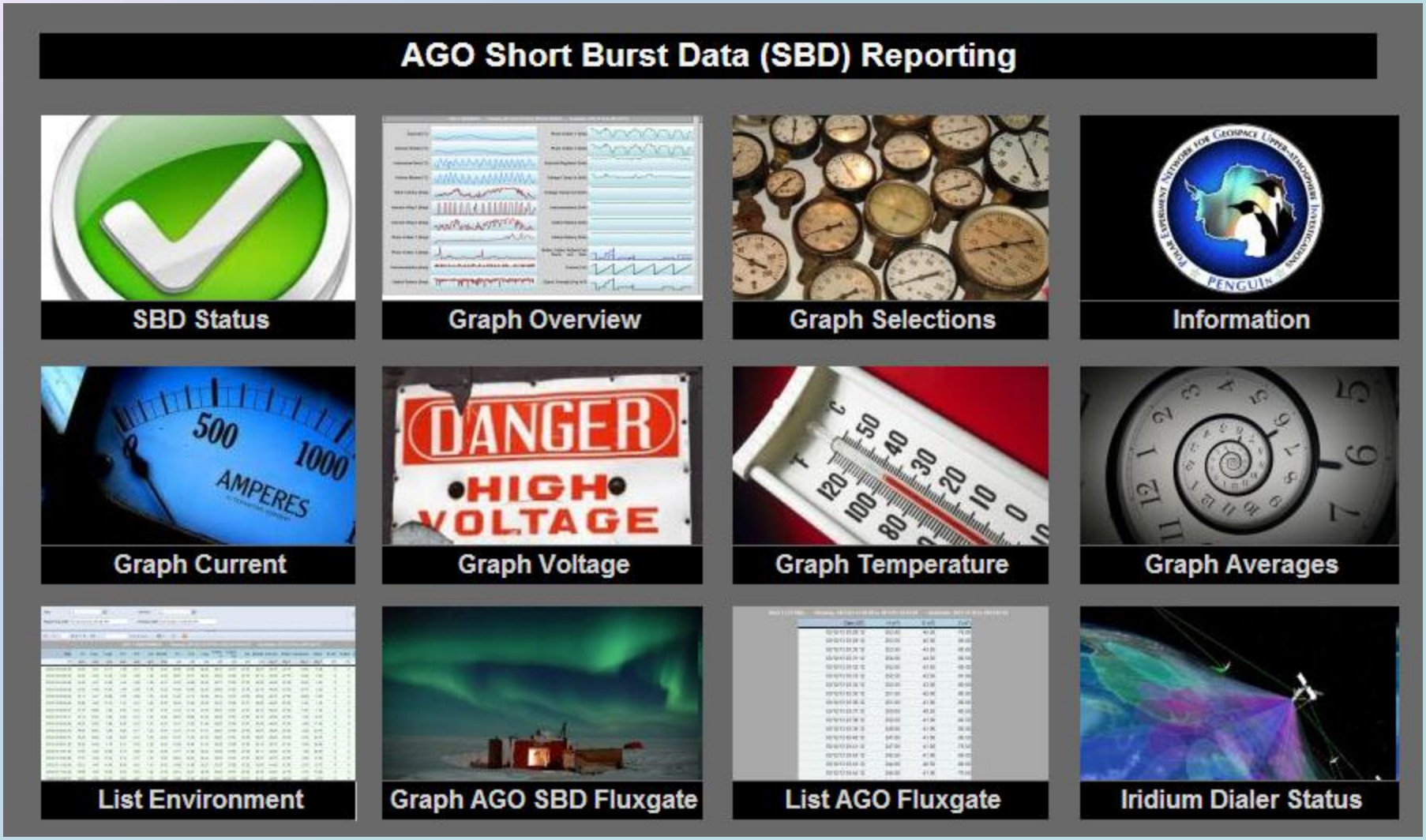
- Previously mentioned using multiple destinations for messages
- Transactional or snapshot replication implemented in SQL keeps multiple servers in sync automatically when failed server is restored

Sampled science data via SBD

A buffer full of 30 readings - sent every half-hour



Stateside reporting: Menu



Stateside reporting: Status

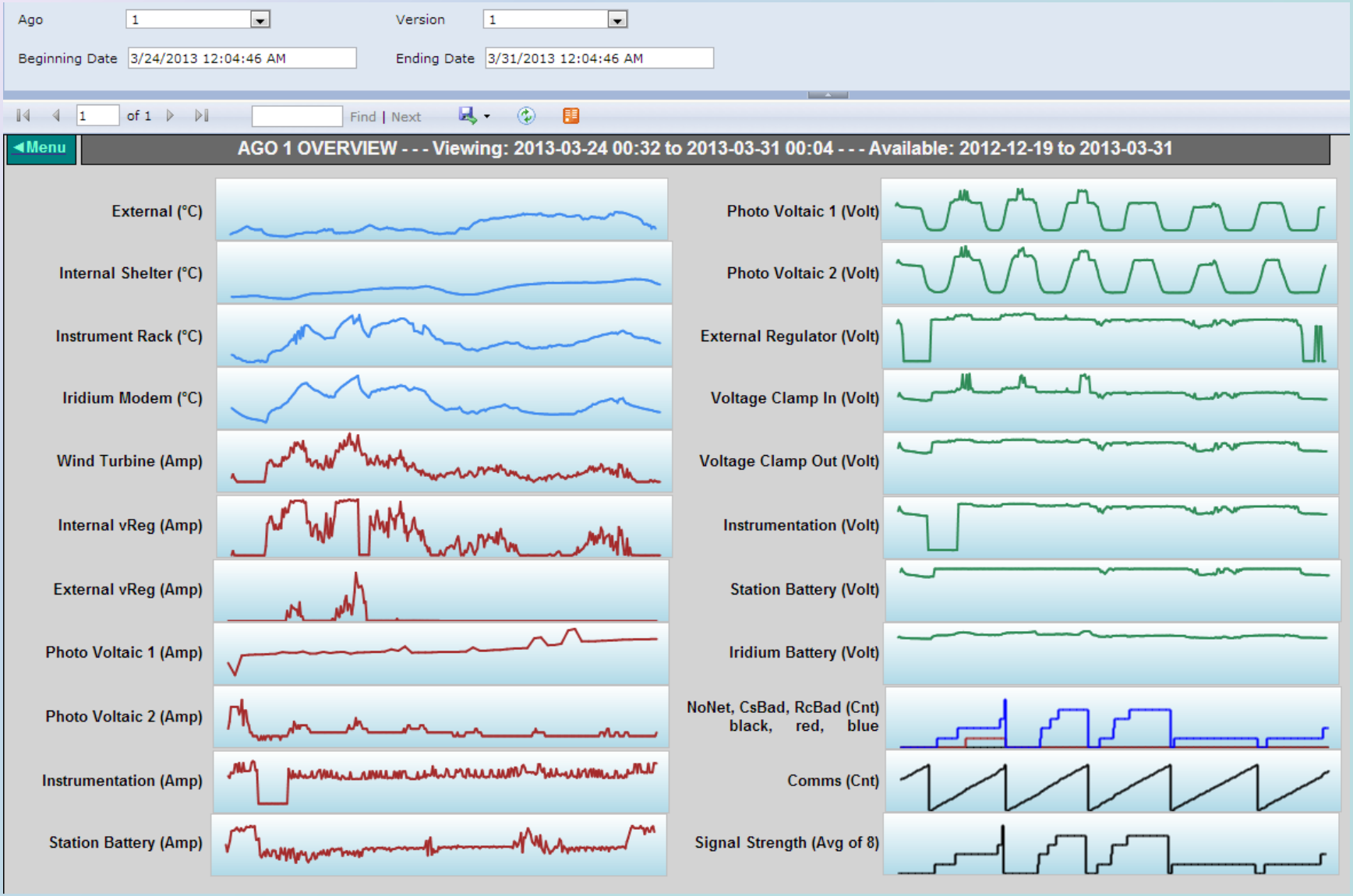
◄Menu

SBD Status as of 2013-03-31 00:18:45 (UT)

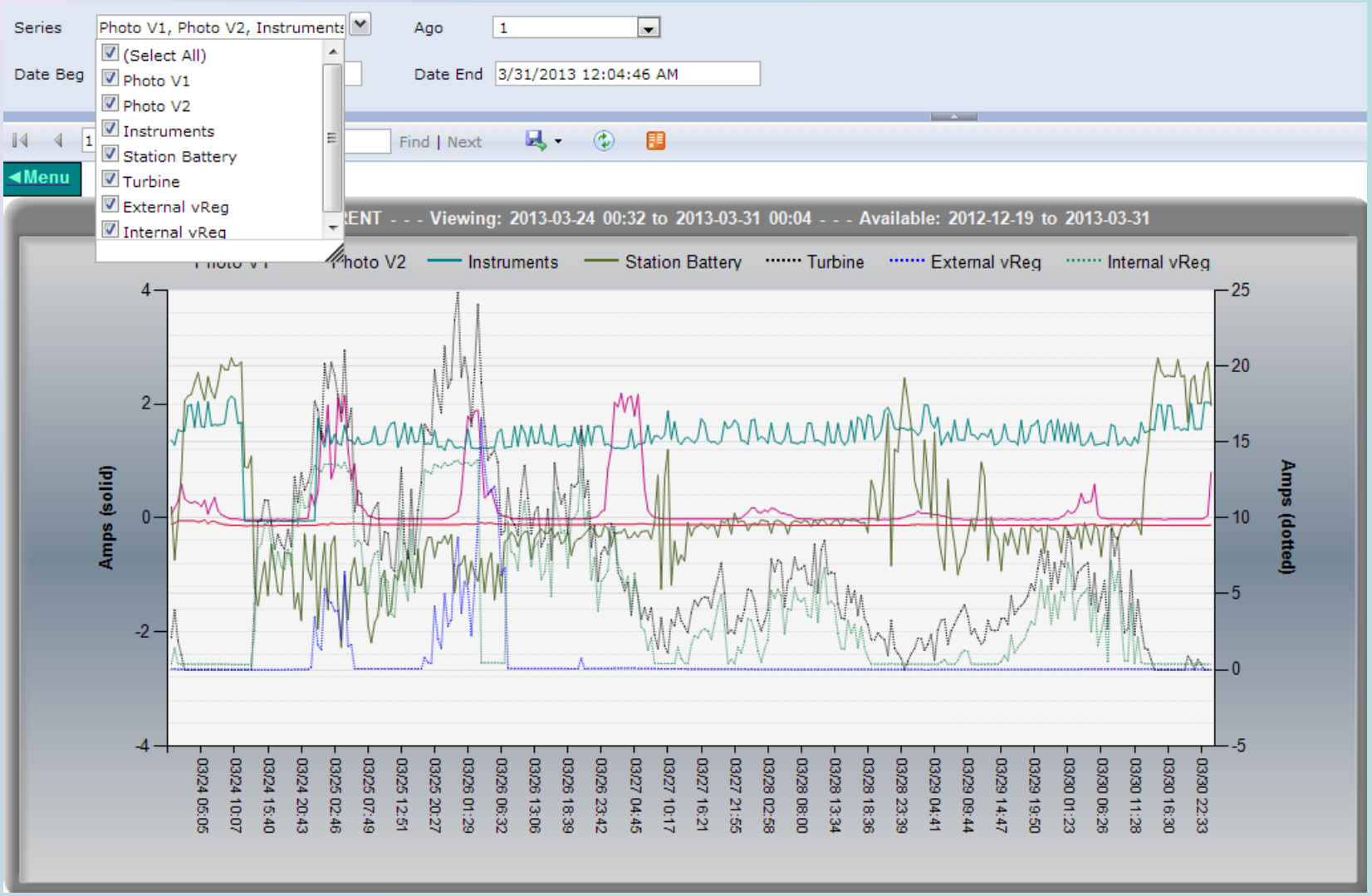
Status: 'On Time' (within 1% of scheduled), 'Delayed' (within 10%), 'Overdue' (within 400%), 'Off Line' (over 400%)

AGO	Modem	Last Received	Scheduled Each	Since Last Receive	Status
Station	IMEI	UT	Hours	Hours	Current
1	300234011873870	2013-03-31 (Sun) 00:04:46	0.5	0.23	On Time
2	300234011881310	2013-03-30 (Sat) 22:59:42	2.0	1.32	On Time
3	300234011585820	2013-03-07 (Thu) 17:10:03	2.0	> 2 wks	Off Line
4	300234010254620	2013-03-30 (Sat) 23:34:11	4.0	0.73	On Time

Stateside reporting: Overview



Stateside reporting: Current



Stateside reporting: Fluxgate

Version 1 Ago 1

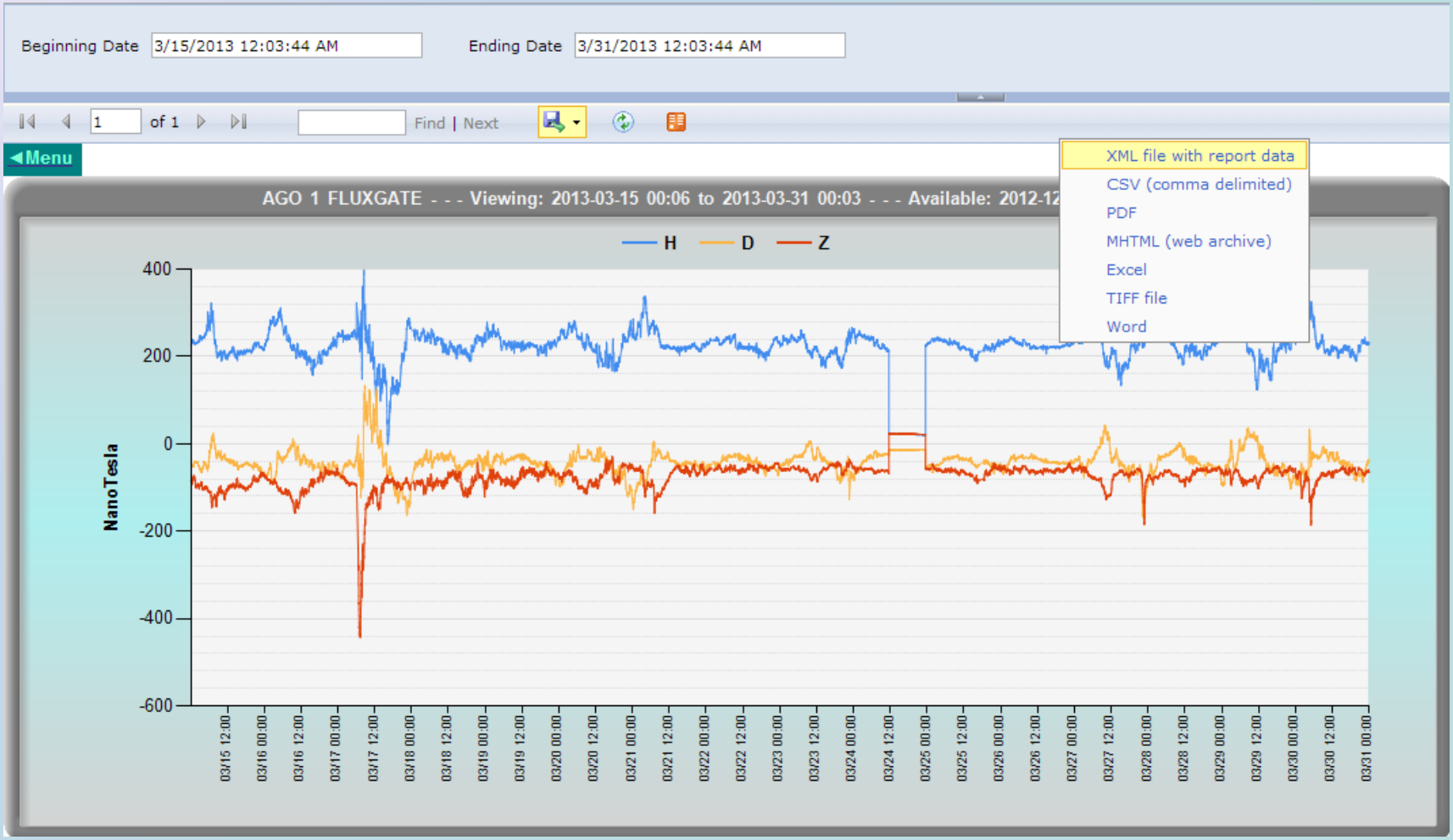
Beginning Date 3/27/2013 3:55:16 PM Ending Date 4/3/2013 3:55:16 PM

1 of 2 ? Find | Next

Menu **AGO 1 ENVIRONMENT - - - Viewing: 2013-03-27 16:21 to 2013-04-03 15:55 - - - Available: 2012-12-19 to 2013-04-03**

Date	WT	Vreg1	Vreg2	PV1	PV2	Inst	Sta Batt	PV1	PV2	Vreg	Vclamp In	Vclamp Out	Inst	Sta Batt	External	Shelter	Instruments	Iridium	No Net	Cs Bad	Rc Bad	Succs	Comms	Sig St
UT	amp	amp	amp	amp	amp	amp	amp	volt	volt	volt	volt	volt	volt	volt	deg C	deg C	deg C	deg C	cnt	cnt	cnt	cnt	cnt	8 sum
03/27/13 04:21:51	4.67	2.56	0.04	-0.02	-0.12	1.74	-0.09	-0.40	-0.51	27.95	26.07	26.29	25.81	26.95	-53.00	-41.50	-21.50	-13.25	0	0	3	22	25	38
03/27/13 04:52:05	4.79	2.69	0.05	-0.02	-0.12	1.66	-0.14	-0.40	-0.51	27.93	26.16	26.30	25.85	26.89	-53.50	-41.75	-21.50	-12.75	0	0	3	23	26	38
03/27/13 05:22:21	4.76	2.56	0.04	-0.02	-0.12	1.37	-0.19	-0.38	-0.48	28.05	26.12	26.27	25.91	26.97	-53.25	-42.00	-21.75	-13.00	0	0	3	24	27	39
03/27/13 05:52:44	4.08	2.02	0.04	-0.02	-0.12	1.33	-0.12	-0.36	-0.46	27.86	26.16	26.24	25.86	26.94	-53.75	-42.25	-21.75	-13.00	0	0	3	25	28	38
03/27/13 06:23:07	5.26	3.06	0.04	-0.02	-0.12	1.34	-0.15	-0.26	-0.41	28.08	26.19	26.35	25.97	26.95	-53.25	-42.50	-22.00	-12.75	0	0	3	26	29	38
03/27/13 06:53:28	6.07	4.20	0.04	-0.02	-0.13	1.29	-0.34	-0.05	-0.36	28.12	26.19	26.40	26.05	26.97	-53.75	-42.50	-22.25	-13.00	0	0	3	27	30	38
03/27/13 07:23:45	7.05	4.95	0.04	-0.02	-0.13	1.35	-0.05	0.40	-0.27	28.08	26.37	26.56	26.13	26.92	-53.50	-42.75	-22.25	-12.25	0	0	3	28	31	38
03/27/13 07:54:09	5.04	2.96	0.05	-0.02	-0.13	1.69	-0.09	1.57	-0.05	27.98	26.26	26.47	25.90	26.90	-52.00	-43.00	-22.00	-10.75	0	0	3	29	32	39
03/27/13 08:54:54	2.40	0.39	0.04	-0.02	-0.12	1.57	-0.02	10.70	2.76	27.04	25.11	25.24	24.56	26.64	-50.50	-43.00	-23.00	-13.00	0	0	4	30	34	36
03/27/13 09:25:08	2.64	0.70	0.04	-0.02	-0.13	1.61	-0.28	17.80	6.65	27.67	25.88	26.03	25.57	26.92	-49.00	-43.25	-23.75	-16.00	0	0	4	31	35	36
03/27/13 09:55:23	2.38	0.39	0.04	-0.02	-0.13	1.72	0.08	23.87	10.89	26.99	25.28	25.58	24.83	26.78	-48.00	-43.25	-24.50	-17.25	0	0	4	32	36	36
03/27/13 10:25:51	3.58	1.50	0.04	-0.02	-0.13	1.65	-0.08	27.38	15.80	27.81	26.07	26.26	25.69	26.95	-48.75	-43.00	-25.00	-18.00	0	0	4	33	37	35
03/27/13 10:56:09	3.20	1.11	0.04	0.00	-0.13	1.36	-0.05	27.31	19.69	27.76	25.95	26.09	25.74	26.94	-48.50	-43.00	-25.25	-18.50	0	0	4	34	38	32
03/27/13 11:26:31	3.99	1.92	0.04	0.05	-0.13	1.35	-0.07	27.57	25.62	27.88	26.12	26.30	25.85	26.92	-48.75	-43.00	-25.50	-19.00	0	0	4	35	39	32
03/27/13 11:56:47	5.34	3.37	0.03	0.10	-0.12	1.29	-0.22	27.64	27.34	27.98	26.12	26.34	25.89	26.91	-49.50	-43.00	-25.50	-18.50	0	0	4	36	40	32
03/28/13 12:27:06	5.22	3.27	0.04	0.17	-0.12	1.71	-0.12	27.60	27.48	27.98	26.14	26.34	25.80	26.96	-48.75	-43.00	-25.50	-17.25	0	0	4	37	41	33
03/28/13 12:57:34	4.56	2.55	0.03	0.18	-0.12	1.73	-0.09	27.64	27.51	27.95	26.12	26.29	25.95	26.95	-49.00	-43.00	-25.00	-16.75	0	0	4	38	42	33
03/28/13 01:27:49	3.25	1.24	0.03	0.10	-0.12	1.37	-0.12	27.57	27.24	27.79	25.95	26.14	25.78	26.89	-47.00	-43.00	-25.25	-16.50	0	0	4	39	43	33
03/28/13 01:58:01	2.57	0.53	0.03	0.09	-0.12	1.43	-0.03	27.26	27.20	27.43	25.81	26.08	25.62	26.87	-45.75	-43.00	-25.50	-18.00	0	0	4	40	44	34
03/28/13 02:28:14	3.20	1.37	0.03	0.14	-0.12	1.39	-0.05	27.48	27.34	27.74	25.93	26.16	25.71	26.90	-44.25	-42.75	-25.75	-19.00	0	0	4	41	45	35
03/28/13 02:58:28	3.92	1.96	0.03	0.11	-0.12	1.31	-0.06	27.55	27.34	27.84	25.98	26.22	25.86	26.90	-43.00	-42.75	-26.25	-19.00	0	0	4	42	46	38
03/28/13 03:28:42	7.30	5.26	0.03	0.17	-0.11	1.67	-0.27	27.79	27.63	28.10	26.23	26.49	25.98	26.88	-42.75	-42.50	-25.75	-17.50	0	0	4	43	47	38
03/28/13 03:58:56	6.45	4.72	0.03	0.16	-0.11	1.36	-0.06	27.69	27.51	28.03	26.23	26.43	25.97	26.90	-42.00	-42.25	-25.25	-15.75	0	0	4	44	48	38
03/28/13 04:29:09	7.26	5.31	0.03	0.12	-0.12	1.32	-0.04	27.74	27.67	28.10	26.23	26.51	26.06	26.91	-41.00	-42.00	-25.00	-15.25	0	0	4	45	49	40
03/28/13 04:59:27	7.04	4.88	0.03	0.08	-0.12	1.30	-0.07	27.72	27.58	28.00	26.23	26.40	26.05	26.93	-40.25	-41.75	-24.75	-14.50	0	0	4	46	50	39
03/28/13 05:29:39	4.14	2.37	0.03	0.08	-0.12	1.39	-0.11	27.53	27.34	27.74	26.00	26.30	25.88	26.92	-40.00	-41.50	-24.50	-14.00	0	0	4	47	51	39

Stateside reporting: Fluxgate



Acknowledgements

- Dan Wagster, of ASC, was very helpful with both technical and management issues for the 9602a modules.
- Tom Banwell, of Applied Communication Sciences, provided extensive guidance on the design of the analog circuitry.

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Rothera
AGO 3
EAST
AGO 2
Thomas Hills
Union Glacier
Amundsen-Scott South Pole Station
AGO 4
Pine Island Glacier
WEST
ANTARCTICA
Transantarctic
WAIS Divide
AGO 1
WISSARD SLW
LISSARD
Wannamaker Plateau
Byrd Surface Camp
WISSARD
G-line
CTAM Camp
AGO 5
Siple Dome
ANTARCTICA
Wannamaker
Ross Ice Shelf
Mountains
Casey Station
Roosevelt Island
Fosdick Mountains
McMurdo
Station
0
125
250
500
750
1,000
Nautical Miles

Questions?