Winter Operation of a 65-Watt Methanol Fuel Cell at an Unattended Arctic Site

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Proof of Concept of DMFC

- **Clean power source for carbon flux research sites**
  - **Small amounts of Water and Carbon Dioxide are byproducts**
- **All-year operational potential**
- **Study thermal management, air exchange, and problems of water production in <0 °C environments**
- **Enhanced broadband communications network for Imnavait Creek research area to retrieve large research data files**

Anode: $CH_3OH + H_2O \rightarrow 6\ H^+ + 6\ e^- + CO_2$

Cathode: $3/2\ O_2 + 6\ H^+ + 6\ e^- \rightarrow 3\ H_2O$

Overall: $CH_3OH + 3/2\ O_2 \rightarrow 2\ H_2O + CO_2$

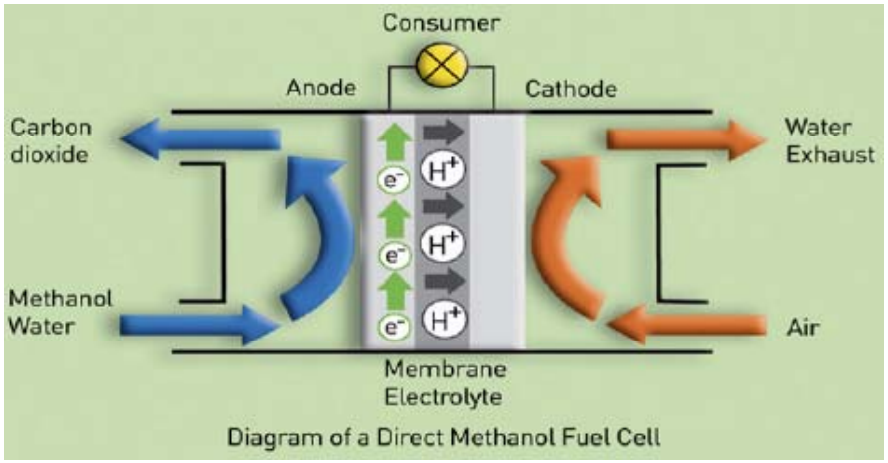
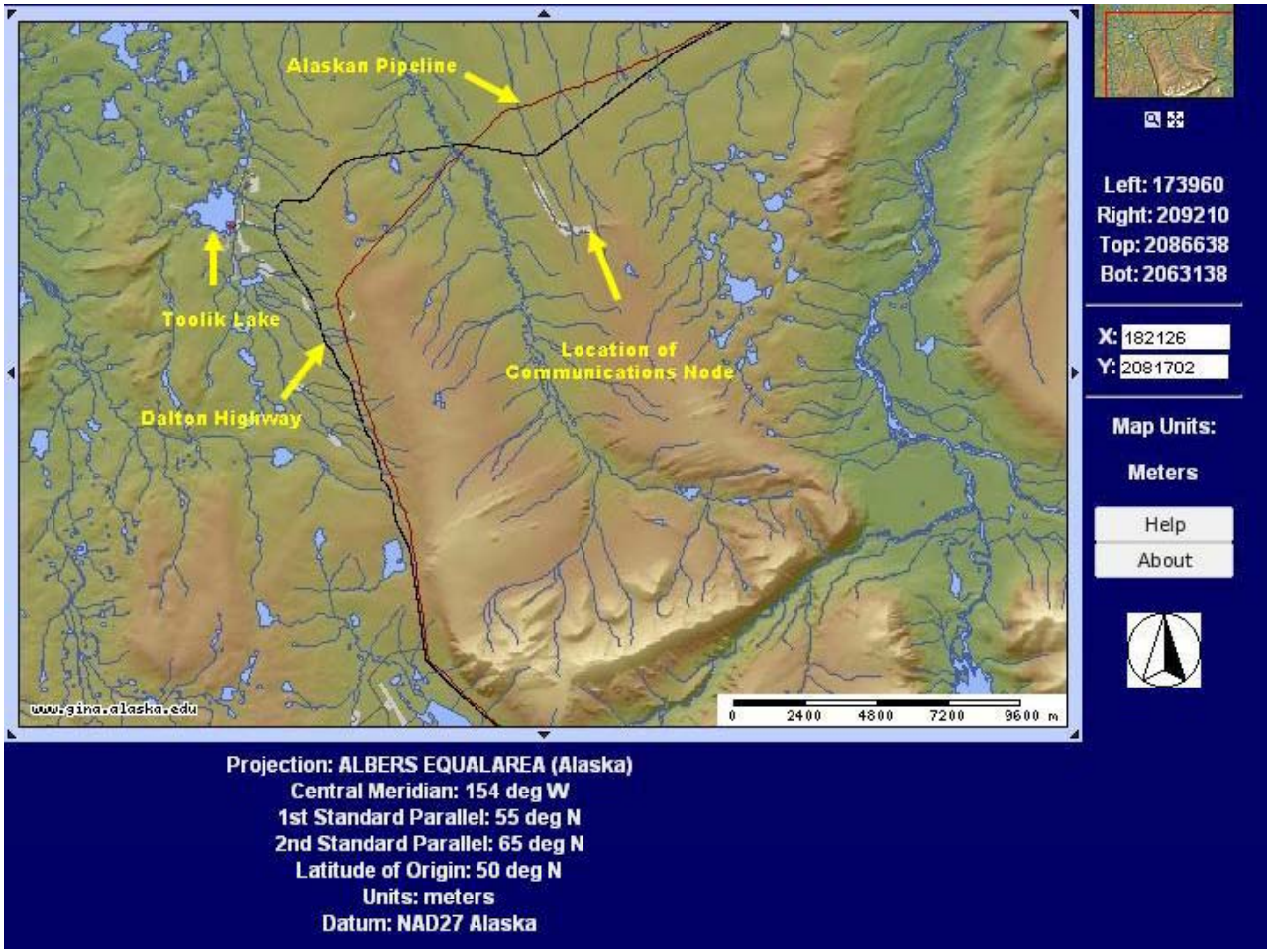


Diagram of a Direct Methanol Fuel Cell

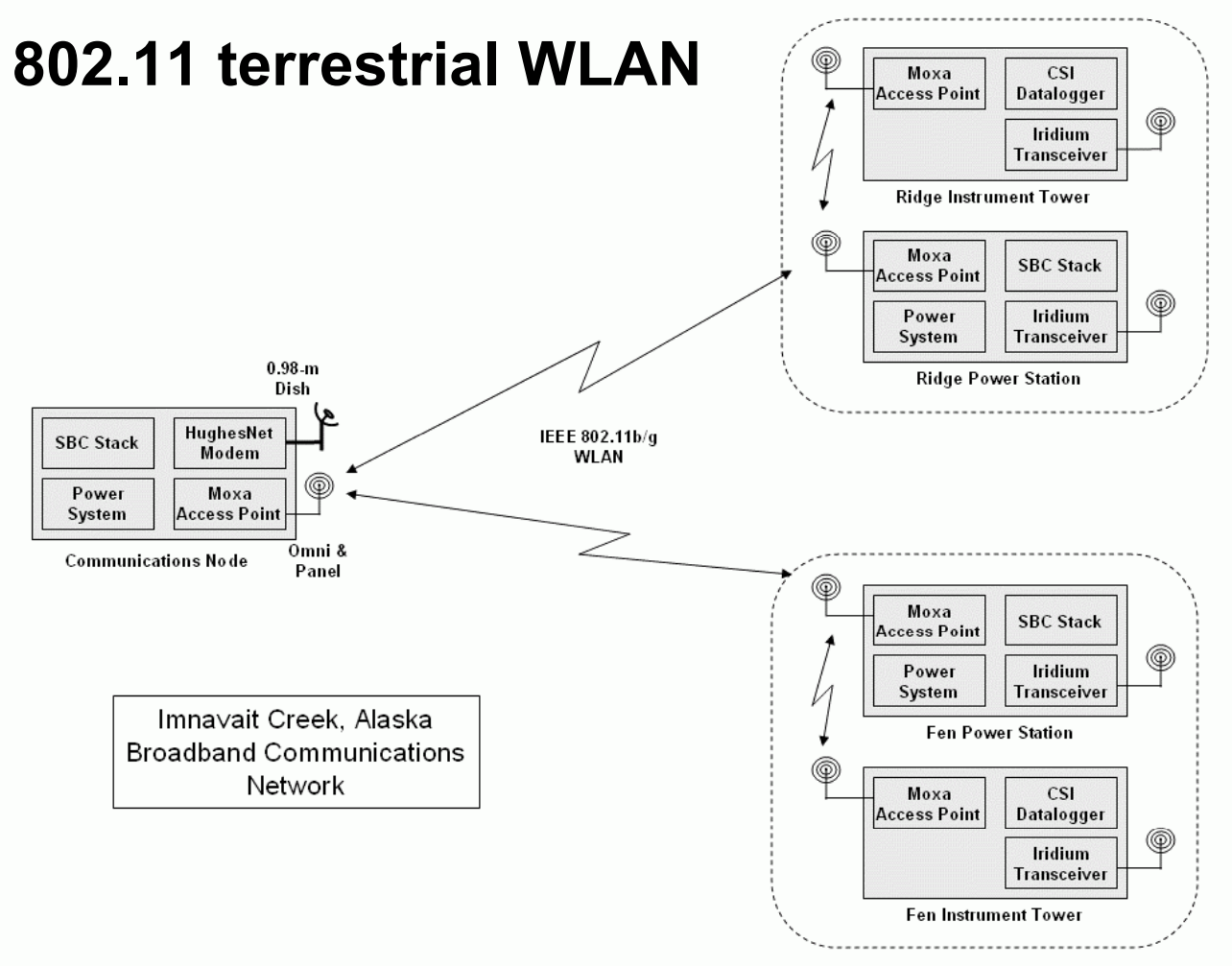
Imnavait Creek Communications Node

- **East of Toolik Field Station along Dalton Highway**



Broadband Internet Point of Presence

- HughesNet broadband geostationary satellite link
- IEEE 802.11 terrestrial WLAN

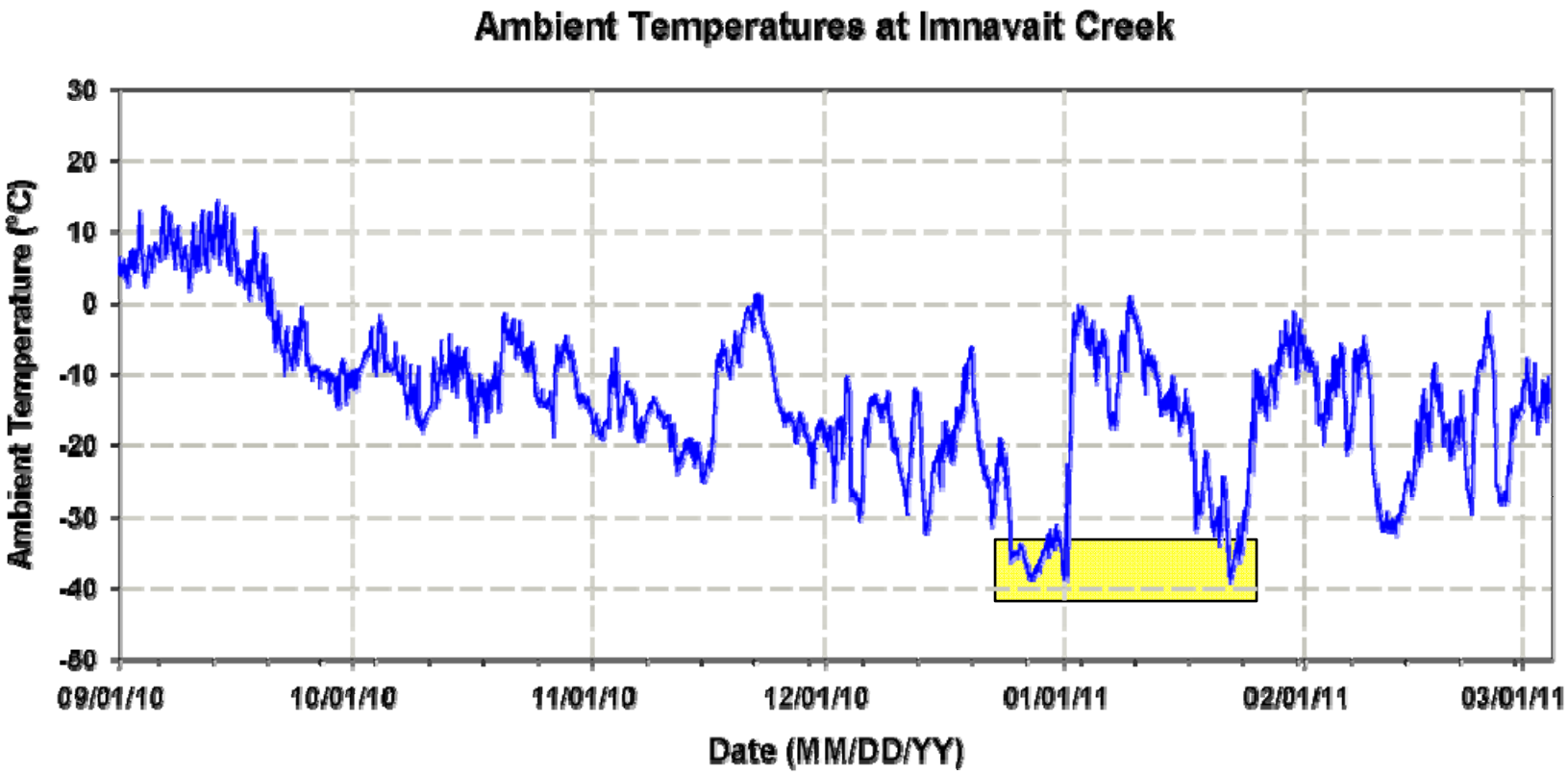


Imnavait Creek Communications Node

- **65-Watt EFOY Pro 1600 Fuel Cell for winter power**
  - **Wind power not reliable in Interior Alaska in winter**
  - **40-Watt PV panel for Spring – Fall primary power**

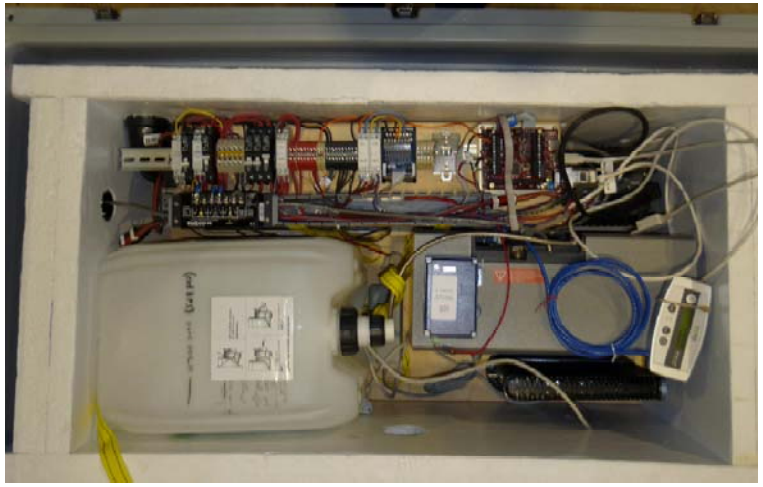
Ambient Temperatures at Ridge Site

- System running well at -39 °C
  - System ran well in California at ~ 20 °C

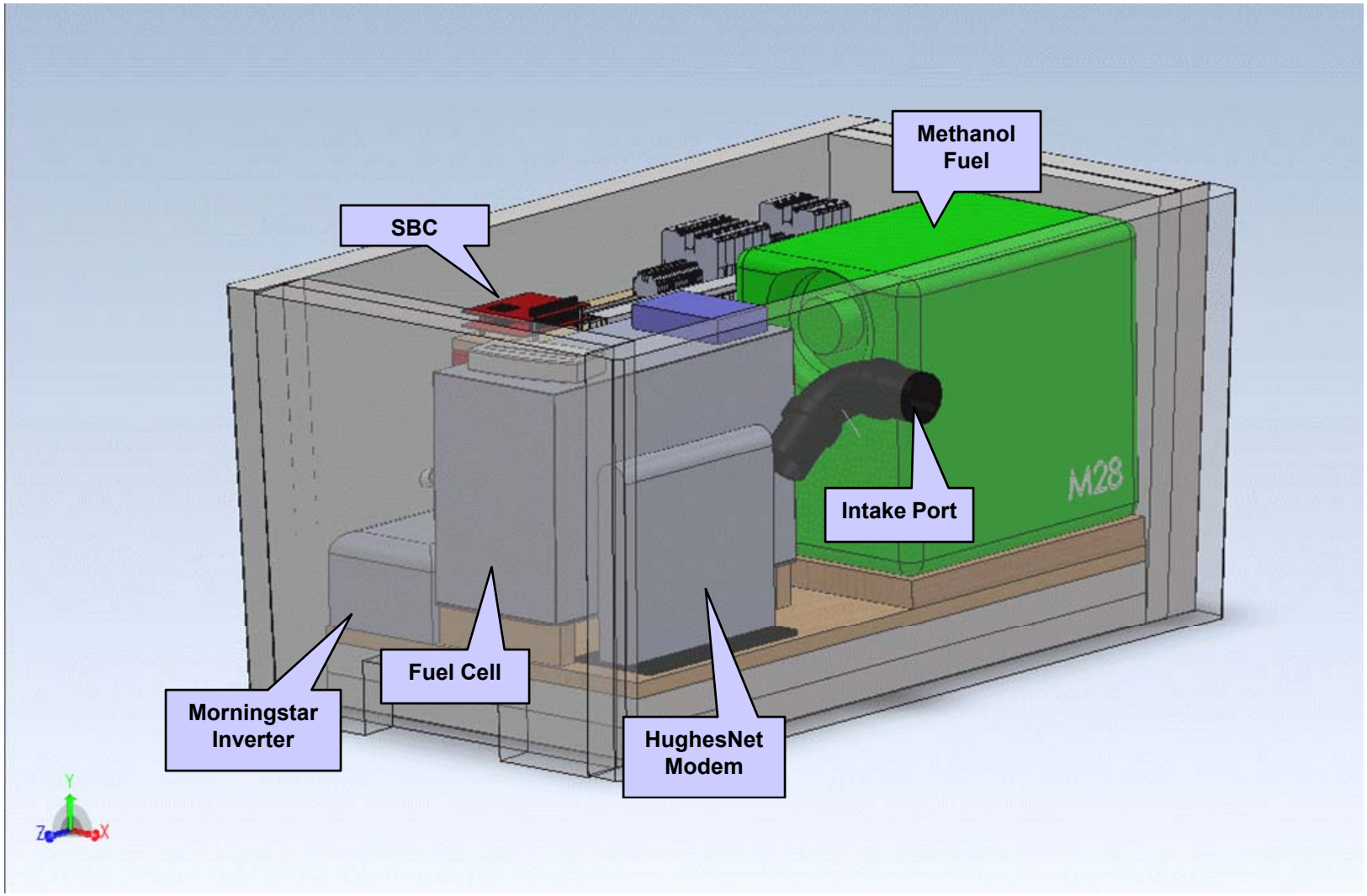


IRP "Grizzly" Enclosure

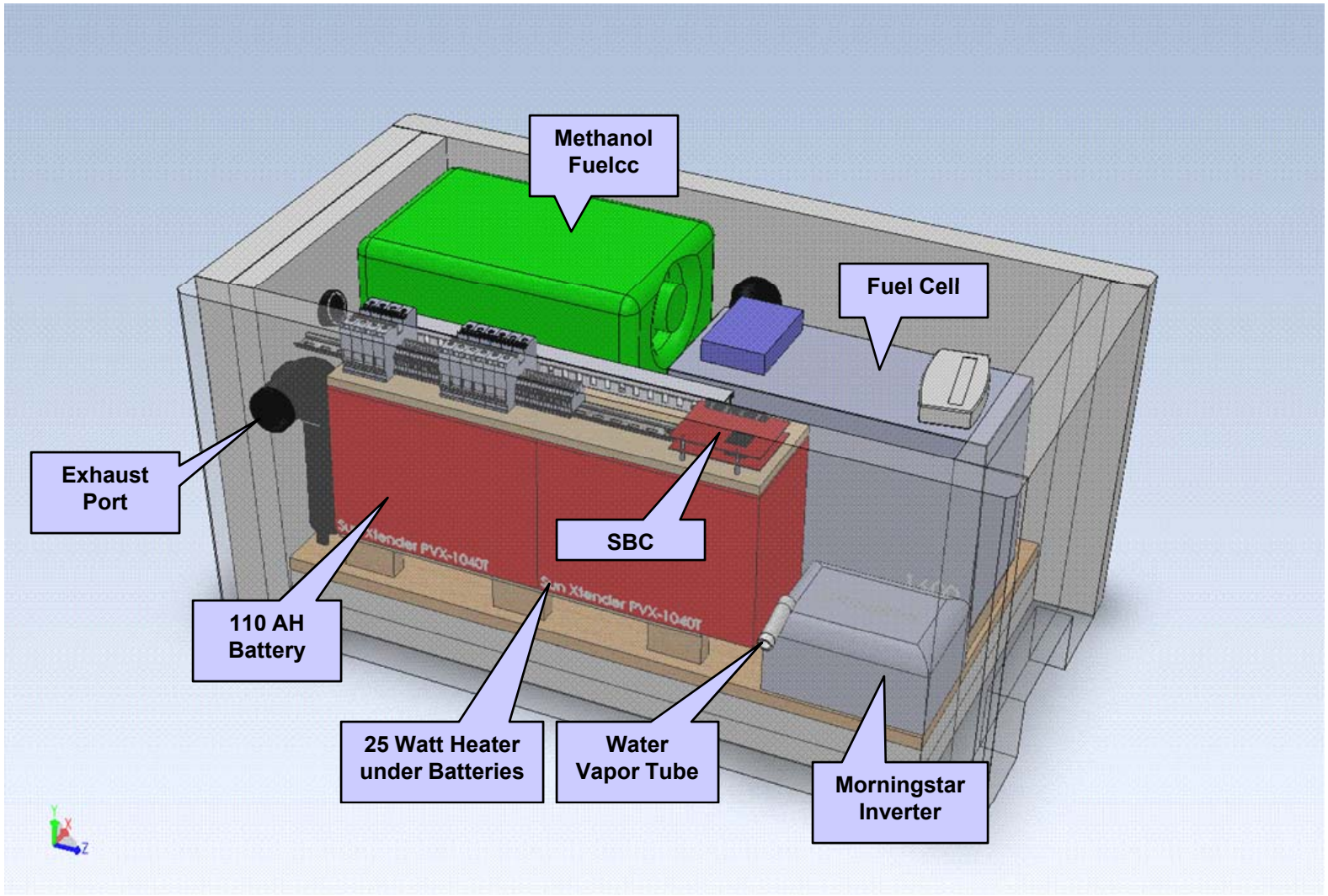
- **Exterior**
  - **57 x 31 x 30"**
- **Internal capacity**
  - **384 lbs prepared game**
  - **520 12-oz cans**
- **R5 value increased with foam**



Comms Node Interior – Intake Side



Comms Node Interior – Exhaust Side



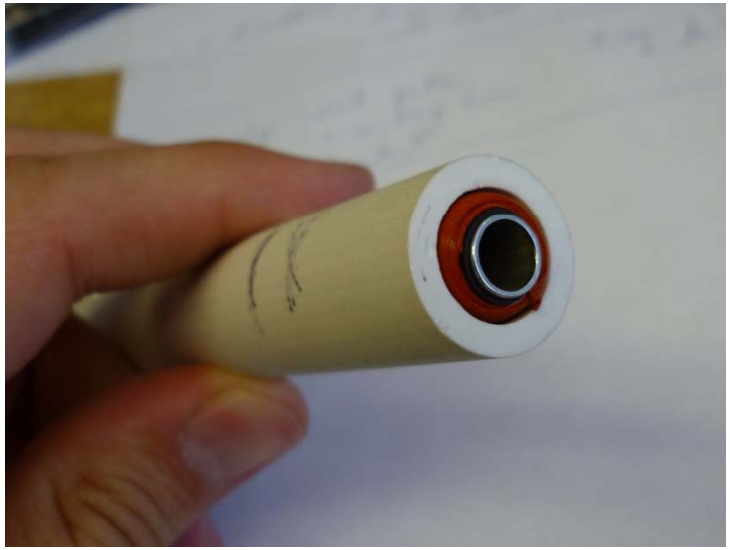
Water Vapor Tube with Heater

Heat Shrink Tubing

Stainless steel tube with 10-W heater

Conformal Heat Shrink over heater

Finished Exterior End



Installed Vapor Port Tube w/ Heater

- **Inclined to ensure water runoff**
- **Internal flexible tubing has no positive slope**
- **Fuel cell errors indicate when tube is blocked with ice**
  - **Run deicing heater cycle before restarting fuel cell operation**

Finished Exterior End

Finished Interior End

Vapor Port Icicle Formation

- **15 December 2010**

Vapor Port Icicle Growth

- **21 January 2011**
- **Fuel is mostly water that needs to be shed**
- **Some designs retain the water inside the enclosure**
  - **Raises internal humidity**
  - **Interior must stay warm**

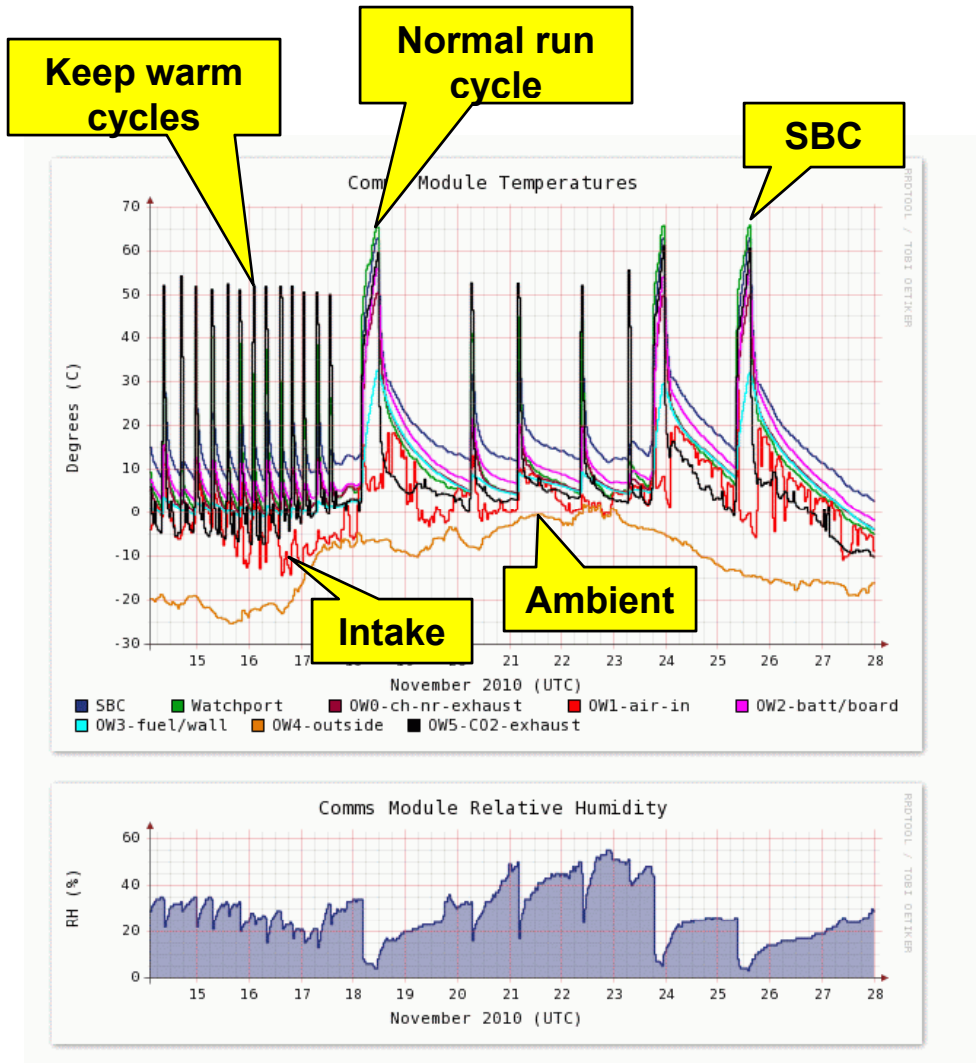
Water Vapor Icicle

28 October 2010

15 December 2010

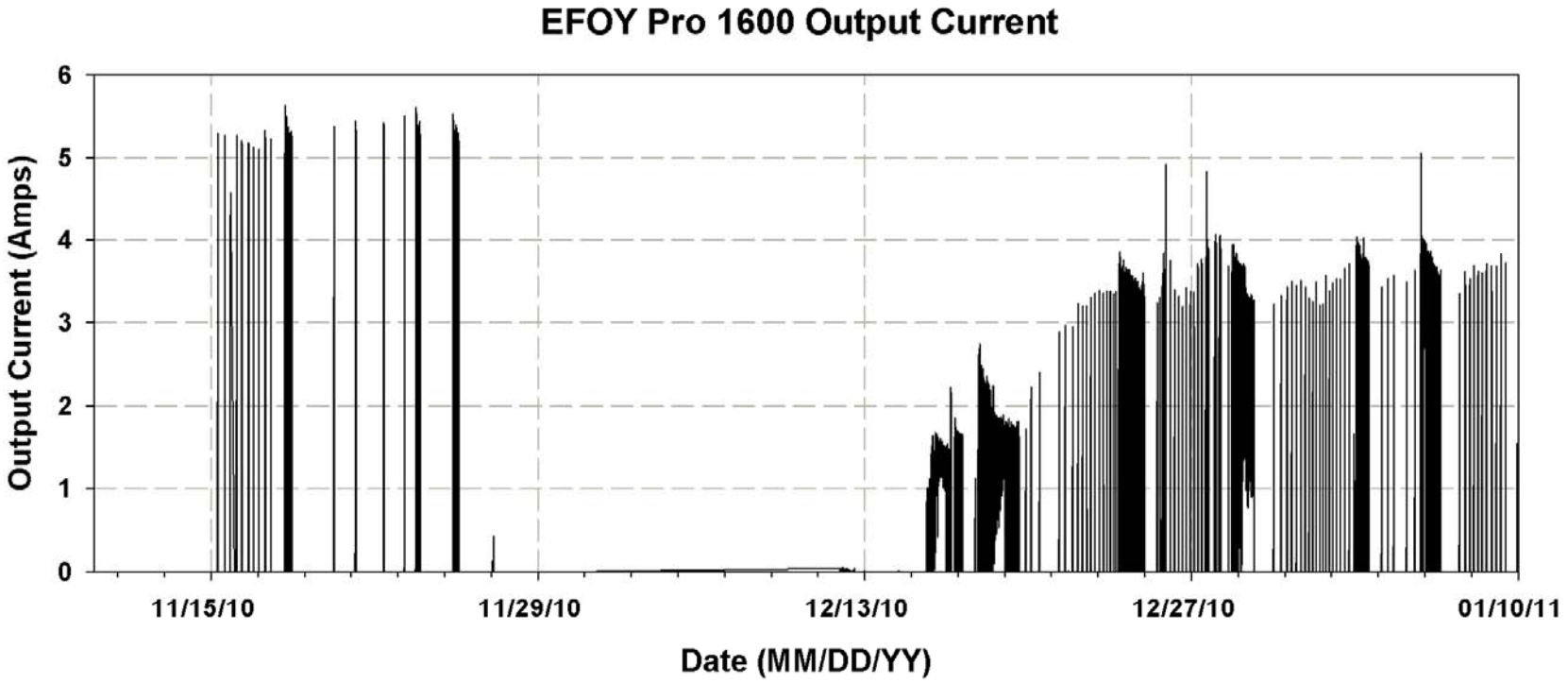
Overheating Event Causes Fault

- Restricted air intakes to keep warm air inside
- Interior temperature exceeded EFOY spec
- Service fluid reservoir dried out, shutting down fuel cell before SRI could limit run time
- Interior drops to ambient and stack freezes



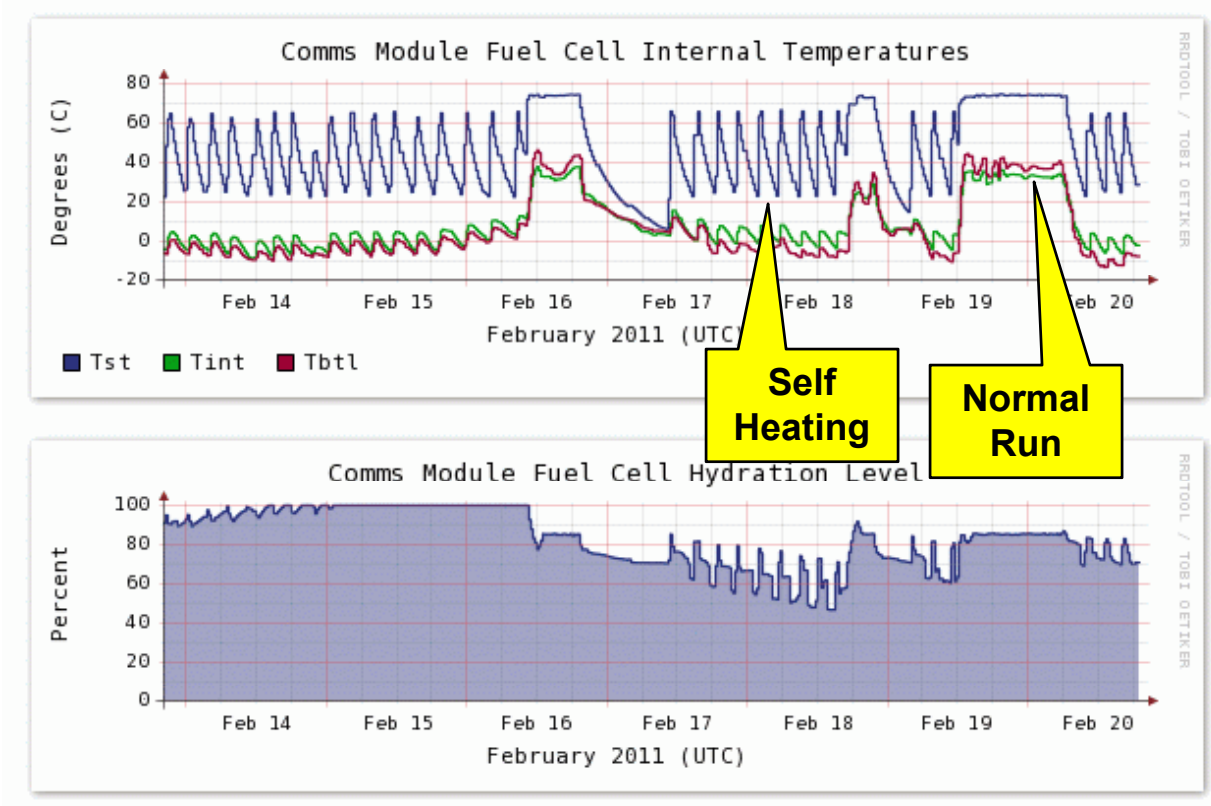
Frozen Stack Power Recovery

- **Initial operation very pessimistic (~1 Amp)**
- **Present operation restored to ~85% of previous output**



Service Fluid Replenishment

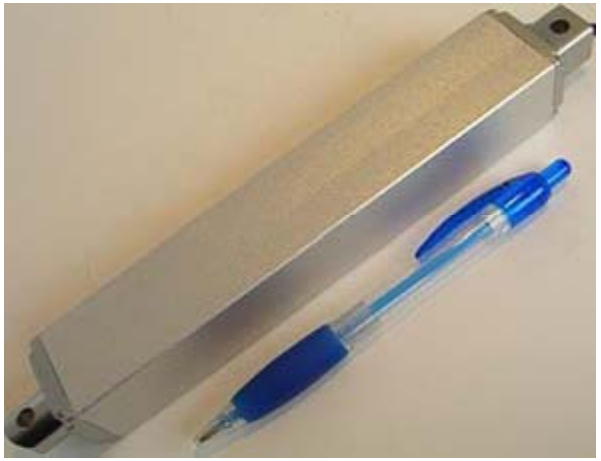
- Only during normal Run cycle; not always for Self Heating runs (May correlate w/ fully charged battery)
- Undocumented log command provides critical data



Tst 22.1C
Tint 23.4C
Twt 22.9C
Tdcdc 24.3C
Tpcb 24.8C
Tres 23.6C
Ubat 12.29V
Uaus 12.26V
Uklemm 12.26V
Ust 1.76V
Uzell 88mV
IntSteiU 0.000e+00n
Iaus 0.00A
Ist 0.00A
FuellSt 70.1n
LastError 1n
Error 0n
StBtrb 0.00h
SysBtrb 82.02h
PcStack 0n
PcMedien 0n
AdW 0n
ResF 0n
DHV 110.00n
DC-DC 0.0%
ULF1 0.0V
Tbtl 24.3C
Uref 2.48V
Ubb 3.02V
FS 0n
SysTime 2009-07-22_12:47:24

Need Closed Vents When Not Running

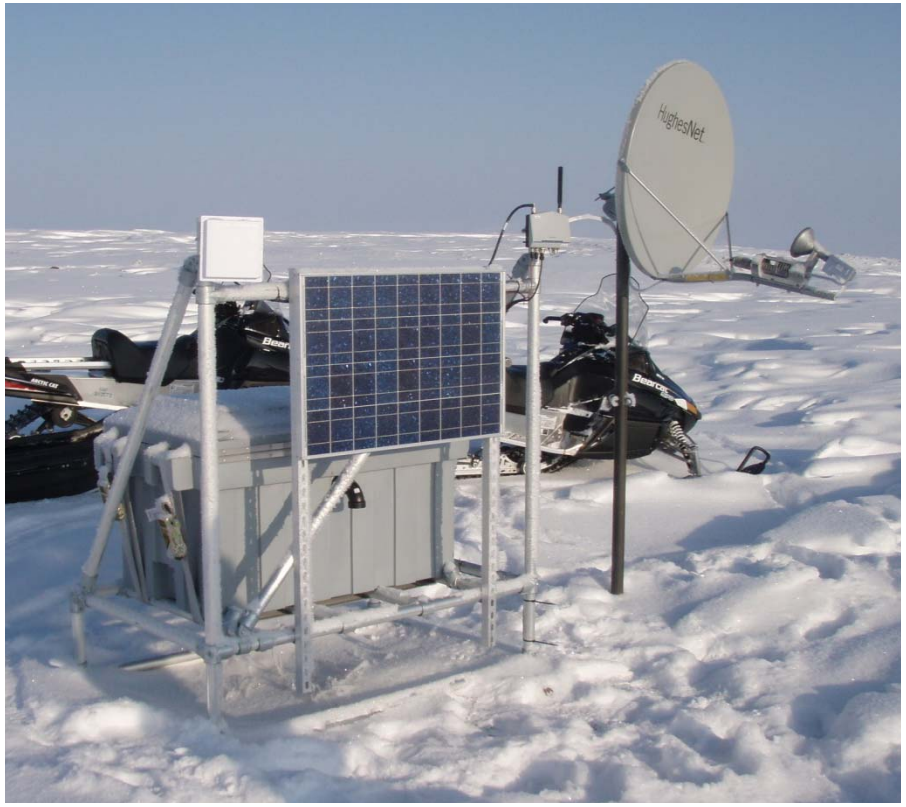
- **Differential pressure across enclosure causes cold ambient wind to blow into enclosure vents**
- **Linear actuator driving**
  - **Aircraft heater box (damper)**
  - **Sliding air port**



Elevated Support

- **Eliminates drifting snow that could clog air ports**

Communications Node



RE Power Station

Conclusions

- Proper thermal and water management permits winter operation of a fuel cell
  - Heated Water Vapor port is mandatory
- Open ports caused extra fuel (70%) to be used
  - This system projected to burn ~ 50 liters of Methanol / year
- Need to monitor Service Fluid level to prevent unrecoverable stack failure/freezing
- Elevated enclosure prevents drifts from forming and blocking air ports
- Occasional control fight between fuel cell and SBC
  - Control algorithm could get very complex