Technology for autonomous monitoring and investigations of polar environments

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Funding/
Logistics via

Thoughts about Presentation

- New concepts are being/have been developed for the polar environment remote sensing investigations
- The common model is to work with the Science PI (Steffen, Kamb, Englehardt, Carsey, Box, Fahnestock, Truffer, Zwally, Slawek, Fricker, Holland, Lane, Parish, Bromwich. Howat, Finnegan, Bindschladler, Tedesco, Adler, Smith, Kyle Kohler, as well as Danish Polar Inst., BAS, AAD, UNAVCO) to solve a needed measurement challenge.
- In addition new technology applicable to polar investigations is introduced to Science PI's (Workshops, WAIS, PARCA, AGU, etc.)

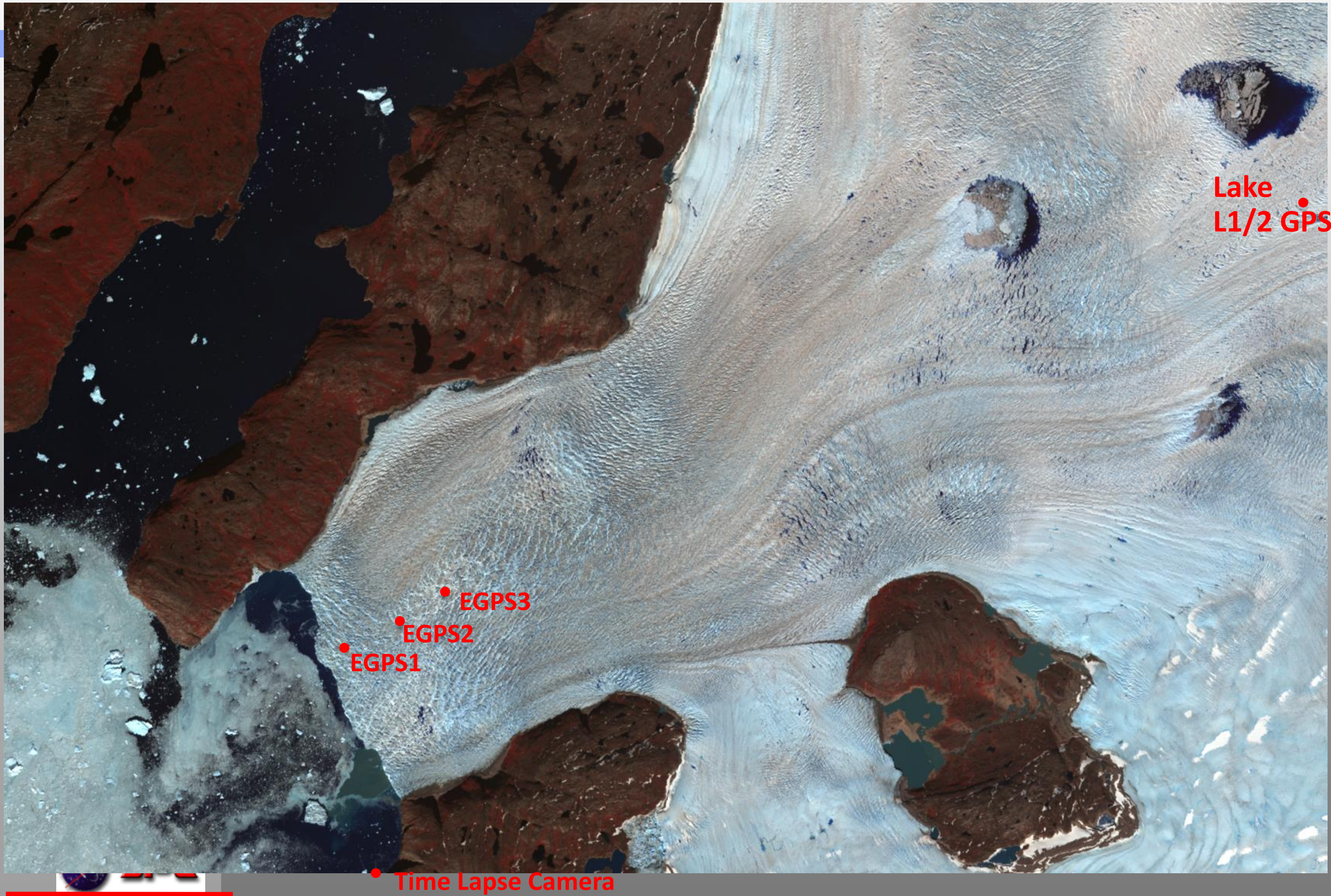
Ice Front Flow Measurements using Expendable Rovers

System Design

- •Expendable GPS Rovers that transmit their position at Glacier front to a local base station
- •Base station at rock base sends time corrections to rovers and records positions sent back
- •Unit deploys in a few hours
- •Runs autonomously
- •Can be set up for reconfiguration from a remote site via a separate radio link
- •Update rate for positions set to every 5 secs.

JPL

West Greenland Store Field Deployment 2008



5 km

Set Up

Helo Charter

High-gain omnidirectional RF Antennas (1 per rover)

Dual Frequency GPS Antenna

RTCM Correction

DGPS Position (NEMA ASCII)

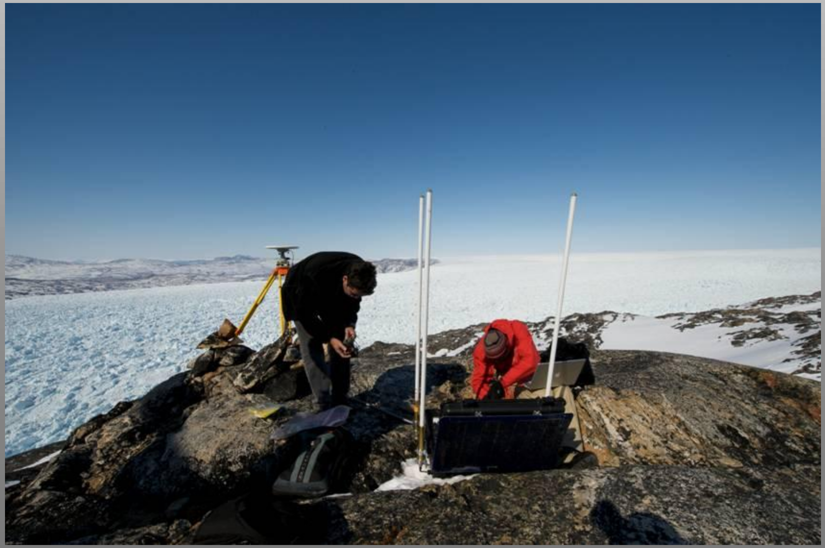
L1/2 GPS Receiver
Dataloggers
Freewave RF Modems

Batteries
Solar Panel and Charge Regulator

Ice Flow using Expendable Rovers

Base Station

- Trimble NetRS GPS Sends Time Corrections
- Uses Freewave Radios (one per rover)
- Records Positions to CF Industrial 4GB Flash
- 100 Ah SLA Batteries
- 30 Watt Solar Panel
- Range to Rovers >20km

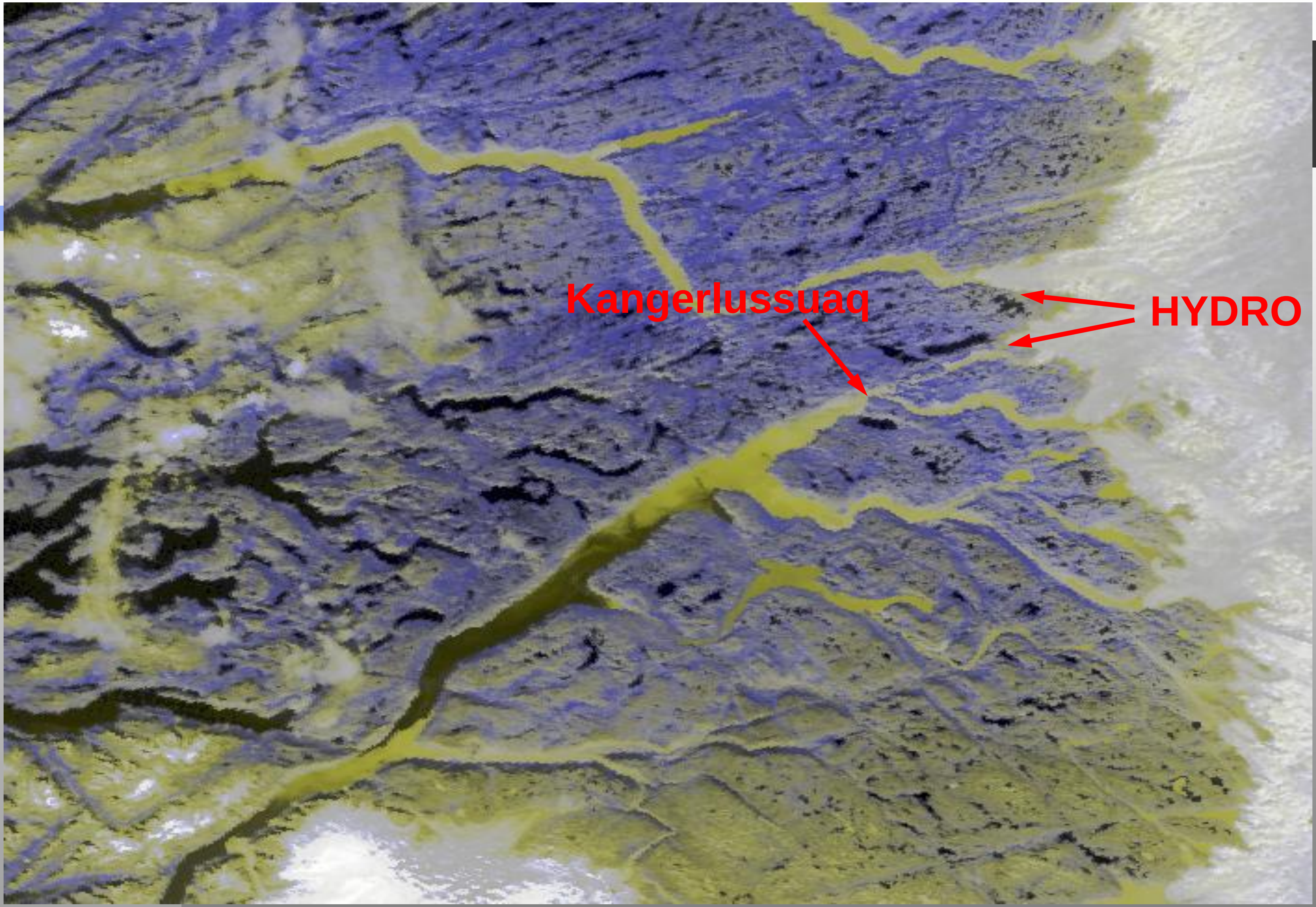


Ice Flow using Expendable Rovers

Expendable Rovers

- •Novatel GPS Receiving Time Corrections
  - •RTCM from Trimble at Base Station
- •Uses Free Wave Radios (one per rover)
- •19 Ah SLA Battery
- •10 Watt Solar Panel
- •Range to Base Station >20km
- •3 to 4 rovers per site

Ice-sheet hydrology from rivers



July 7, 2007 MODIS 250m

Glacial Runoff Depth Measurements

Units to send water depth and atmos. pressure of glacier runoff in a West Greenland fjord

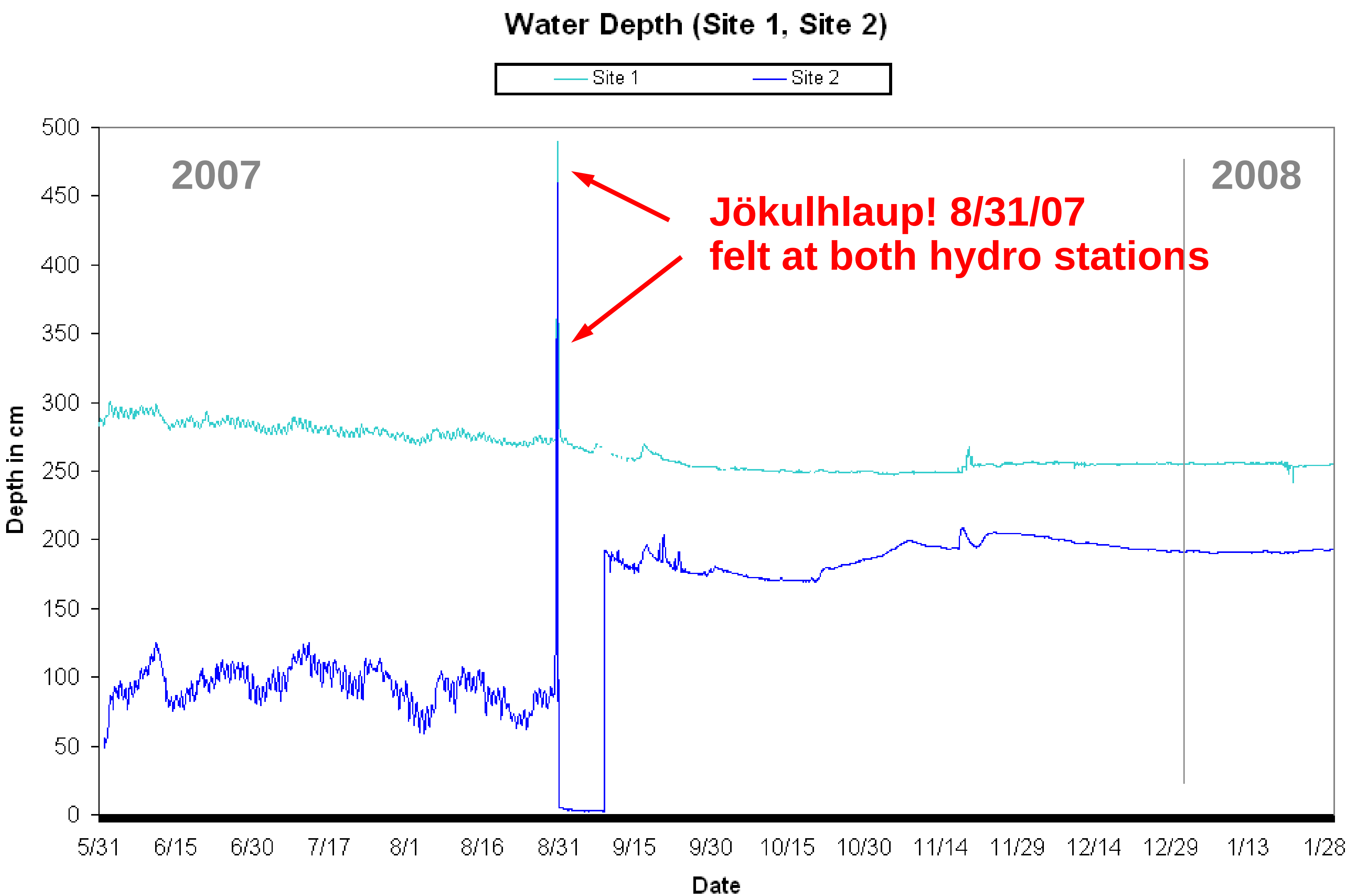
Remote Unit Details:

1. Recording Frequency: Pressure data: once per 2 hours, ~32 bytes
2. Data per day: 360 bytes (Depth Reading, Temp, Atmos Pressure, System Voltage)
3. Download/receive frequency: Once per day
4. Connection Method: Iridium Modem, 9601 SBD Transceiver
5. Number of stations: 2 separate locations each with its own comm. capability.

Operations base Details:

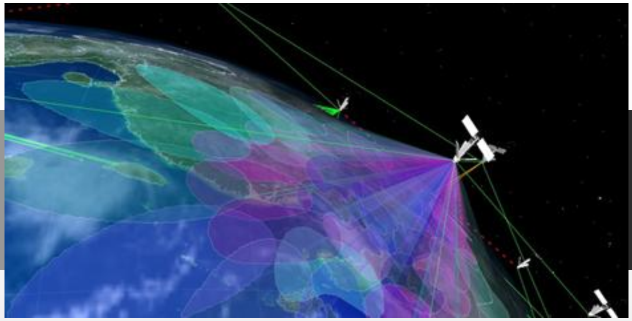
1. Communication with Iridium Network is via MIME Email Attachment.

Lagoon from river before reaching De Quervain Harbor



Water Depth (Site 1, Site 2)
Site 1
Site 2
Depth in cm
500
450
400
350
300
250
200
150
100
50
0
2007
2008
Jökulhlaup! 8/31/07
felt at both hydro stations
5/31
6/15
6/30
7/17
8/1
8/16
8/31
9/15
9/30
10/15
10/30
11/14
11/29
12/14
12/29
1/13
1/28
Date

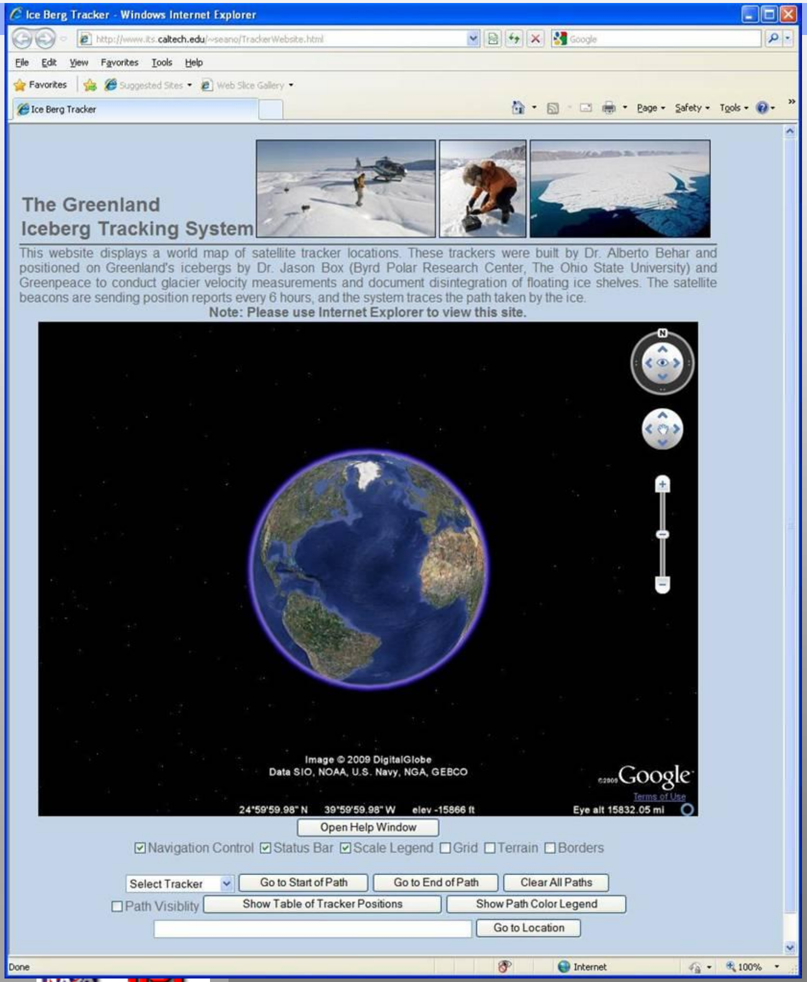
Iceberg Satellite Tracker

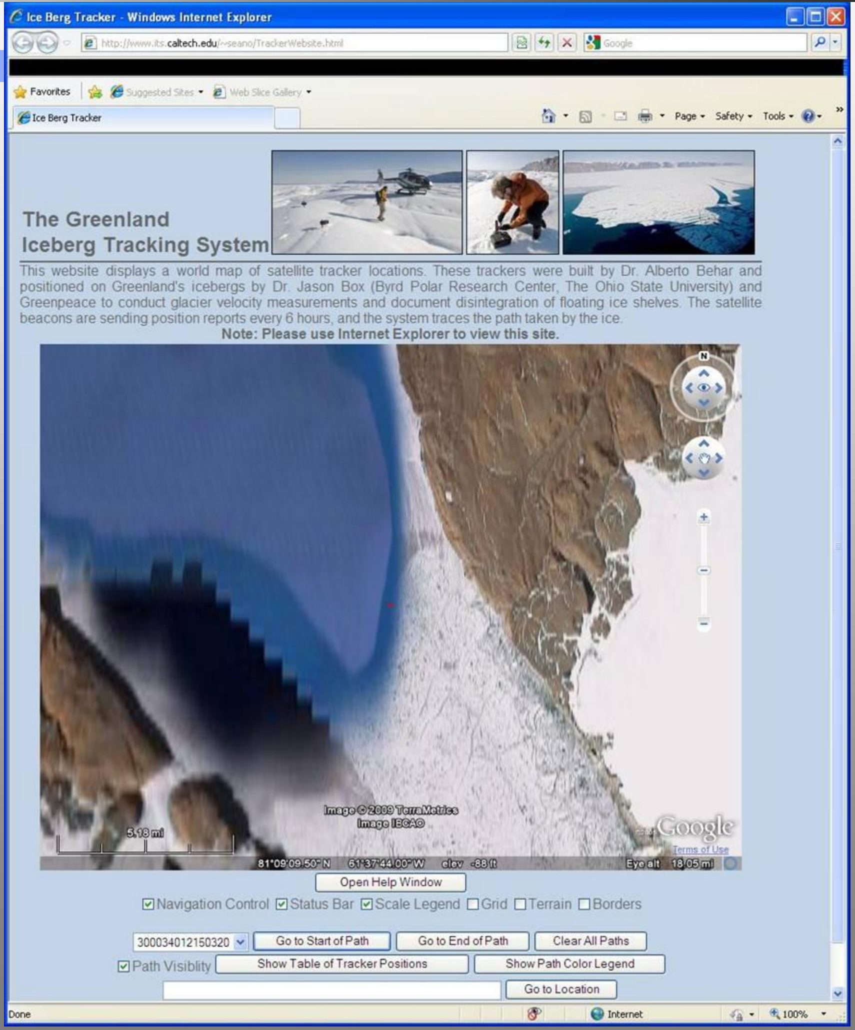


- Tracker is based on a adapted NAL modem
- Uses Iridium Satellite Network
- System Operational (3 units running since June)
- Two way comms. for setting any update rate
- Cost: Unit ~3K, Subscription $30/month
- Long Life (years, depending on update rate)
- Display software interfaces with Google Earth
- Can download positions
- Updates can arrive via email (human readable)
- Can be used to track icebergs or monitor events

Ice Berg Tracker Deployment

Iceberg Tracker Position History





SPOT-based Position Tracker

- **Tracker is based on an adapted Spot Unit**
- **Uses Globalstar Satellite Network**
- **System Function Verified as high as Ummanaq**
- **Programmable controller for any update rate**
- **Low cost: Unit ~1K, Subscription $150/yr**
- **Long Life (years, depending on update rate)**
- **All display software is free (uses Spot Website)**
- **Can download positions in several formats**
- **Updates can also arrive via email or SMS**
- **Can be used to track icebergs or high value items**

Off the Shelf Unit and Early Prototype

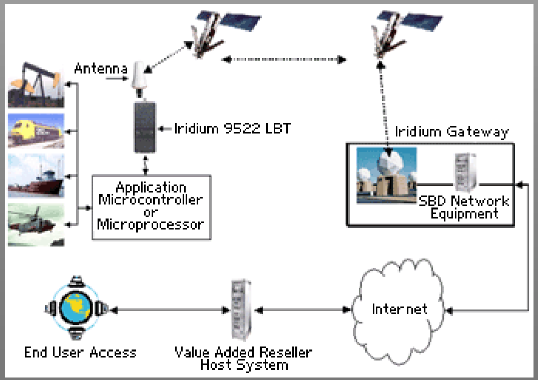
Tracking Website (Helicopter Ferry flight)

Geodetic Data via NetRS to SBD Iridium
4 units built (3 Greenland, 1 Antarctica)

- **Streams GPS position data (BINEX open format) from a Trimble NetRS to a microcontroller + Iridium modem that sends data through the Iridium Network to an operations base where it is repackaged to look like the original stream**

- **Remote Unit Configuration:**
  - **Records position every 30 sec, 35kb/hour**
  - **7200 epochs/day, (100-220bytes/epoch) ~1mbyte/day**
  - **Download/receive frequency: Every 4-5 mins.**
  - **Receiver and Format: Trimble NetRS in BINEX, 9600bps**
  - **Connection Method: Iridium Modem, LBT9522 with DOD Sim card**

- **Operations base Details:**
  - **PC Computer located at UNAVCO, Boulder, Colorado**
  - **Communication with Iridium Network is via TCP/IP Direct IP Sockets.**
  - **Runs a Linux simple application (shell script) that reassembles the data into 24hr UTC break files.**

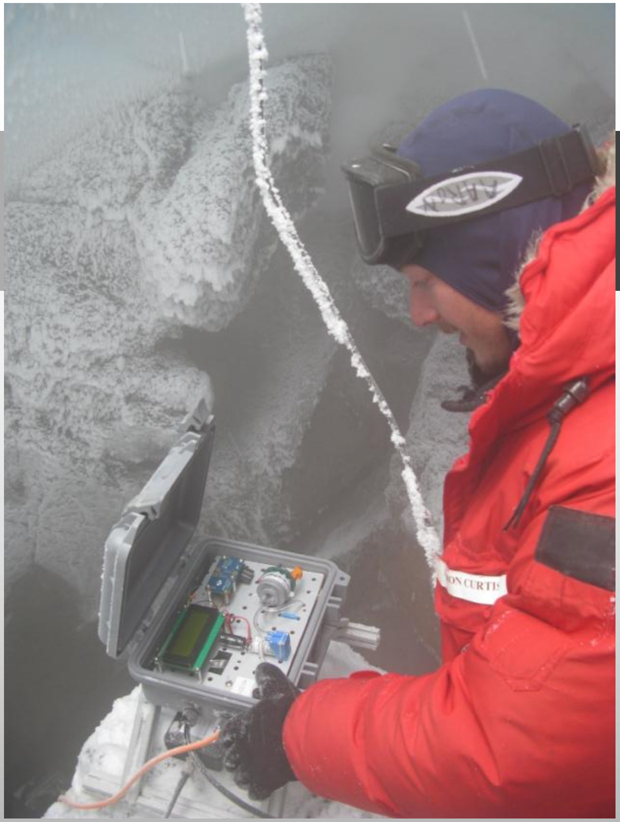


Greenland Nikon Cameras (Weather and Health Data)

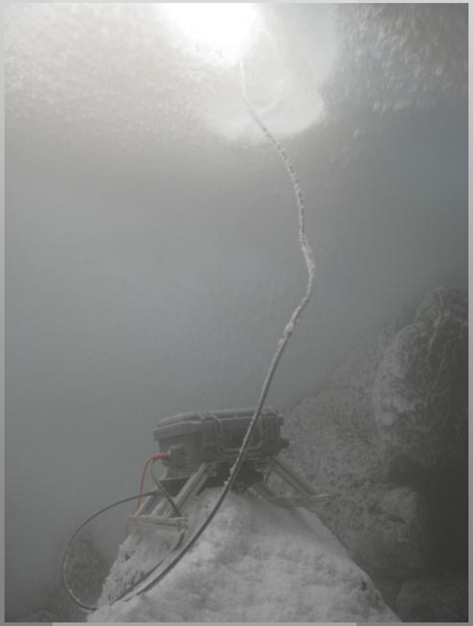
5 camera health data units that record Temp/Humidity & Battery Voltage readings every two hours and send once a day

Alberto Behar, PhD

Mt Erebus Volcano and Ice Cave Monitor



- **Self-contained sensor and comms. package**
  - **Sensor – CO_2, SO_2, Viasala Weather Station, (Wind speed/direction temperature, pressure, humidity)**



Field deployment: Volcano Monitor

- Self-contained sensor and comms. package
  - Sensor – SO_2, temperature, humidity.
  - Battery (works to schedule: can increase data acquisition rate on trigger)
  - Iridium satellite modem link
- Data uplinked to web site
- Triggers sensor web satellite detection
- Data collection can also be triggered by sensor web: demonstrates 2-way autonomous operations

Field deployment: Volcano Monitor

- Deployment: two units deployed on Kilauea Volcano, Hawai'i (volcanic gas detection) running since November 2007

- Weight: <4 kg

- Data collected every hour (normal mode)

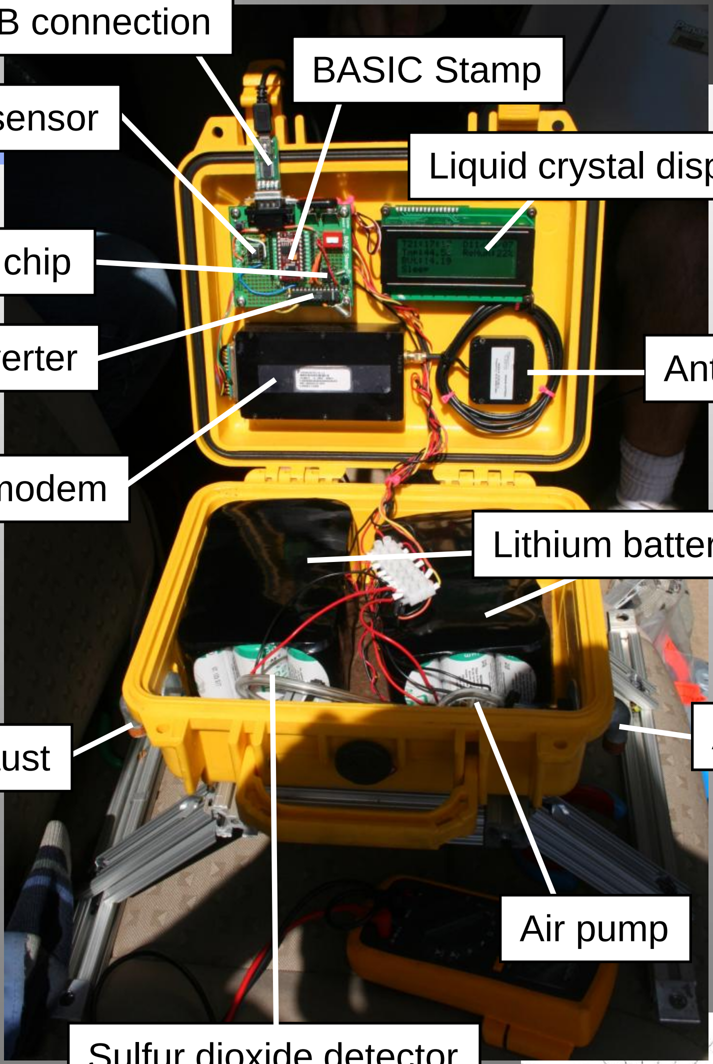
- "Burst mode" = collection every min/10 mins

- 1 year lifetime (normal mode)

- expendable units

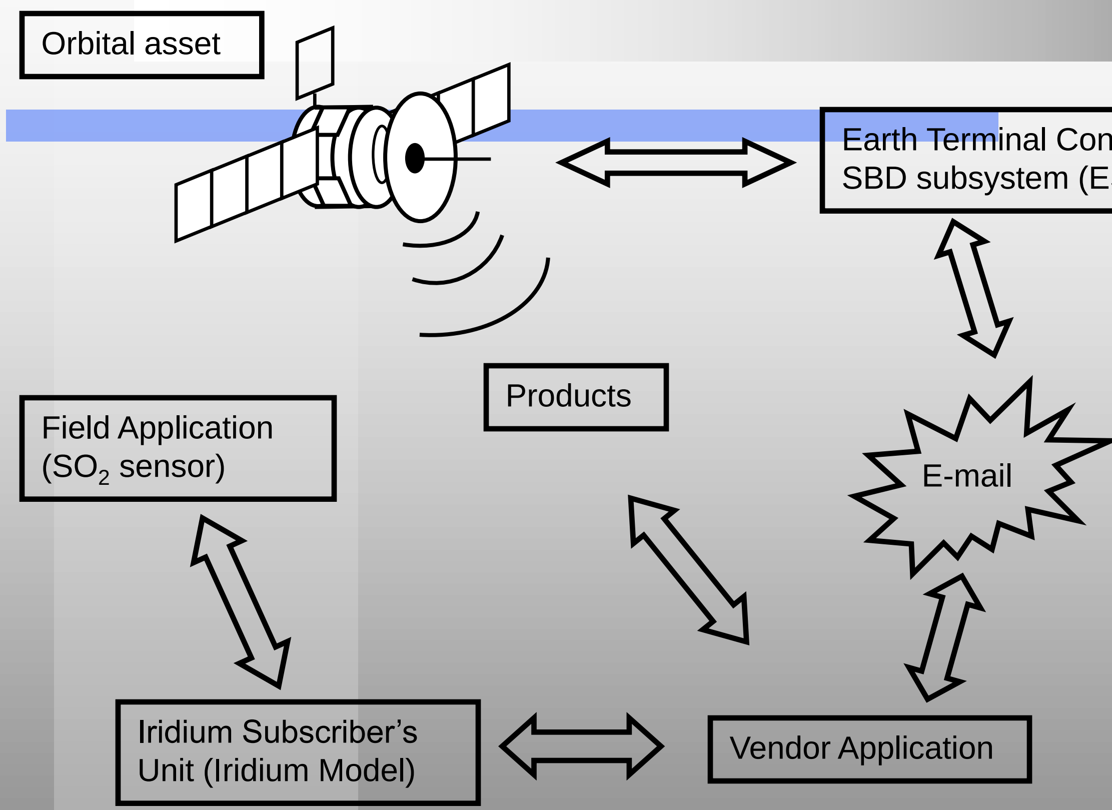
- Data being used by HVO

- Data being used by US Park Service (Volcanoes National Park) for assessing environmental conditions in the Park

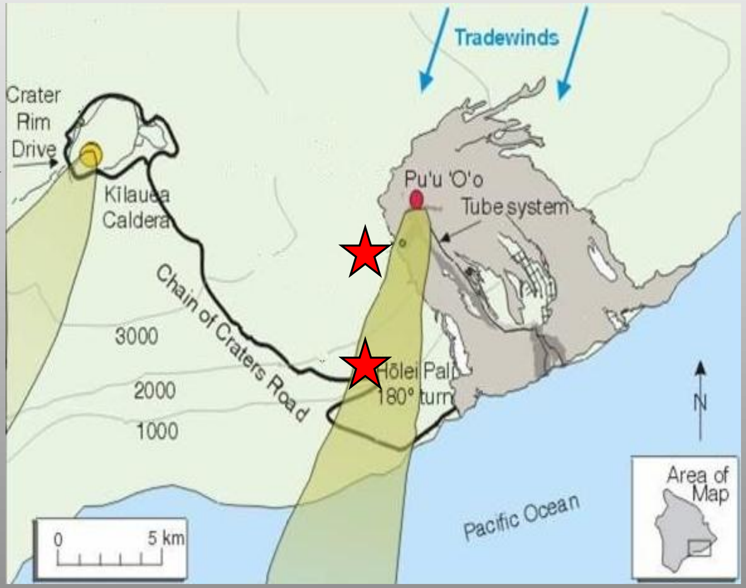


ESTO Earth Science Technology Office

Field deployment: Volcano Monitor



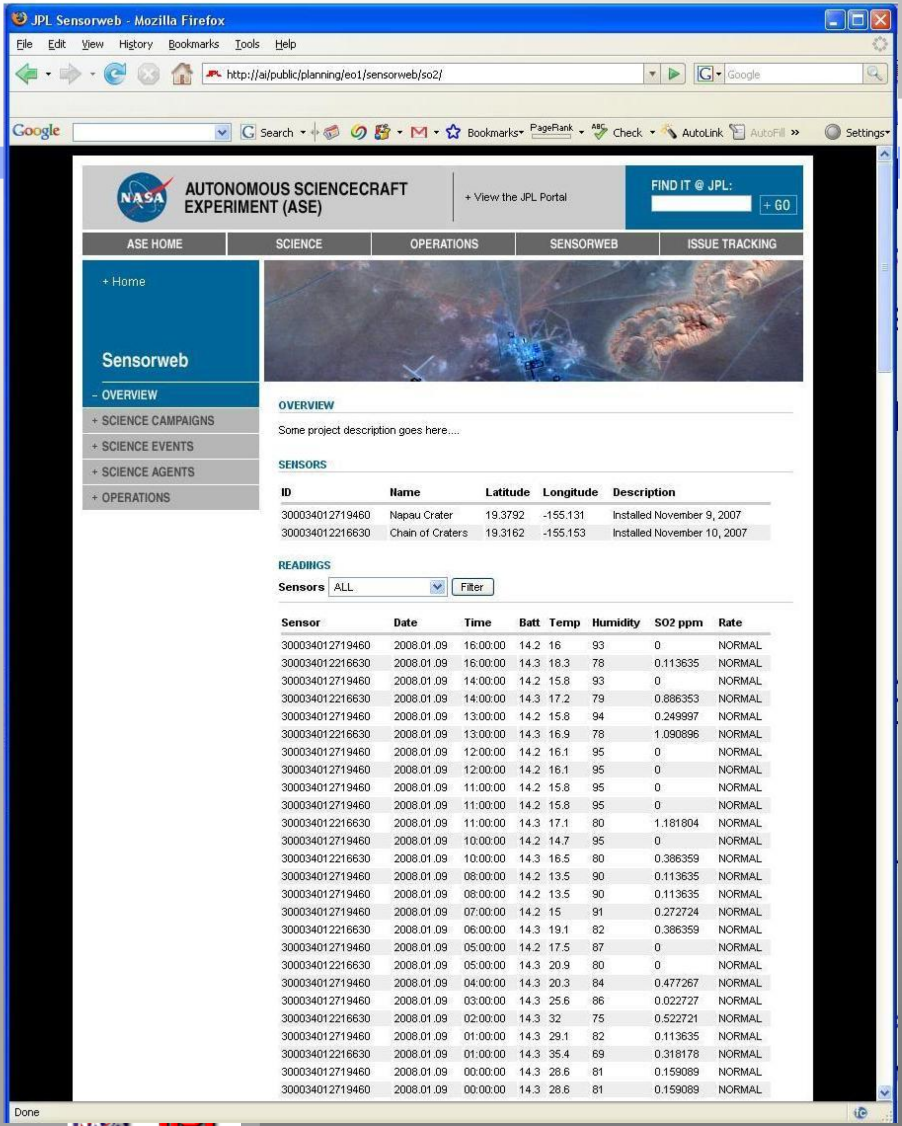
★ Volcano Monitor location



Example transmission: T02:00D07/20t79.4H60S30B12 translates to:
Time: 2:00 AM, *Day:* 07/20, *Temperature:* 79.4º F, *Humidity:* 60%, *Sulfur dioxide detected:* 30 ppm.

ESTO Earth Science Technology Office

Web Services: Volcano Monitor



JPL Sensorweb - Mozilla Firefox

http://ai/public/planning/eo1/sensorweb/so2/

AUTONOMOUS SCIENCECRAFT EXPERIMENT (ASE)

+ View the JPL Portal

FIND IT @ JPL:

ASE HOME | SCIENCE | OPERATIONS | SENSORWEB | ISSUE TRACKING

+ Home

Sensorweb

- OVERVIEW
+ SCIENCE CAMPAIGNS
+ SCIENCE EVENTS
+ SCIENCE AGENTS
+ OPERATIONS

OVERVIEW

Some project description goes here....

SENSORS

ID	Name	Latitude	Longitude	Description
300034012719460	Napau Crater	19.3792	-155.131	Installed November 9, 2007
300034012216630	Chain of Craters	19.3162	-155.153	Installed November 10, 2007

READINGS

Sensors ALL Filter

Sensor	Date	Time	Batt	Temp	Humidity	SO2 ppm	Rate
300034012719460	2008.01.09	16:00:00	14.2	16	93	0	NORMAL
300034012216630	2008.01.09	16:00:00	14.3	18.3	78	0.113635	NORMAL
300034012719460	2008.01.09	14:00:00	14.2	15.8	93	0	NORMAL
300034012216630	2008.01.09	14:00:00	14.3	17.2	79	0.886353	NORMAL
300034012719460	2008.01.09	13:00:00	14.2	15.8	94	0.249997	NORMAL
300034012216630	2008.01.09	13:00:00	14.3	16.9	78	1.090896	NORMAL
300034012719460	2008.01.09	12:00:00	14.2	16.1	95	0	NORMAL
300034012719460	2008.01.09	12:00:00	14.2	16.1	95	0	NORMAL
300034012719460	2008.01.09	11:00:00	14.2	15.8	95	0	NORMAL
300034012719460	2008.01.09	11:00:00	14.2	15.8	95	0	NORMAL
300034012216630	2008.01.09	11:00:00	14.3	17.1	80	1.181804	NORMAL
300034012719460	2008.01.09	10:00:00	14.2	14.7	95	0	NORMAL
300034012216630	2008.01.09	10:00:00	14.3	16.5	80	0.386359	NORMAL
300034012719460	2008.01.09	08:00:00	14.2	13.5	90	0.113635	NORMAL
300034012719460	2008.01.09	08:00:00	14.2	13.5	90	0.113635	NORMAL
300034012719460	2008.01.09	07:00:00	14.2	15	91	0.272724	NORMAL
300034012216630	2008.01.09	06:00:00	14.3	19.1	82	0.386359	NORMAL
300034012719460	2008.01.09	05:00:00	14.2	17.5	87	0	NORMAL
300034012216630	2008.01.09	05:00:00	14.3	20.9	80	0	NORMAL
300034012719460	2008.01.09	04:00:00	14.3	20.3	84	0.477267	NORMAL
300034012719460	2008.01.09	03:00:00	14.3	25.6	86	0.022727	NORMAL
300034012216630	2008.01.09	02:00:00	14.3	32	75	0.522721	NORMAL
300034012719460	2008.01.09	01:00:00	14.3	29.1	82	0.113635	NORMAL
300034012216630	2008.01.09	01:00:00	14.3	35.4	69	0.318178	NORMAL
300034012719460	2008.01.09	00:00:00	14.3	28.6	81	0.159089	NORMAL
300034012719460	2008.01.09	00:00:00	14.3	28.6	81	0.159089	NORMAL

Done

The two volcano monitors ("Napau Crater" and "Chain of Craters") send data every hour to JPL. Reported voltages are converted to SO_2 concentrations in PPM.

Information is displayed on a web site at JPL.

Access to this website has been given to Hawaiian Volcanoes Observatory and Volcanoes National Park personnel.

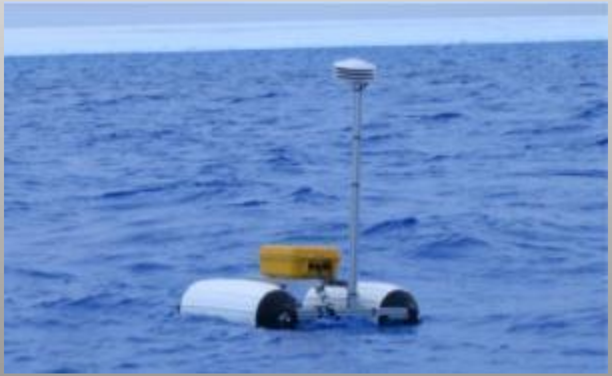
Earth Science Technology Office

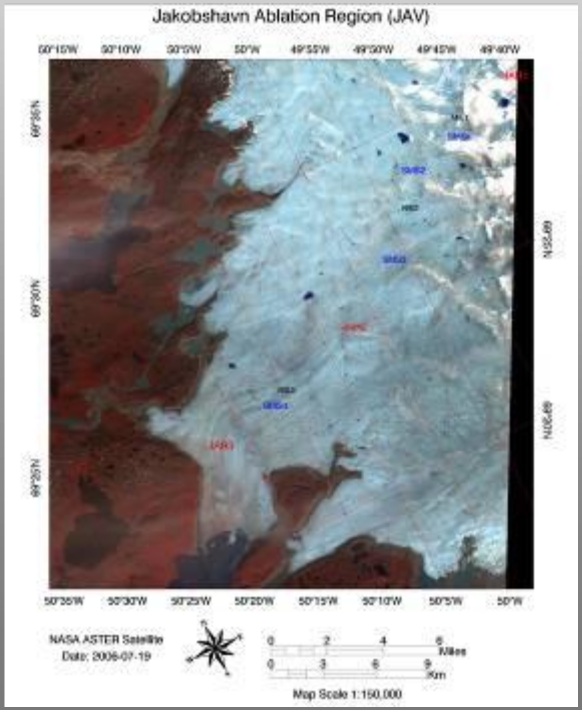
Surface Lakes Depth Measurements

Units (Buoys) to send water depth/temp profile of surface lake in West Greenland fjord

Remote Unit Details:

1. **Recording Frequency: Pressure data: once per hour, ~32 bytes**
2. **Data per day: 360 bytes (Depth Reading, Temp (9), System Voltage)**
3. **Download/receive frequency: Once per day**
4. **Connection Method: Iridium Modem, 9601 SBD Transceiver**
5. **Number of stations: 2 separate locations each with its own comm. capability.**



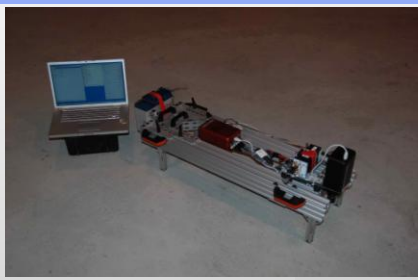


, PhD

West Greenland Supra-Glacial Lake Investigator

Designed to determine the depths of Summer melt lakes (supraglacial lakes) on Greenland's ice sheet through passive airborne measurement of reflectance spectra

PI: Alberto Behar, NASA Jet Propulsion Laboratory   **Co-Investigator: John Adler, NOAA**



Imaging mount retracted

Mount extended, in helicopter

Objective:

1. Passively record the reflectance spectra of the lakes
2. Correlate data from from the on-board inertial navigation unit with spectral measurements to perform georeferencing
3. With a calibrated spectral processing algorithm, compute a depth map of the observed supraglacial lakes

Scope:

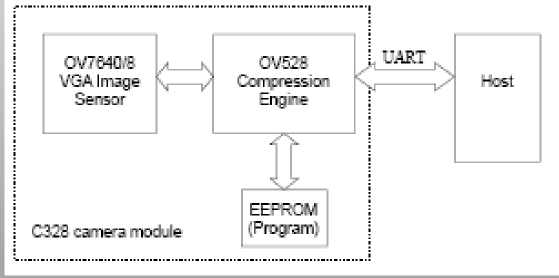
1. Enhancing Greenland ice sheet mass balance models by determining supraglacial lake volumes (Science)
2. Developing techniques for remote sensing of lake depths (Technology)
3. Serving as an airborne proof-of-concept for repurposing existing satellite-borne hyperspectral imagers to perform lake monitoring (Technology)

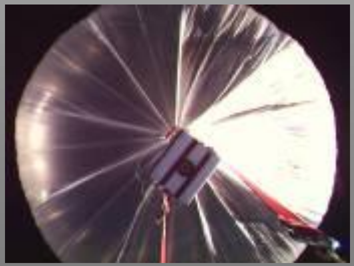
In flight over a lake

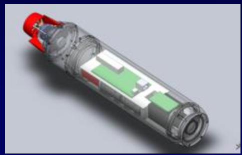
This lake had drained the previous night. Notice the high water mark given added contrast by darker cryoconite dust

Global WebCam using a Miniature JPEG Camera

- Low-cost, & low-powered solution for medium resolution image capture (640x480) 300K pixels
- JPEG Encoder on board (resolution, compression ratio adjustable)
- Simple serial interface, low image size (2-20Kb)
- Tied to an iridium modem that can give real time context images for status, commanding and decision making
- Sample images below from 30km altitude (Mars Aerobot)





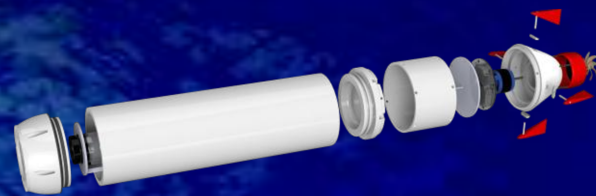


Micro-Submersible Lake Exploration Device

Alberto Behar, C. Walter, T. Nordheim, A. Camery, A. Elliot, C. Ho, E. Olson, P. Kapoor , P. Naik, J. Khan
Jet Propulsion Laboratory, California Institute of Technology

Abstract

As the number of unexplored areas of the world rapidly dwindle, highly precise and efficient instruments are needed to retrieve accurate data from remote aquatic habitats. Since the discovery of subglacial lakes in Antarctica, underwater vehicles are essential to investigating these challenging aquatic habitats and gaining insight on glacial formation, ice flow and discharge, basal water transfer, and the geometry of ice-water interface. The Micro-Subglacial Lake Exploration Device (MSLED) is a compact underwater vehicle designed specifically to explore aquatic, isolated environments. Equipped with conductivity, temperature and depth sensors (CTD), semi-autonomous capabilities, a camera, fiber optic cable, and other technologies, the MSLED is a one-of-a-kind instrument built to explore and gather data in stark terrain.



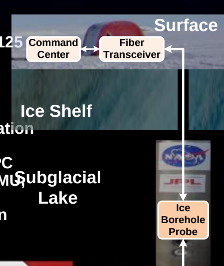
Science

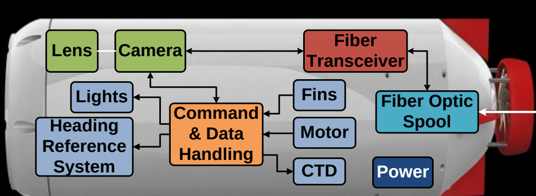
With an inventory of at least 145 Antarctic subglacial lakes, understanding the movement of ice flow is imperative to predicting the future of ice sheets and their effect on rising sea levels. The other avenue of exploration is to gain information on the subglacial biotic ecosystem that is currently not well understood. These studies illustrate that the subglacial environment is a vastly understudied, po-tential, ecosystem with the potential to impact our understanding of global biogeochemical cycles, astrobiology, and the biodiversity of cold, aquatic, dark environments. Also, with the prospect of subglacial lakes on Jupiter's moon Europa, a strong foundation of knowledge is necessary for successful extra-terrestrial exploration. Using various biogeochemical measurements will also test the hypotheses that glaciological, hydro-oceanographic sedimentological, and biochemical processes combine to stabilize the ice shelf and control the structure and function of microorganisms inhabiting the subglacial habitat.

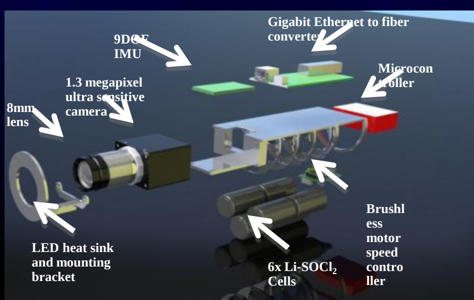
System Overview

The communication sub-system on board MSLED transmits and receives data simul-taneously over a single multi-mode fiber optic transmission line. The surface station requires real-time video, heading reference system data, and CTD data to navigate and explore areas of interests. MSLED receives commands to operate the fins, motor, lights and camera. In order to couple all the data together, the command and data handling system packetizes the data from all the subsystems digitally. This digital data is managed by the camera and the electrical signal is converted to optics using a fiber optic transceiver. The transceiver transmits the data, through the existing Ice Borehole Probe, to the surface ground station, to be converted back to electrical signals. The data can then be coordinated by the graphical user interface.

Technical requirements and constraints:
•Fiber communication must integrate into 1 km of 62.5/125 multi-mode fiber cable currently being used on the Ice Borehole Probe
•Components must fit within a 7.5 cm diameter, 25 cm long cylinder
•Signals must transmit 3 km without noticeable degradation to video quality or sensor data fidelity
•Components must withstand temperatures -10 to +65 ºC
•Transmit high definition video and sensor data (CTD, IMU, status, etc.) to surface station
•Receive navigation control signals from surface station
•Transmit data at gigabit speed simultaneously







Mechanical

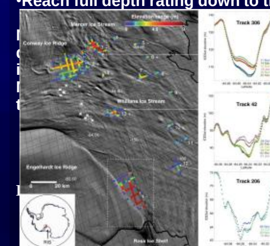
Structure determines function. Due to the strict size dimensions of MSLED, the structure has certain design requirements to house and protect the internal components. These constraints include rated pressure, rated temperature, and size. The structure subsystem has the following constraints:
•Withstand pressures at 3km of depth
•Withstand temperatures ranging from +/-10 ºC
•Overall size of the device which will be no more than 8 cm in diameter by 40 cm in length

The structure is composed of an external and an internal component. The external shell provides protection from the environment while the internal shell is where the various components are mounted. The external structure is divided into three major sections: the nosecone, the main hull and the tail cone. The nosecone contains the camera, camera lens and LED's. The main hull has two sections: the forward part of the hull is where the electronics, power and communication subsystems are housed; the aft section of the hull contains the fiber optic cable. The tail cone holds the propulsion, the control hardware and CTD sensor.

Mission Summary

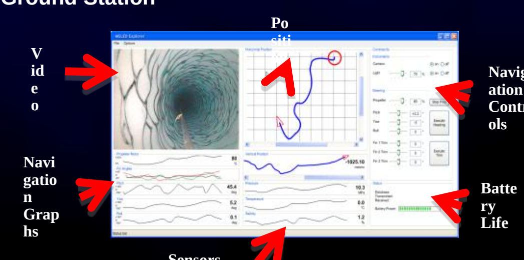
A finely crafted underwater vehicle will be needed to address the questions surrounding subglacial environments. MSLED is a small (8 cm diameter and 30 cm in length) torpedo-shaped underwater robot designed to be submerged in subglacial Antarctic lakes to navigate semi-autonomously and record data within the lake. Tethered to the Ice Borehole Probe, MSLED will have the capability to detach and roam freely due to the optical fiber cable with a range of 1 km and will eventually reattach and be brought to the surface. Of primary importance are the innovative size and capabilities of MSLED, for example:

•Capture high-resolution video and images of the lake
•Record up to 2.5 hours of real-time video
•Navigate towards pressure, temperature, turbidity, and depth gradients semi-autonomously
•Stop at significant detected geothermal hotspots and conduct further measurements
•Reach full depth rating down to three kilometers



...ake Engelhardt to collect measurable ...nd conductivity, as well as visual ...p to four hours. If space per-mits, ...th appropriate biosensors to detect ...

Ground Station



The operator at the Ground station will monitor the vehicle by a graphical user interface that displays the submarine's video, status data of the different sensors, as well as horizontal and vertical position in real-time and with history, where possible. Furthermore, the operator shall be able to control the vehicle and send commands for camera, lighting, fins, and heading.

Acknowledgements

The work described here was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration and funded by the National Science Foundation and through the NASA Earth Science Cryosphere Program. The authors would like to thank the scientists and engineers at the following institutions; Woods Hole Oceanographic Institution (Dana Yoerger), Communications Architectures and Research at JPL (Malcom Wright), WHOI Deep Ocean Exploration Institute (Chris German) and the Monterey Bay Aquarium Research Institute (Hans Thomas). Also special thanks to UCSC Department of Earth and Planetary Sciences (Slawek Tulaczyk), UCSD Institute of Geophysics and Planetary Physics (Helen Fricker) for their science support and collaboration.

Questions?

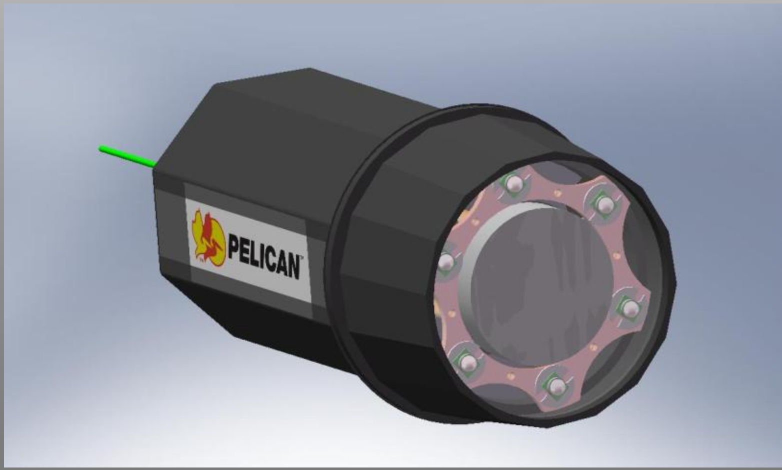

Recent Work
Spiderbot Microgravity Testing '05
SubGlacial Antarctic Lake UV Probe '06
Tumbleweed Air Drop System '05
Space Station Cell Growth Micro Images '02-05
Hydrothermal Vent Bio Sampler '03-06
CHILL Glacial Subsurface Exploration ASTEP '05-06
PAUSE Mars Aerobot '04-05
Tumbleweed Deployment South Pole '03-04
Tumbleweed Deployment Greenland '03-04
JSC Mars Drill Tests '02
JSC Advanced Space Propulsion Lab '02
Solar Sail KC-135 Tests '01
Proposals Out
Antarctic GPS Stations NSF '06
Radiation Tolerant Microbe Hi Alt. Test RTD '06
South Pole Winds Tumbleweed RTD '06
Pine Island Glacier Investigation '06 NASA/NSF/JPY
Tumbleweed ASTEP '05
Aerial Mars Missions PIDDP '05
Education
USC
PhD in EE, Astronautics Minor '98
MS in CS, Robotics Specialization '94
Rensselaer
ME in EE '92
UNIVERSITY OF FLORIDA
BS in CSE '90
Private Pilot '95 Instrument Rated
Rescue Diver '88
PADI
Emergency Medical Technician - I '96
Wilderness Medicine Certificate '97
Career Path
JPL
Robotic Vehicles Group Section 347, since '91
JSC Adv. Dev. Office '02
HQ Mars Office '01
MER Rover Driver (training)
Mars Odyssey Gamma Ray Spectrometer Investigation Scientist
Antarctic Ice Borehole Probe Antarctica '01, '03, '04, Alaska '02
Ross (90 days), Ronne (60 days) Shelf
ISAS, Tokyo, Japan, '99-00
Space Engineering Division
Visiting Researcher (1 year)
MUSES-C Asteroid Mission
Rover System Engineer '96-98
Rover Camera Engineer '00
Awards
One Nasa Award, '05
NASA Tech Briefs: Space Station Cell Imager '05, Antarctic Ice Probe '03, Ultra Micro-Sub '03, Tumbleweed Rover '03
Mission Architect Development Program Intern JSC (5 months) '02, NASA HQ (6 months) '01
Award for Exceptional Technical Excellence '01
NOVA Award '00 MUSES-CN Electronics Team
DOD
Ultra-Miniature Vision Sensors Provisional Patent '01
NASA Group Achievement Award Mars Science Microrover Demo '92
NASA Graduate Student Researchers Fellowship at JPL '92-96

Stream Motion Sensor

- Contains Iridium Tracking GPS
- Contained in a Pressure Vessel
- Follows water pathway
- Sends Postion/Velocity
- Buoyant/Robust Shell

Moulin Explorer Cam 2009

- HD Camera, Recording to SD Card
- Contained in a Robust Pressure Vessel
- Sends Live Video to Video Goggles
- LCD Display and DVR on Surface
- 1km of fiber optic tether



Alberto Behar, PhD

Moulin Explorer Camera '09

- HD Digital Video Recorder on Solid State (Memory Stick)
- 1Km of Fiber Optic Cable, Bright White LED's
- Live Video Feed on Portable Video Screen

Moulin Explorer Cam 2007

Alberto Behar, PhD

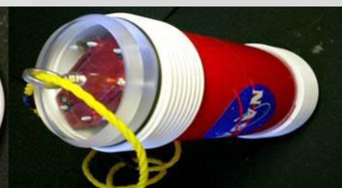
The Moulin Explorer

Designed to Collect 3-Axis Acceleration, Pressure (≤400m deep), and Temperature Data for Glacier Melt Water Flow through Greenland Moulins.

Andrew Elliott, Henry Wang, Sean O'Hern, Sujitha Martin, Collin Lutz, Alberto Behar
Jet Propulsion Laboratory, Pasadena, CA

Abstract

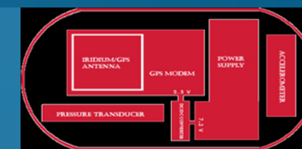
Recent data shows that the Greenland ice sheet has been melting at an accelerated rate over the past decade. This meltwater flows from the surface of the glacier to the bedrock below by draining into tubular crevasses known as moulins. Scientists believe these pathways converge to the ocean. The Moulin Explorer Probe has been developed to traverse autonomously through these moulins. It uses in-situ pressure, temperature, and three-axis accelerometer sensors to log data. At the end of its journey, the probe will surface in the ocean and relay its GPS coordinates so it may be retrieved via helicopter or boat The information gathered can be used to map the pathways and water flow rate through the moulins and help quantify the rise in sea levels and the effects of global warming on the polar ice caps.



Background

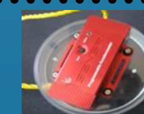
If the Greenland ice cap were to melt we would immediately experience a 20 foot rise in sea levels around the world. The implications of this rise to our costal regions would be disastrous. Scientists previously thought that the Greenland ice sheet would be around for at least another thousand years. However, recent observations suggest that the glacier is melting at a much faster rate than expected. It is thought that surface melt water travels to the bottom of glaciers and lubricates the region between glacier and bedrock, enabling the glacier to advance more rapidly towards the ocean. Understanding this interaction between melt water and glacial advancement is a key factor in understanding the effect of global warming on our poles, and its implications worldwide.

System Specifications



- **GPS Iridium Modem**
- **Dual Iridium-GPS Antenna**
- **6 LSH 20 lithium thionyl chloride D batteries**
- **Wide-input voltage regulator**

- **Buoyant PVC/acrylic cylindrical housing tested at 150 psi**

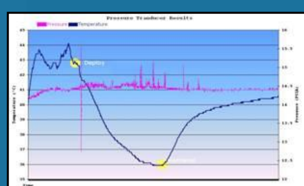


- **3-axis MEMS accelerometer**
- **Eyespliced rope attached to eyebolt for retrieval via helicopter**

- **Pressure (0 - 500 psi) and Temperature (range -40˚ C to 80˚ C) data logged on same unit**

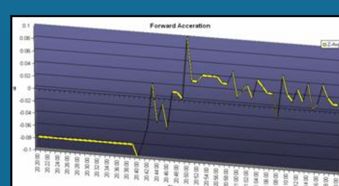
Testing

Before being deployed in Greenland, field tests were successfully performed in August, 2008 at the Santa Ana River near Riverside, CA. The river provided an environment similar to the interior glacial river of a moulin. After being released into the river, the unit drifted for 200 meters and was picked up using a 26 ft. telescoping pole. The system successfully recorded temperature, pressure, and accelerometer data for 2 hours.



Results

- Constant water pressure, 14.5 psi
- Gradual Decrease in temperature due to cooling effect of river water
- Logarithmic return to ambient temperature once retrieved from water
- The temperature drop lasted for approximately 40 minutes, which corresponds well to the time in the water.
- Z-Axis acceleration log reveals slight tilt (-0.08g) due to the accelerometer not sitting exactly parallel to the water surface
- The shallow water creates eddies which slow and accelerate the probe



Tracking Software

- The GPS tracker uploads its coordinates, along with date, time and elevation at predetermined intervals
- The Iridium network sends GPS data from the tracker to an established email as an attachment
- Our program queries the email account and decodes the attachment to obtain the GPS data
- It then formats the GPS reports as they come in from Iridium and uploads them to a central server where a web-based Google Earth API

Contact Information

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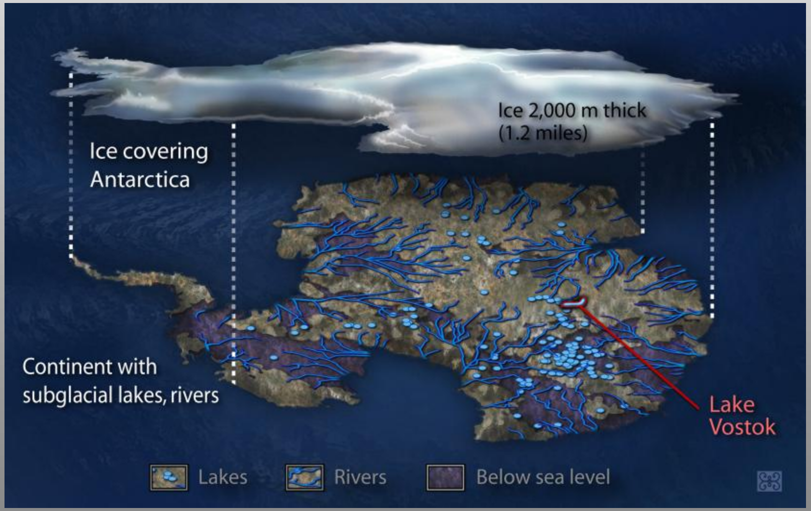
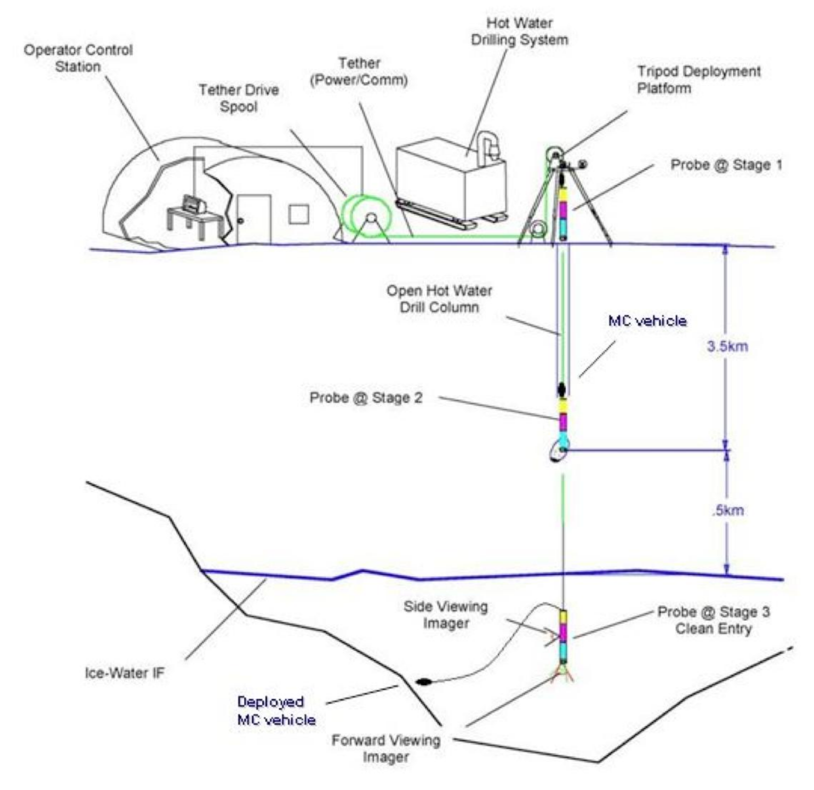
Sub Explorer Snapshot

- **Very miniature submersible for surveying "lake" type extreme environments.**
- **Deployment possibilities: Subglacial Lakes, Rio Tinto, subglacial volcanic lakes, drowned lava tubes, hydro-thermal vents etc.).**
- **Preliminary description:**
  - **Micro-submersible,**
  - **5 cm diameter and 20 cm long,**
  - **Battery powered,**
  - **Liquid compensated slim hull**
  - **comm. via fiber-optic tether (100-1000m),**
  - **camera + MEMS sensor suite**
  - **maybe one other instrument, pH or O_2 dissolved gas sensor, etc.**

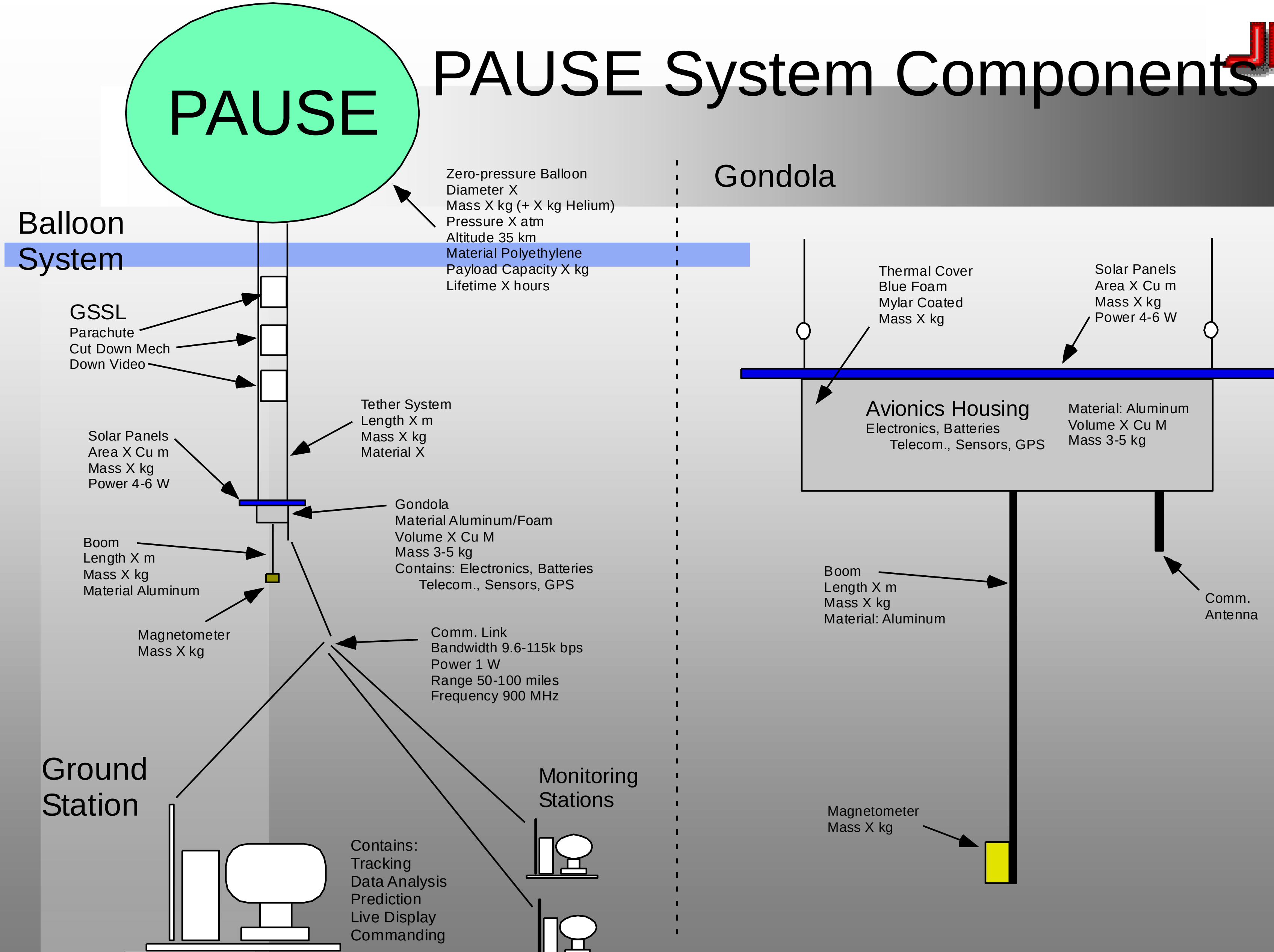


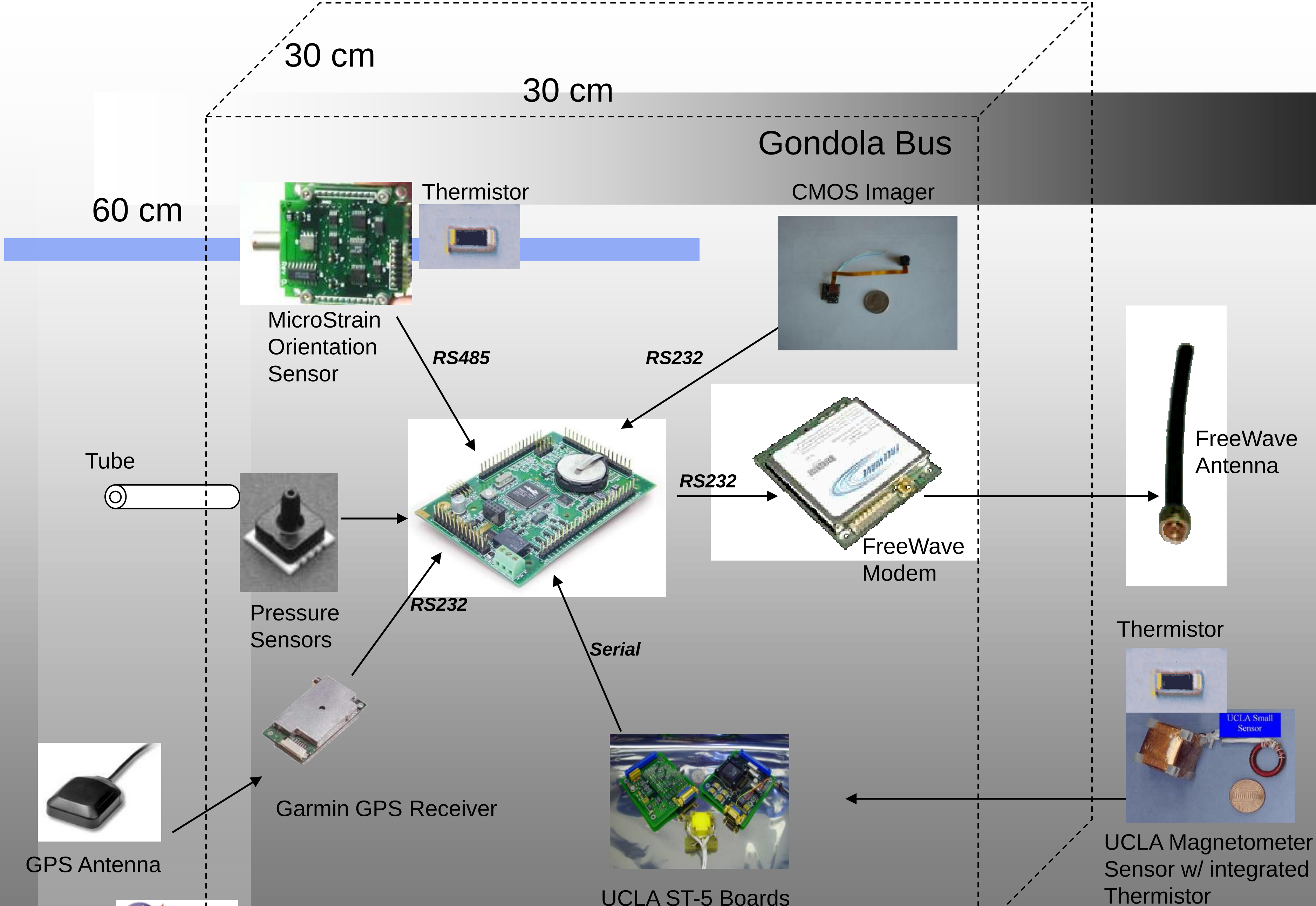
Operations Concept

- **Above the ice, the submerged micro-sub vehicle can be controlled through the fiber optic connection from the Operator Control Station**
- **Through a high resolution display and a Graphical User Interface (GUI) scientists can move the sub, receive vehicle status and collect scientific data in real time.**
- **The vehicle will have a degree of autonomy to simplify its operation, but if a scientific interesting area is found along the way, the controls can easily be taken over manually to make additional and closer observations and measurements**



PAUSE System Components




30 cm
30 cm
60 cm
Gondola Bus
Thermistor
CMOS Imager
MicroStrain Orientation Sensor
RS485
RS232
Tube
RS232
FreeWave Modem
FreeWave Antenna
Pressure Sensors
RS232
Serial
Thermistor
UCLA Small Sensor
Garmin GPS Receiver
GPS Antenna
UCLA ST-5 Boards
UCLA Magnetometer Sensor w/ integrated Thermistor