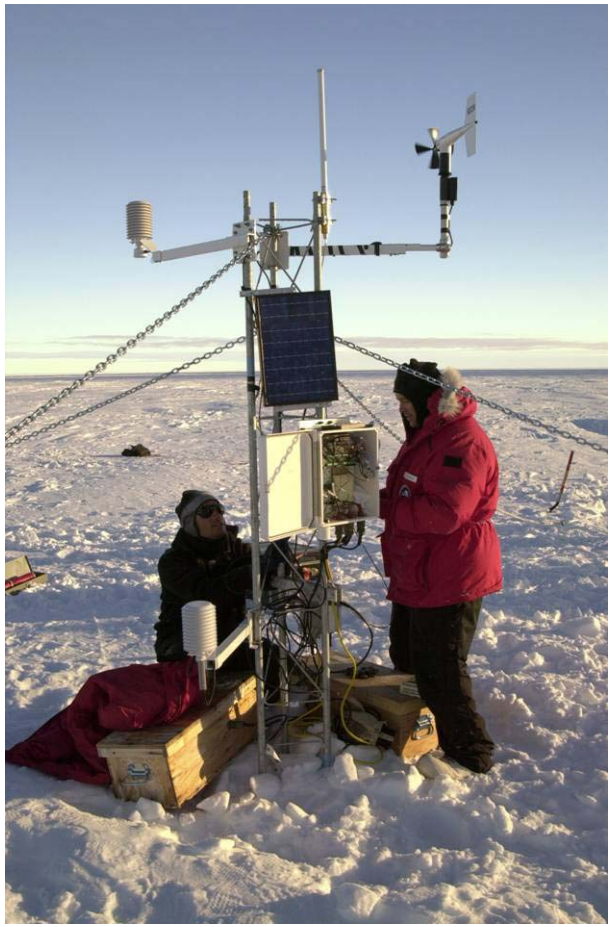
Polar Engineering –
Some Thoughts



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Antarctic Design Environment

- Temperature
  - Lowest Range: -89.4 °C to -13.6 °C at Vostok
  - Highest Range: -53 °C to +15 °C at Lake Vanda
  - Rounding and averaging gives an annual temperature swing of about 70 °C
- Wind
  - On the plateau, winds are usually light and steady at 4-6 m/sec (8-12 knots) but they can be 30 m/sec (60 knots)
  - Along the coast, winds vary from calm to sustained speeds of 30 m/sec
  - During winter, coastal storms can exceed 66 m/sec (130 knots)

Antarctic Design Environment, #2

- Pressure
  - Most of the plateau is 8,000 to 11,000 feet
  - Add 2,000 feet for “pressure altitude”
  - Combustion and wind dependent systems may have to be adjusted
- Static Discharge
  - Extremely low humidity and blowing snow precipitates a large static charge build-up
  - Grounding systems in snow is very hard
- Radiation
  - Intense ultraviolet radiation can accelerate the degradation of plastics
  - Cosmic rays can cause problems with magnetic storage media

Antarctic Design Environment, #3

- Logistics imposes constraints on design
  - Heavy equipment goes by ship a year in advance
  - Science gear goes by air
    - Should be at Port Hueneme by August
    - Pack your gear as if you are going straight to the field
  - Access to coastal areas and the dry valleys is by helicopter
    - Allowable cargo load is 2100 lbs without sling loading
    - 1950 lbs with a sling load
    - Passengers estimated at 250 lbs each
  - Access to the plateau is by Twin Otter
    - Allowable cargo load is 1500 lbs and varies with distance
    - Passengers estimated at 300 lbs each

5 Engineering Issues

- Power
- Thermal environment
- Data storage
- Communications
- Packaging

Logistics is the Reality Check

Power

- Watts = Pounds
  - Every pound counts
  - Keep loads low
- Fossil fuels
  - Reliable & easy to regulate
  - Engines & generators require greater maintenance to set up and keep running
  - Diesel & gasoline turn to gel at winter lows
  - Consider propane; must boil liquid to vapor at winter lows
  - Discharge of water vapor requires engineering design
- Solar panels
  - Excellent choice for daylight operation
  - Most efficient orientation is vertical facing North
  - Can be mounted facing down to catch reflection off the snow

Power, Continued

- Batteries
  - Good choice, but must be “de-rated” for cold operation
  - Consider Gel Cells or Absorbed Glass Mat batteries
  - NiMH batteries have high energy density but poor performance when cold. At -20 °C, they are about 20% efficient.
  - Acceptable rate of charge decreases as temperature decreases
    - Chargers are usually preset
    - Be careful not to overcharge!
  - Batteries are heavy
    - Look at logistics for both initial installation and seasonal replacements
    - If your experiment goes down, how many replacement batteries do you take?

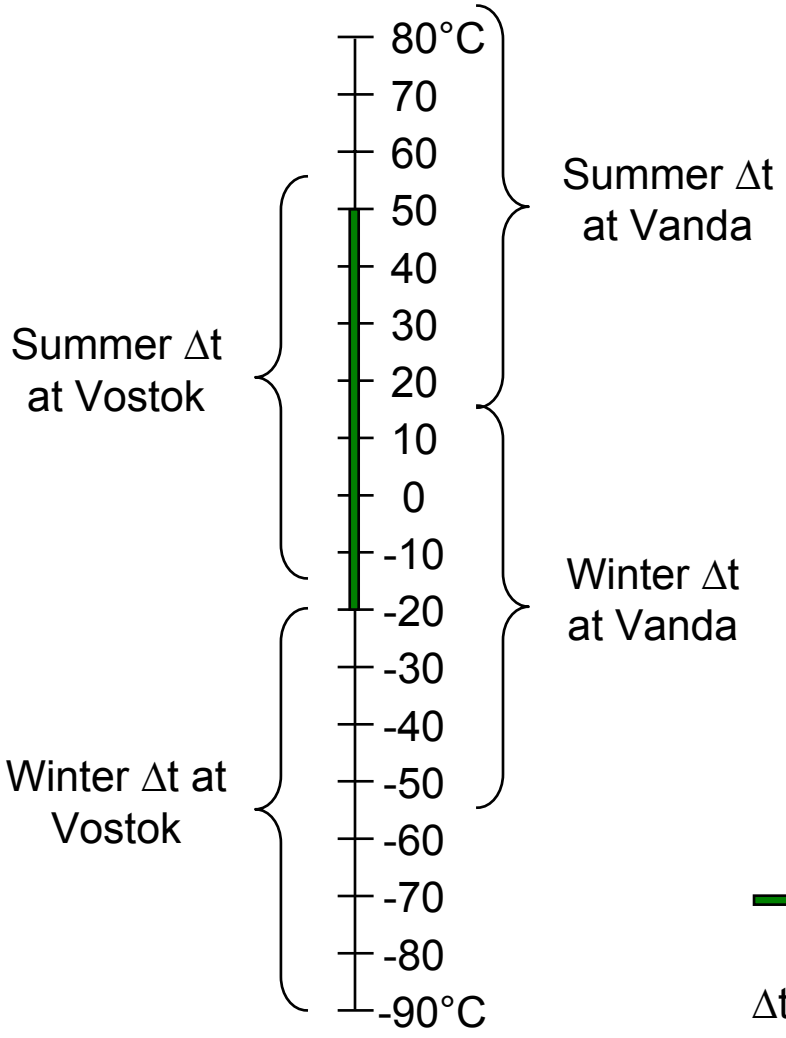
Power, Continued

- Fuel Cells
  - Fuel cells are receiving intense commercial attention from the automotive industry
  - Fuel cells have not demonstrated effective long-term unattended operation (mid-Feb to mid-Oct = 5800 hours)
  - At 32% efficiency, a 50 watt fuel cell operating 5800 hours consumes 71 kg propane and produces 32 gallons of water
  - Fuel cells pass the logistic test: fuel + cells are light enough to replace every year by Twin Otter
  - Hydrogen gas is a dangerous feed stock & hard to transport safely
  - Propane is a good source of hydrogen and we know how to transport it safely
  - Beware of fuels containing sulfur, which poisons catalysts

Thermal Environment

- Given: 70 °C annual temperature swing
- Industrial electronics have operating limits of -40 °C and +85 °C (For a cushion and safety, set limits of -20 °C and +50 °C)
- In winter, heating is required (Scavenge waste heat)
- In summer, cooling is required (Consider a heat pipe)
  - Heat pipes can be turned off 3 ways: choose a working fluid that (1) freezes, (2) undercharges when cold, or (3) forms a gas bubble at the cold end that stops the wicking
- Consider vacuum insulated panels at R-30 per inch (Styrofoam panels are R-5 per inch)
- Avoid thermal bridges at shelter corners and mounting points

Why Do We Need Cooling?



Data Storage

- Flash memory cards are an attractive choice
- Consider redundant storage
- With the USB 2.0 specification, powering the interface down between saves consumes more power than leaving it on
- Design your memory packaging based on how you plan to service your site
  - Will opening your shelter to get the data card let in wind-driven snow which could damage equipment?
  - Can you remove full cards and install new ones wearing gloves?
  - Can your equipment stand a cold soak while you work on it?

Communications

- GPS satellites are available for position and time
- Communications satellites:
  - Iridium – 2400 baud bi-directional
  - Service Argos – 400 baud one way currently, going up to 4800 baud bi-directional in 2006
- 3 data communications strategies
  - Send all the time
  - Store through the winter and forward in spring/summer
  - Combo: send some data, store all
- Consider wireless for data transfer, software upgrades, and changing system settings during service visits
- Housekeeping data:
  - System operating parameters
  - Weather – Use the standard format for weather data

Packaging

- Packaging has 3 main functions
  - To ensure the system survives the environment
  - To facilitate transporting and erecting the system
  - As the part of the system that provides the primary means of managing the internal temperature
- For the deep field, manpower alone is available for lifting and set-up. Plan on two workers, at most.
- “Handle with Care” means “Don’t drop it more than 4 feet”
- Design the package for maintenance while wearing gloves or mittens as you will be working in the wind
- If you don’t bury the shelter, you will have to raise it every 2-3 years

The key to long-term success

- Design a system that can be maintained with one put-in flight and one pull-out flight
- Several put-in flights are OK for installation
- Test and debug your system before you go to Antarctica
- Pack your equipment at home as if you were going straight to the field (Avoid repacking in McMurdo / SP / Palmer)
- Use board-level replacements as part of the maintenance concept (Avoid cuts and jumpers in the field)
- Try to achieve year-to-year continuity in your service team
- Get your SIPs in on time! Late comers face a struggle for support

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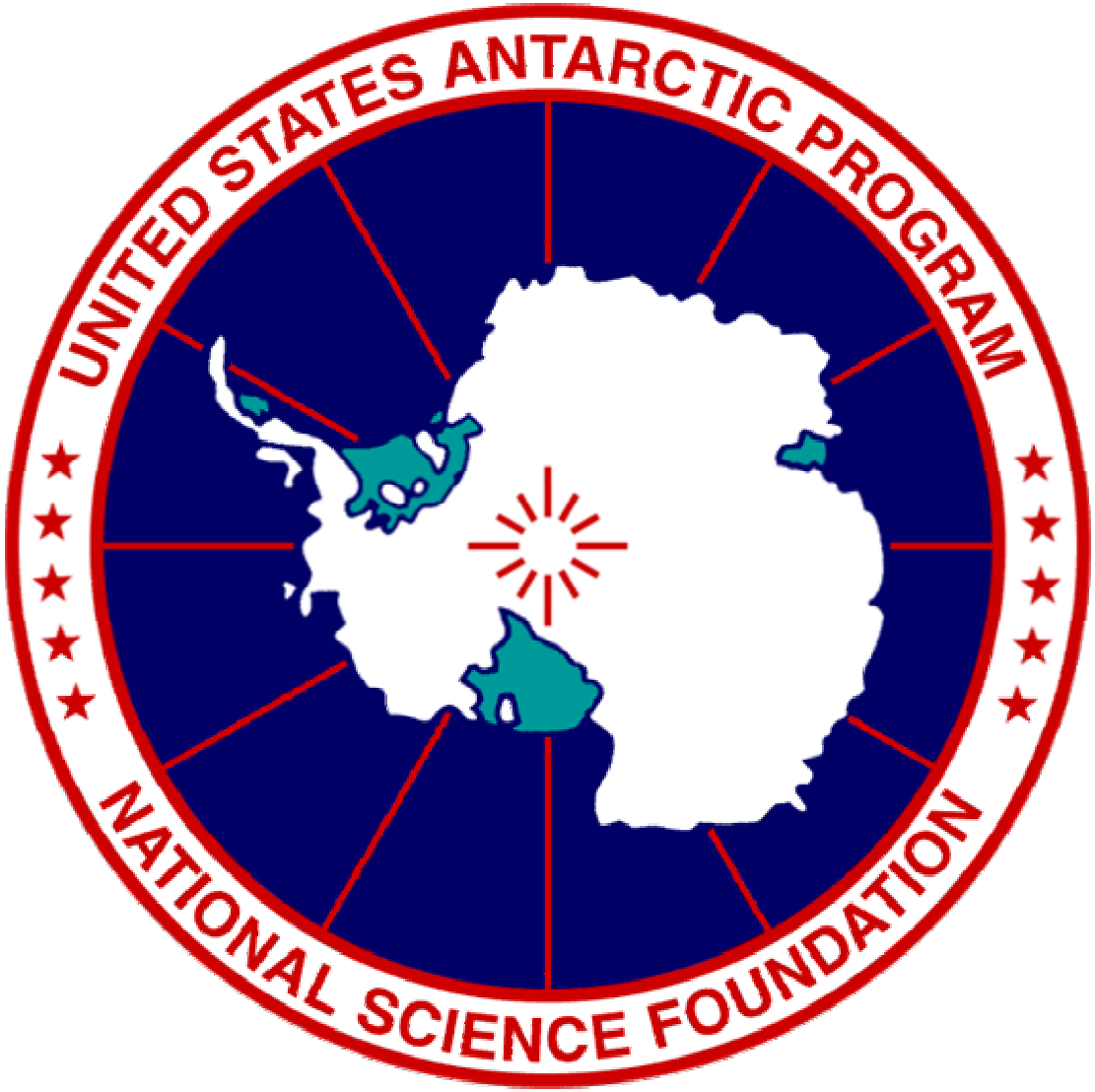
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