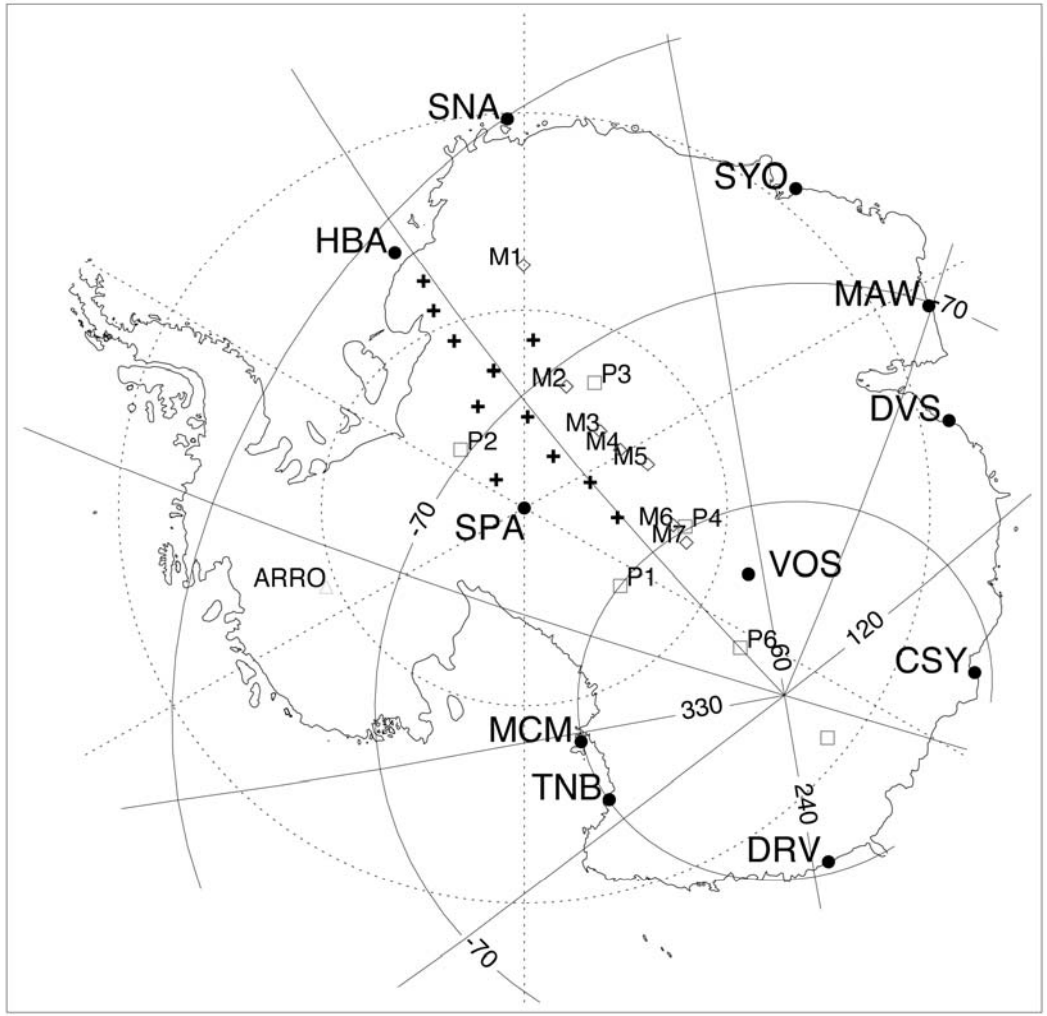
Adaptive Autonomous Low-Power Instrument Platform (AAL-PIP)

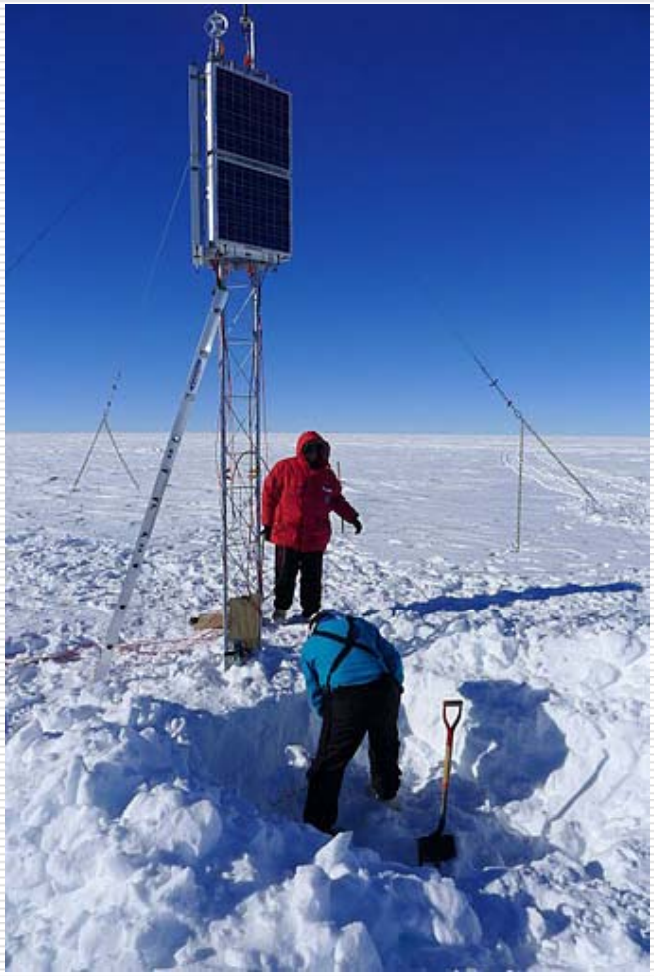
Stephen Musko
University of Michigan
Space Physics Research Laboratory
musko@umich.edu

AAL-PIP Overview

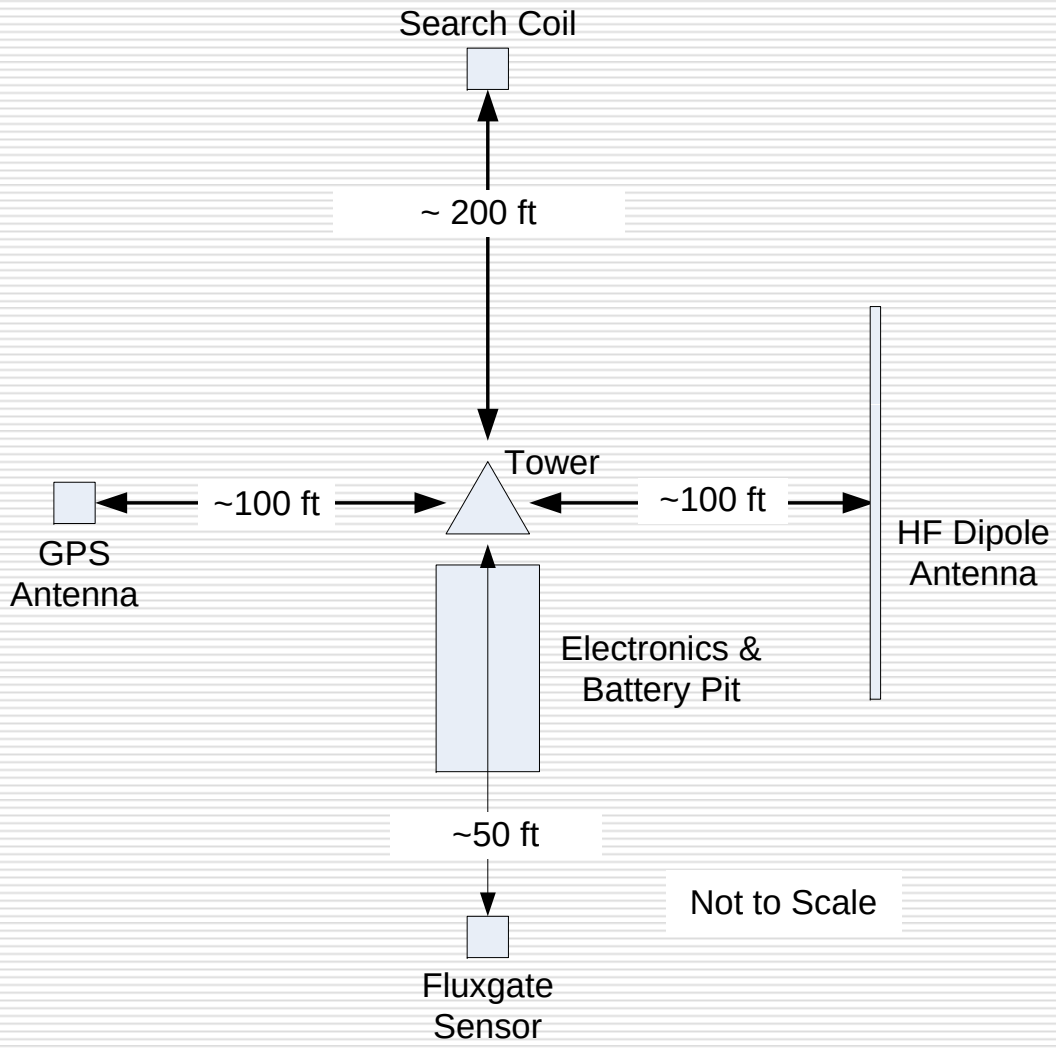
- Objective: Develop and deploy a chain of autonomous adaptive low-power instrument platforms in the Antarctic along the 40° magnetic meridian to study upper atmospheric current systems.
- Funded by a MRI grant from NSF
  - PI is Robert Clauer, Virginia Tech
- System was designed and built by the University of Michigan Space Physics Research Laboratory. Deployed by VT.
- Instruments
  - Fluxgate magnetometer
  - Search coil magnetometer (U of New Hampshire)
  - CASES GPS receiver for Total Electron Content measurement (ASTRA)
- Communications
  - Iridium
  - System to system HF modem
- 5+ year maintenance-free lifetime

AAL-PIP Locations (M1 through M7)





AAL-PIP Site Plan



System Partitioning

- Tower Assembly
- Electronics Box
- Battery Box

Tower Assembly

- 3 x 3 ft plywood base
- Rohn antenna tower
- PV panel winch
- Three guy wire assemblies
- NEMA power control box
- Six 40 W BP PV panels
- Iridium antenna

Mechanical Features

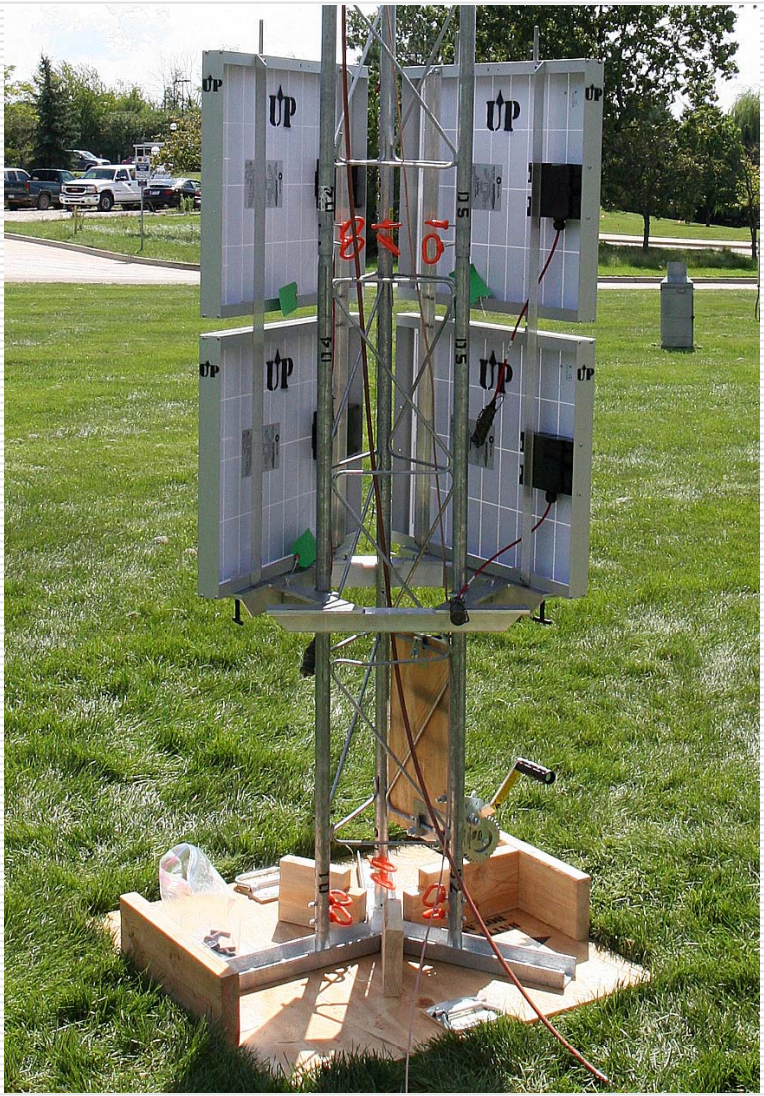
- Tower designed for assembly in extreme cold
- Minimize use of hand tools
- Eliminated most small fasteners. Still have crate and cover screws.
- Almost all assembly is done with gloves on
- Quick release pins instead of nuts and bolts
- T-bolts and captured fasteners instead of nuts and bolts

Mechanical Features - 2

- Big, sturdy connectors with caps
- Large wing nuts instead of hex nuts

Mechanical Features - 3

- PV panels assembled at ground level and then winched to top of tower



Battery Box at South Pole

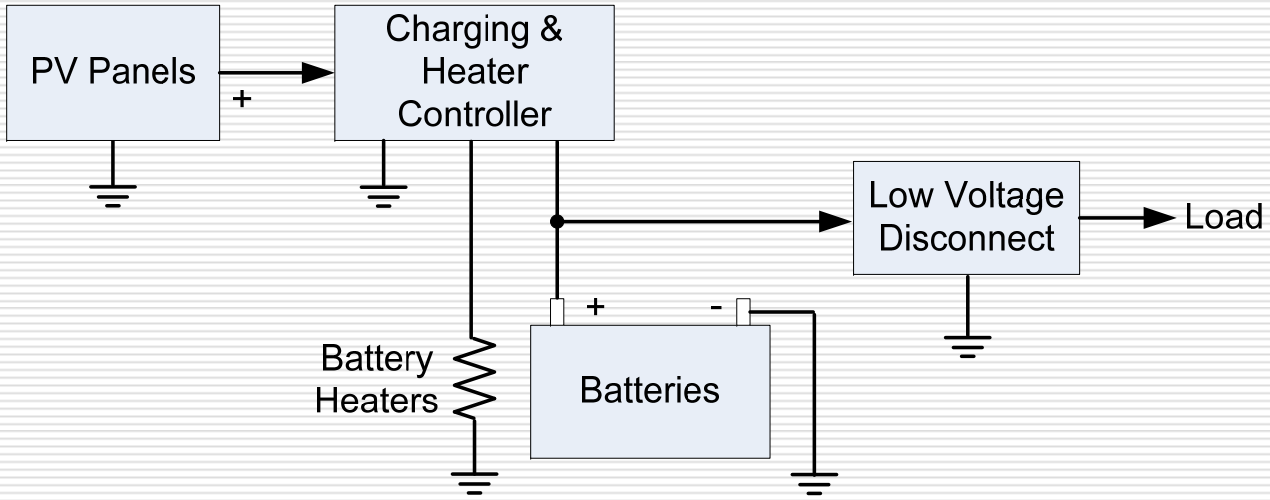
Power System

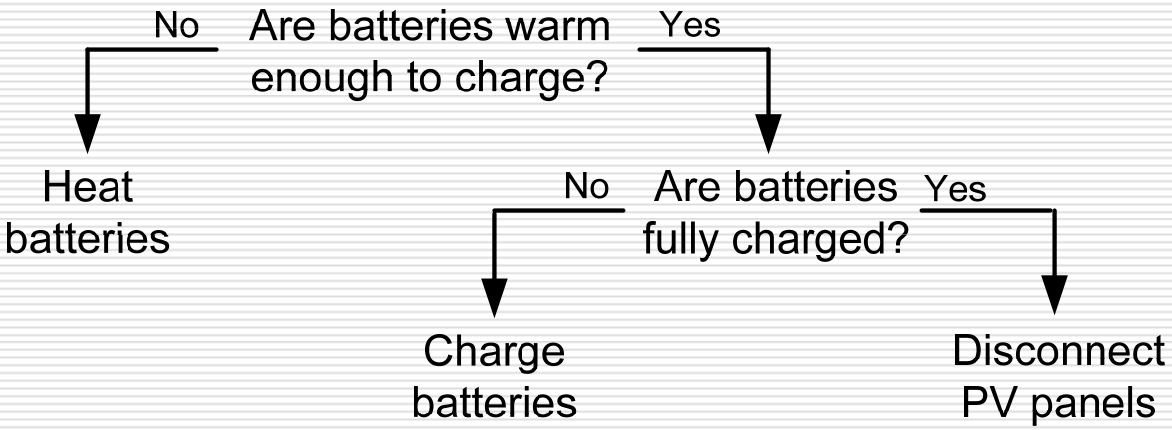
- 12 VDC system
- Power output
  - Summer 20 W continuous
  - Winter 3 W continuous
    - Can be tripled by adding batteries
- Six 40 W BP PV panels
- Sixteen 100 Ah Powersonic AGM batteries. Can be increased to 48 batteries.
- Battery box is lined with 4” of Styrofoam insulation
- Batteries are crated and shipped in pairs. They are installed in the battery box at the field site.

Power System - 2

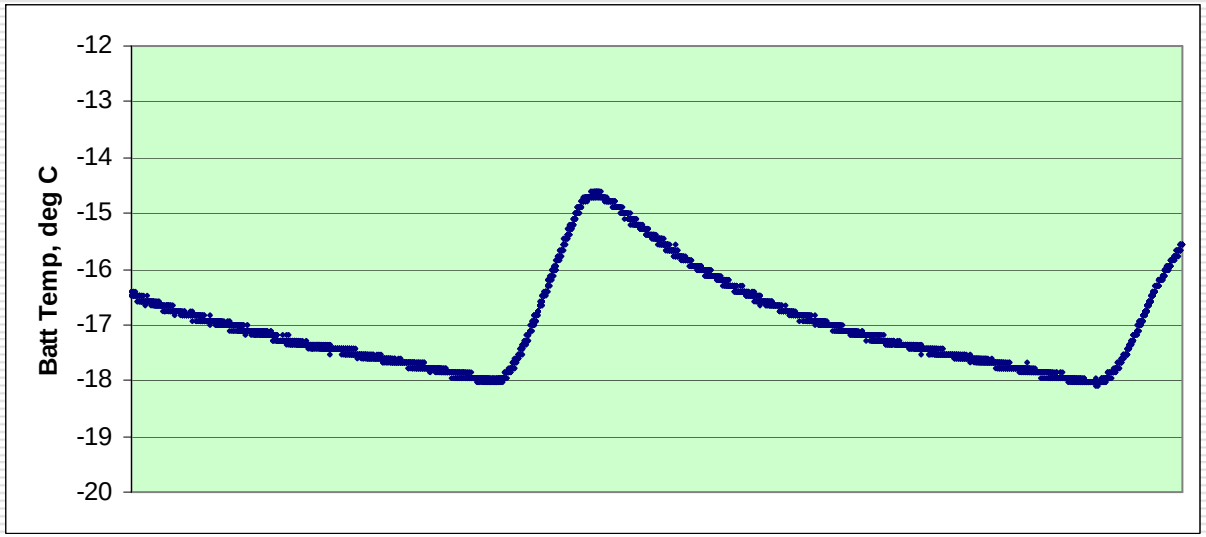
- Custom power control board
  - Battery charge controller
    - Switching controller
    - 13.5 to 14.2 V charging voltage w/hysteresis
  - Battery temp controller
  - Low Voltage Disconnect (LVD). Off at 11.2 V. On at 11.8 V.
  - Very low parasitic power
  - Remains powered up in the winter
  - No relays
- Batteries are heated to -15° to -20° C in the summer for charging
- Batteries are discharged unheated in the winter. At a low discharge rates they retain 40% of their capacity at -60° C.

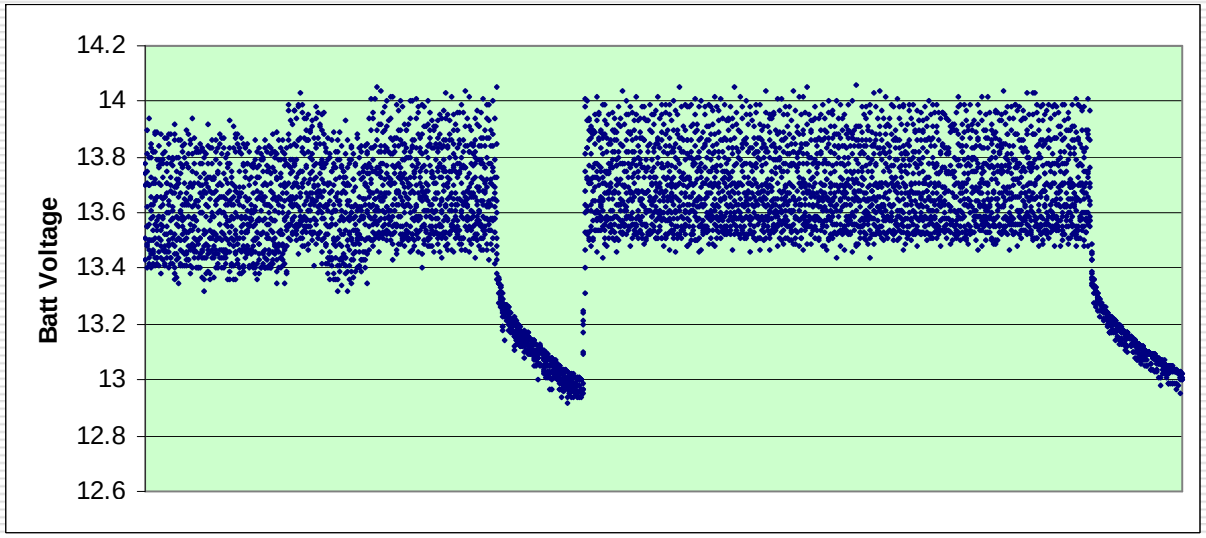
Power Control Block Diagram and Logic





AAL-PIP South Pole 2011-02-15 Battery Temp and Voltage

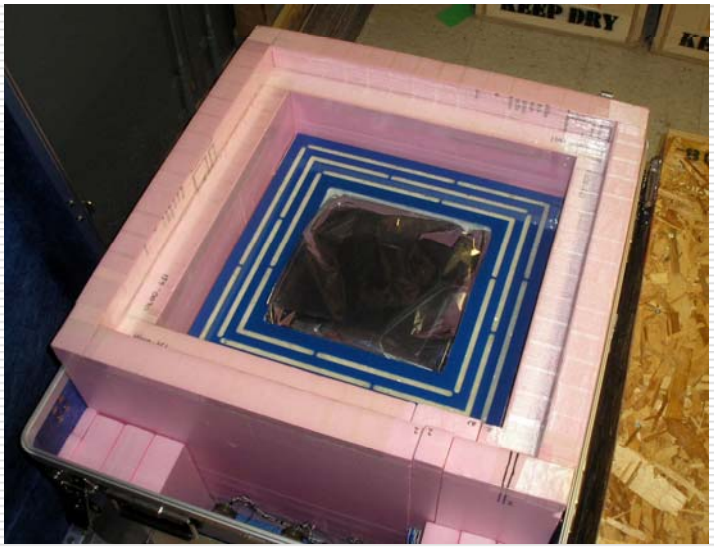


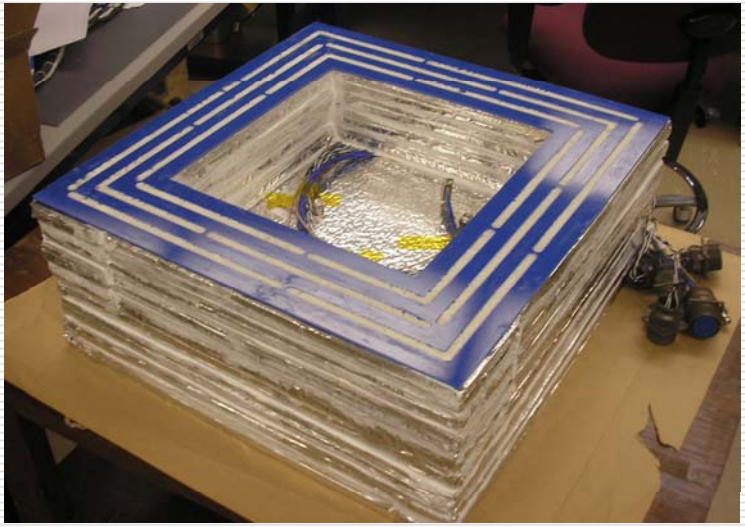


Data Electronics

- Housed in 12” x 12” x 4” superinsulated cavity
  - 4” of vacuum panel, 4” of Styrofoam
  - Fiberglass case from ECS Case

Data Electronics - 2



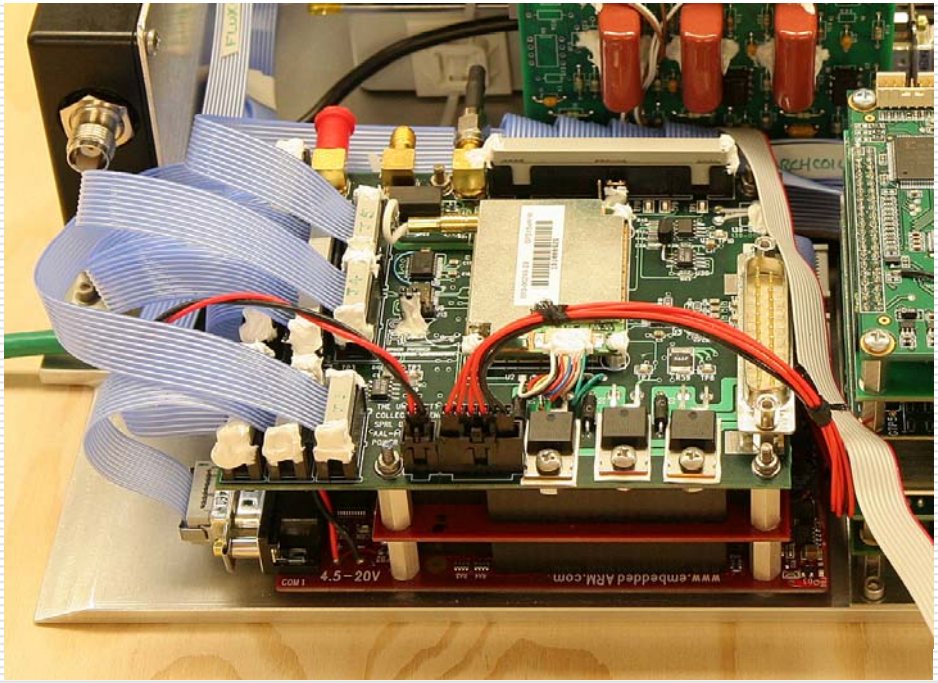


Data Electronics Subsystems

- PC-104 Controller Stack
- CASES GPS receiver
- Fluxgate magnetometer electronics
- Search coil electronics
- HF transceiver and modem
- Iridium modem, NAL A3LA-X

Controller Stack

- Technologics TS-7260 Single Board Computer
  - Cirrus 200Mhz ARM9 32-bit CPU
  - 64 MB RAM, 128 MB Flash
  - PC-104 bus, Ethernet, Two USB ports, 3 serial ports, 30 digital I/O pins, 12-bit A/D converter, Watchdog timer, Battery backed real time clock
  - 4.5 to 20 VDC switching power supply
  - Extended temp range -40 to +85 C
- Technologics TS-SER4 Quad Serial Board
- Custom PC-104 peripheral board
  - Garmin GPS receiver
  - Temp, I, V sensing
  - Warm up thermostat
  - GPS antenna power and signal splitting
  - Misc interconnections
- 4 GB USB flash drive



Software

- Linux 2.6.29 distribution from Todd Valentic, SRI International
- Custom application software written predominantly in Python.
  - A highly modified version of the Data Transport Network by Todd Valentic
  - Nine separate processes that communicate with each other using XMLRPC and TCP/IP sockets.
  - Each process executes in its own address space. This allows a process to crash without taking down the entire system.
    - For example: Iridium comm depends on two well-tested processes. If all the other processes crash, Iridium comm still works.
  - Python is faster than you might think. Handles 9 KB/s of CASES serial data. Required careful coding.

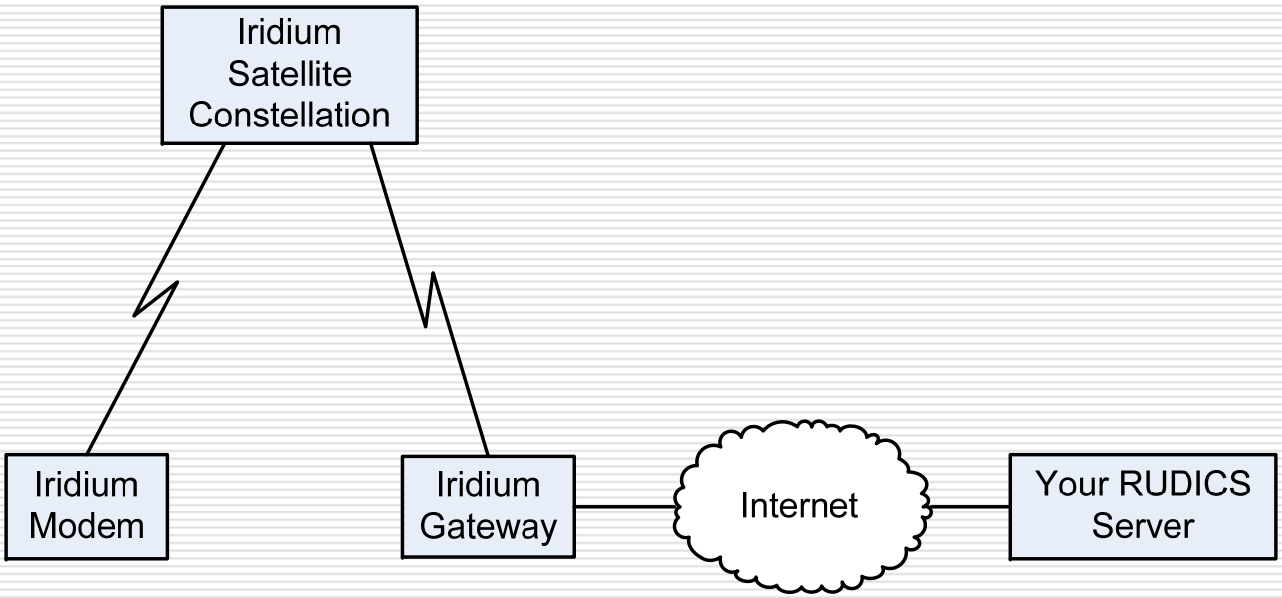
Software - 2

- Embedded Linux pros
  - You have a full operating system out of the box
    - Heavy duty file system
    - Internet protocols
    - A wealth of utilities and tools
  - It's open source. You are not dependent on a single vendor.
  - A wide variety of software development tools
  - Lots of good reference material (sometimes too much)
  - You can get near real-time performance with the 2.6 kernel if you can write a driver
    - For example: The Linux system clock is synchronized with UTC using the Garmin GPS receiver. Required writing a driver, but maintains ±5 millisecond accuracy.

Software - 3

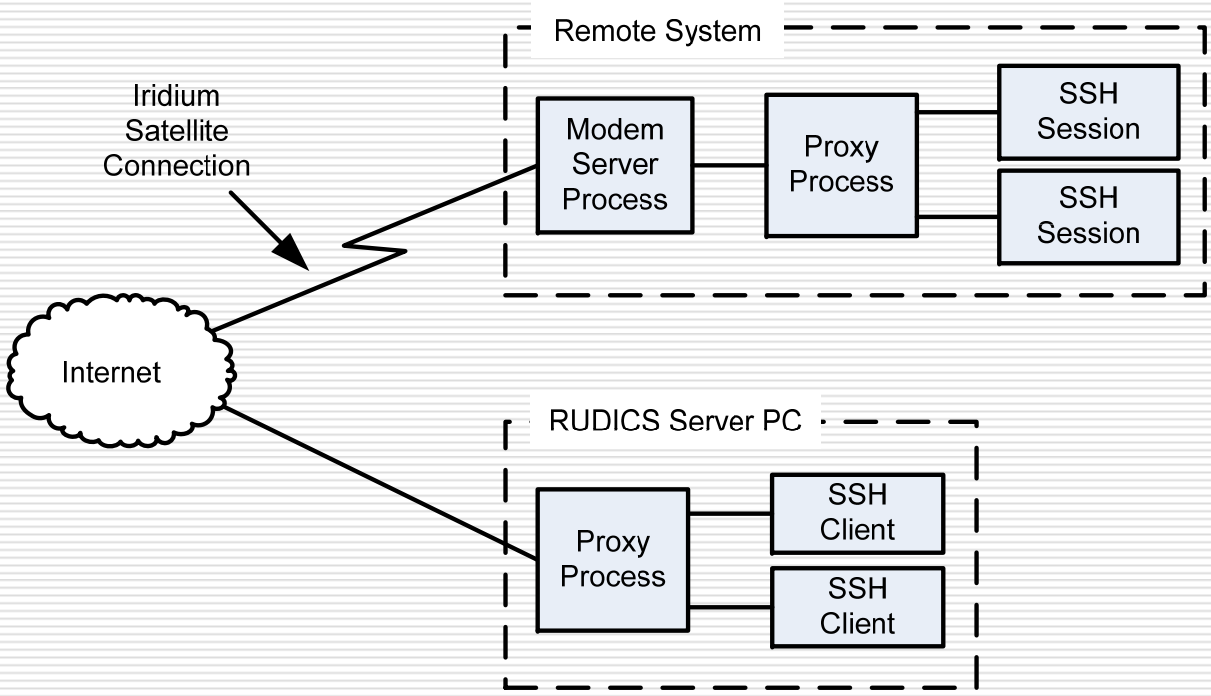
- Linux Cons
  - If you are new to Linux, it's a lot to learn
  - If you need high performance, you need to write a driver
  - In many ways, you are on your own. There's no help desk.

RUDICS



- Advantages
  - Lets you handle many remote systems with a single server
  - Reduces the number of dropped calls by reducing the number of satellite hops
  - Your data center doesn't need any Iridium modems

Communications Software



- Secure Shell (SSH) is used to control remote systems
- Secure Copy (SCP) is used to transfer files
- Data downloads and other routine actions are accomplished by scripts running on the RUDICS server. The scripts use only SSH and SCP to control the remote system.

RUDICS Modem Tips

- Initialization commands
  - **AT&F0=0** **restore factory defaults**
  - **ATE0** **turn command echo off**
  - **AT+CBST=71,0,1** **NAL recommended setup cmd**
  - **AT&S0=1** **auto answer after one ring**
  - **AT&K3** **enable RTS, CTS**
  - **ATS12=150** **set the +++ guard time to 150 msec**
  - **AT&D2** **use DTR to enter command mode**
  - **AT+CSQ** **get the RF signal quality**
  - **AT+CICCID** **get the ICCID from the SIM**
- Use 2 stop bits for modem serial comm. Might just apply to Technologics TS-7260 serial ports.
- Power cycle the modem periodically. Once a day is enough.
- Initiate a call from the modem periodically. Once a day is enough.

Updating Remote System Software

- Any set of remote system files can be updated
- Update procedure
  - Using SCP, upload two files to the "/install“ flash directory on the remote system
    - Image file: a compressed file containing a script and a set of files
    - Checksum file: contains the MD5 checksum of the image file
  - Using SSH, reboot the remote system
  - During the boot process, if the /install directory contains a valid image and checksum files, the image file is decompressed and the shell script executed.

Watchdogs

- It is essential to maintain RUDICS communications
- Three separate watchdogs
  - Hardware watchdog protects against system lockups and kernel panics.
  - Watchdog process in the application software protects against bugs in the application software.
  - Comm watchdog daemon protects against bad software updates. Installs and boots a known good version of the software.

Results and Plans

Four systems have been built

- Two systems were installed at South Pole for testing Dec 2010
  - No major system problems
  - Will be relocated to deep field sites in Dec 2011
- Two more systems will be installed at South Pole in Dec 2011
  - Will be moved to deep field sites in Dec 2011

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