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California Institute of Technology

Moball-Buoy Network : A Near-Real-Time Ground-Truth Distributed Monitoring System to Map Ice, Weather, Chemical Spices, and Radiations in the Arctic

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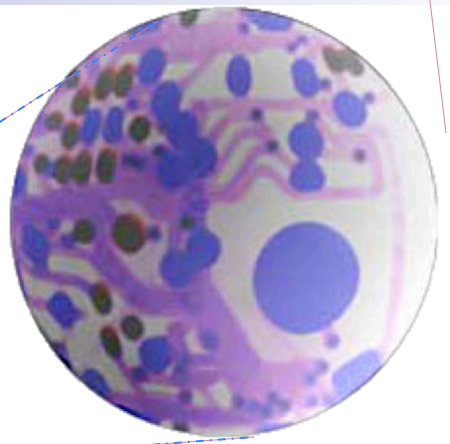
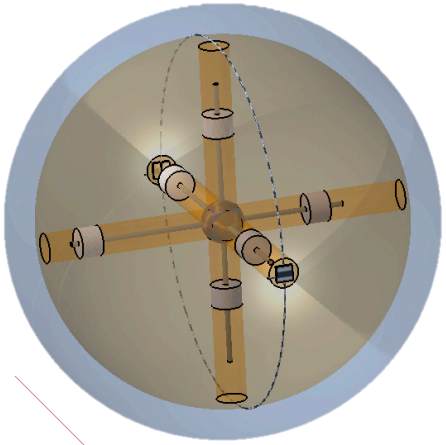
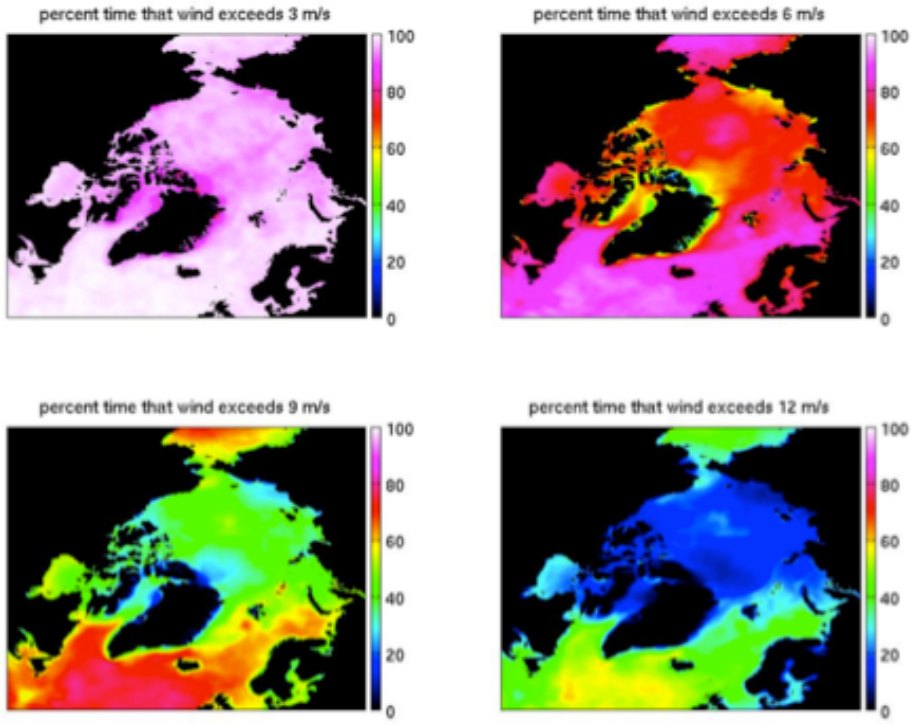
Moball-Buoy Network: A Network of Controllable and Self-Powered Wind-Opportunistic Spherical Mobile Sensors to Monitor the Polar Regions





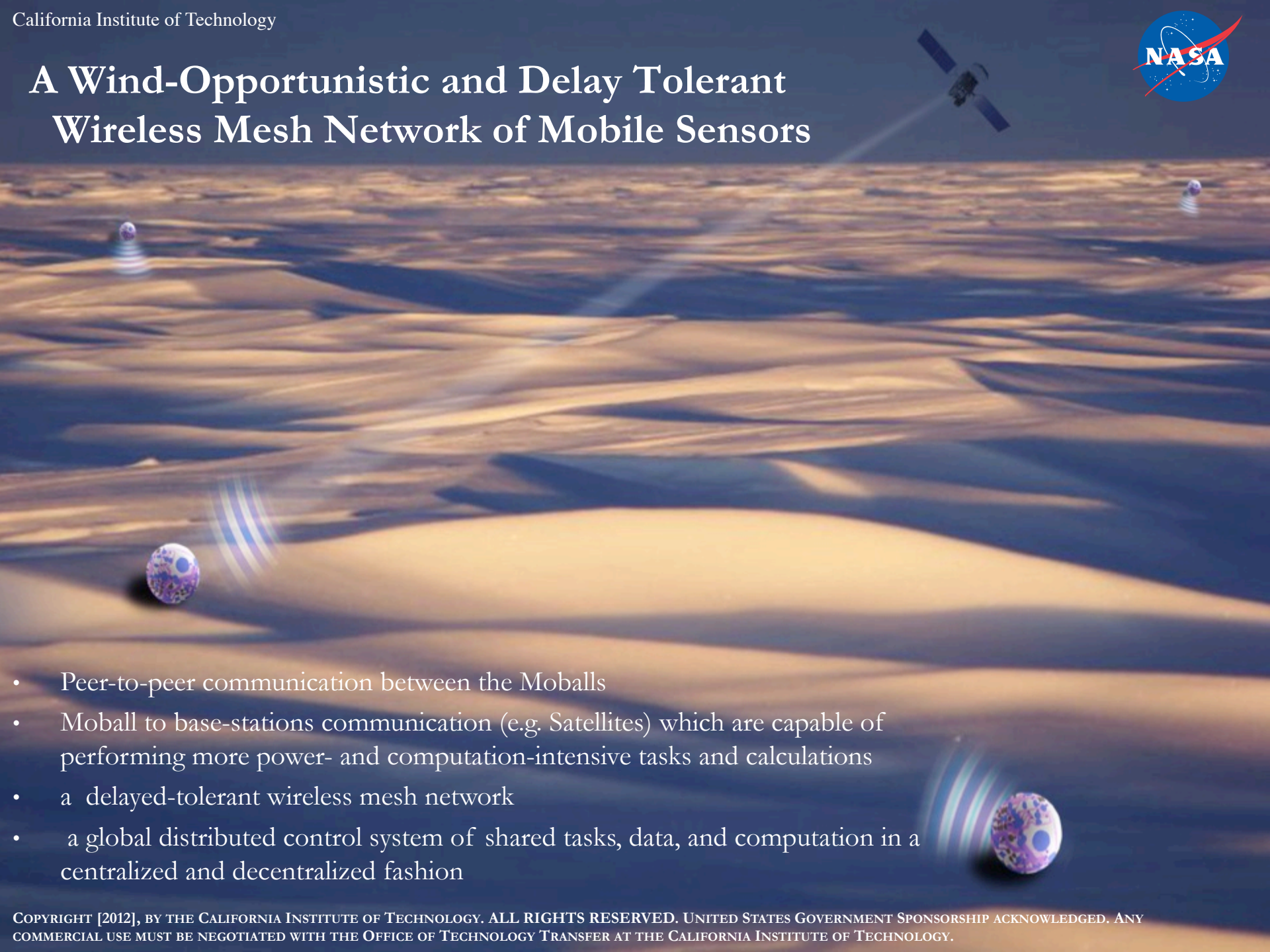
Moballs are self-powered and controllable multifunctioning sensor-platforms comprised of several low-power and low-mass sensors

Moball-Buoy Network



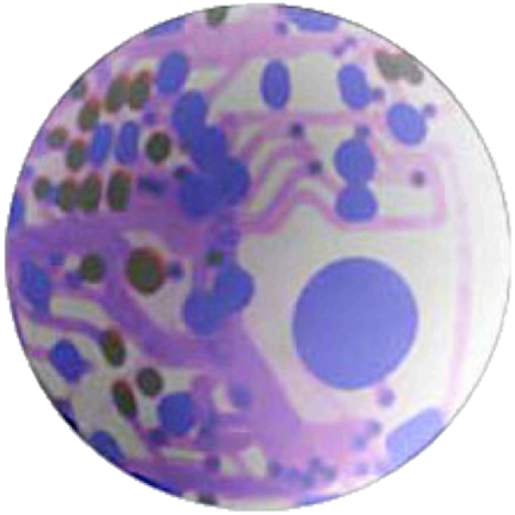
- Moballs take advantage of the abundance of wind, the vast flat regions in the Arctic (and other polar regions), and their novel mechanical and energy harvesting system for their mobility and energy harvesting
- System quickly performs in-situ measuring, mapping, and updating of the ice topography, ice condition, weather, and environmental conditions across the wider polar regions in real-time

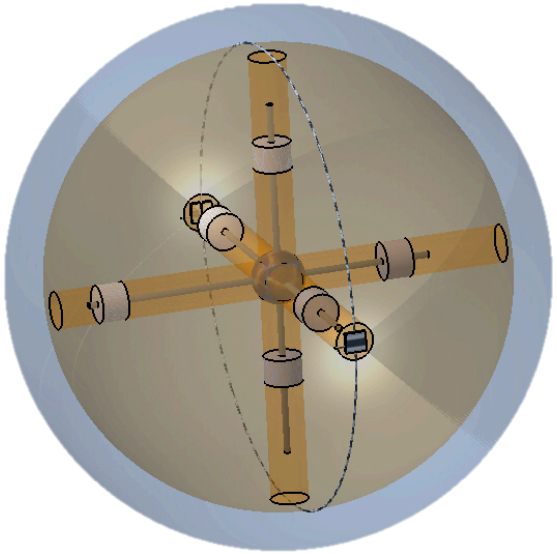
A Wind-Opportunistic and Delay Tolerant Wireless Mesh Network of Mobile Sensors

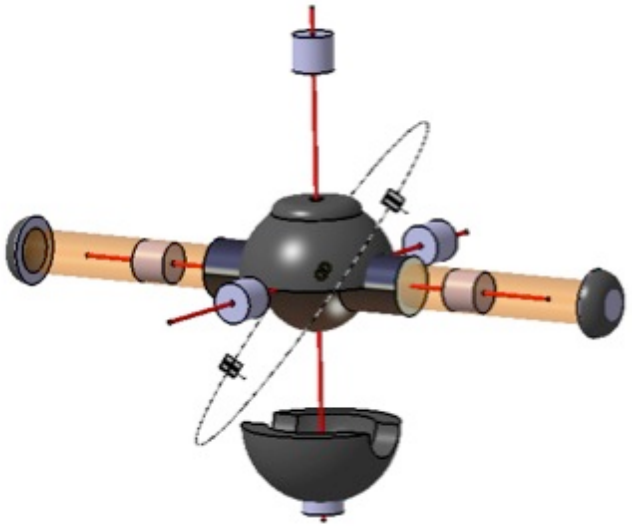


- Peer-to-peer communication between the Moballs
- Moball to base-stations communication (e.g. Satellites) which are capable of performing more power- and computation-intensive tasks and calculations
- a delayed-tolerant wireless mesh network
- a global distributed control system of shared tasks, data, and computation in a centralized and decentralized fashion

Moball-Buoy's Control Systems





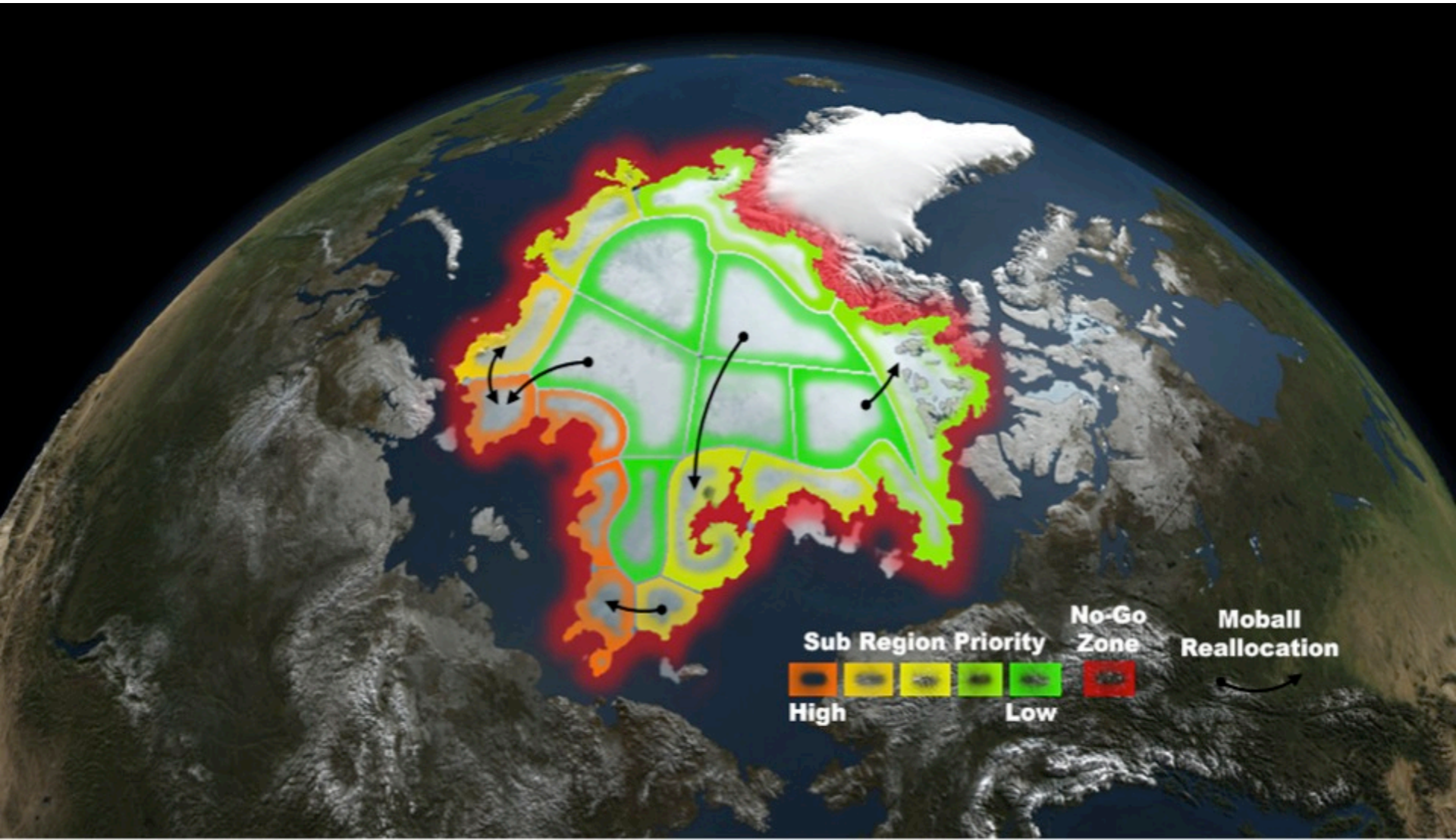


- Moball-Buoys are elastic spherical multifunctioning sensors that could move on the surface of the ice and the water. They can also be used in the water and below the ice sheets
- Moball-Buoys exploit their novel mechanical control systems, shown above, to initiate locomotion, to stop (e.g. bringing the center of the mass down) and to control their speed and trajectory
- Moball's dimensions (mass and diameter) are customized with the wind in the area
- The mechanics above can help the Moballs to harvest energy. (e.g. when the weights are magnets and tubes are covered with solenoid)

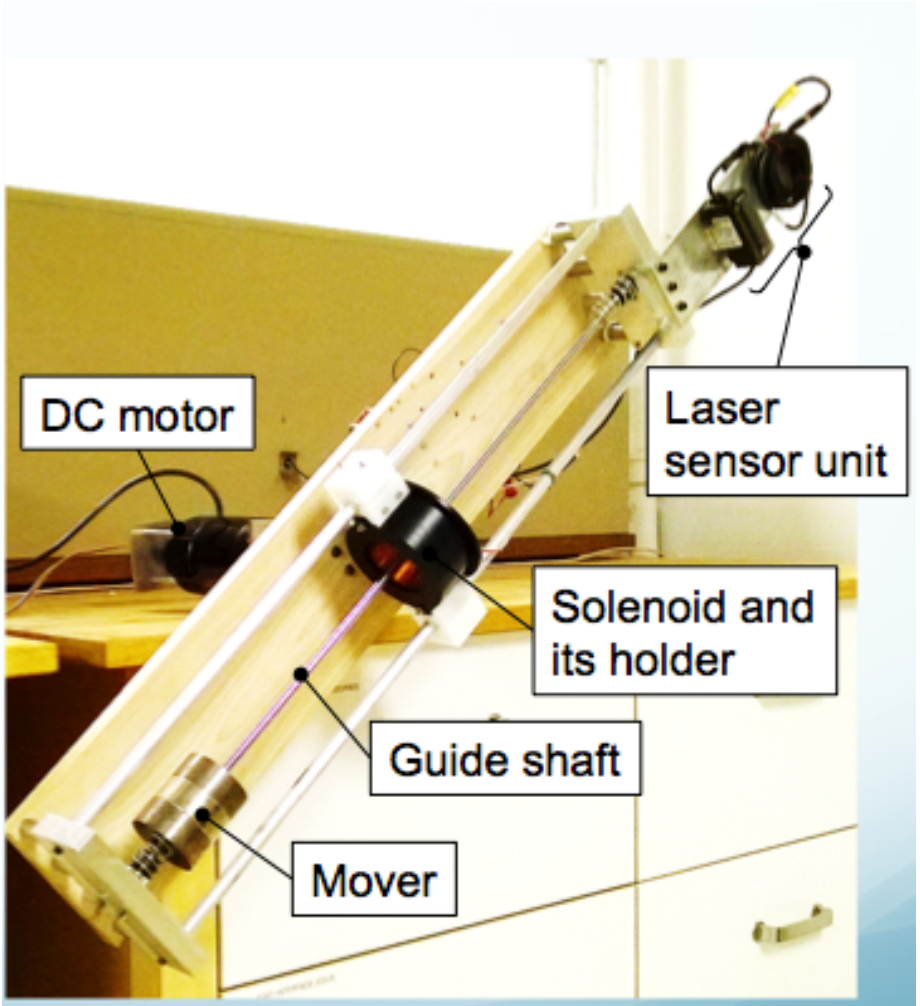
Moballs Can Float on the Surface of the Water Or Submerge under the water

- In Summer and when ice melts, the Moballs act as drifting buoys and could monitor the surface and under the surface of the water, and under the surface of the ice sheets.
- The Moball-buoys can adjust their buoyancy and therefore submergence. They can also use their novel mechanical system to move under the surface of the ice

Arctic Region Divided in Zones with Tunable Dynamic Priority Ratings and No-Go Zones



Current Status of the System Development

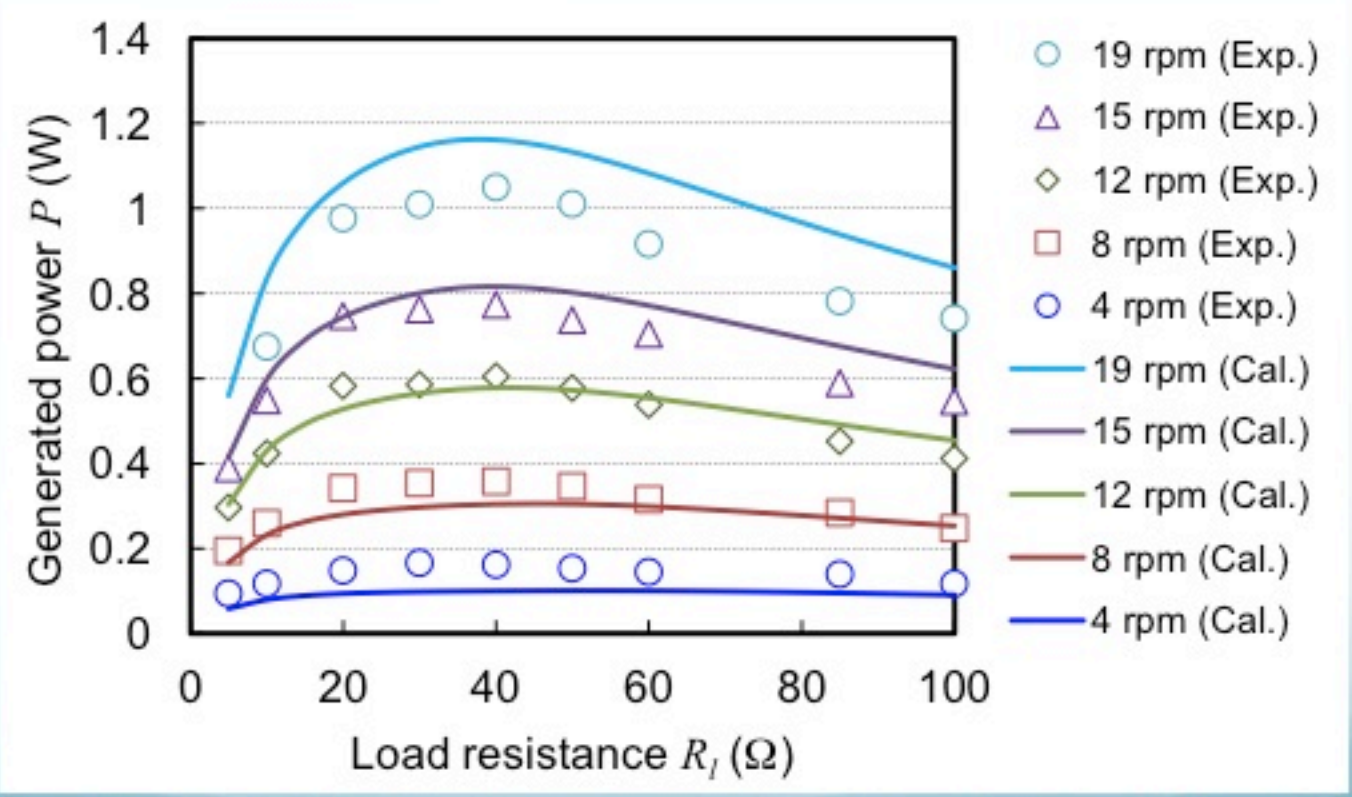


Experimental apparatus

Rotation test

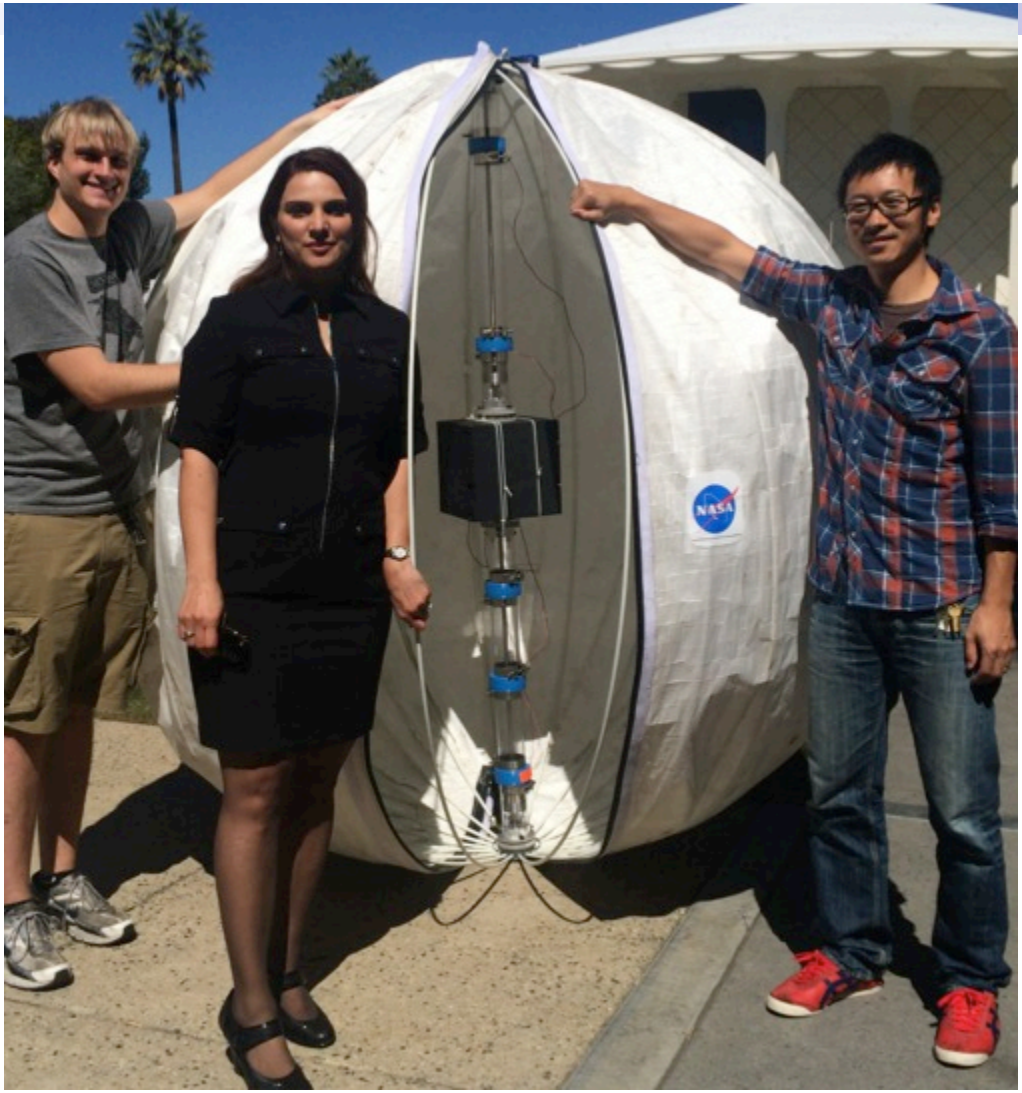
Results

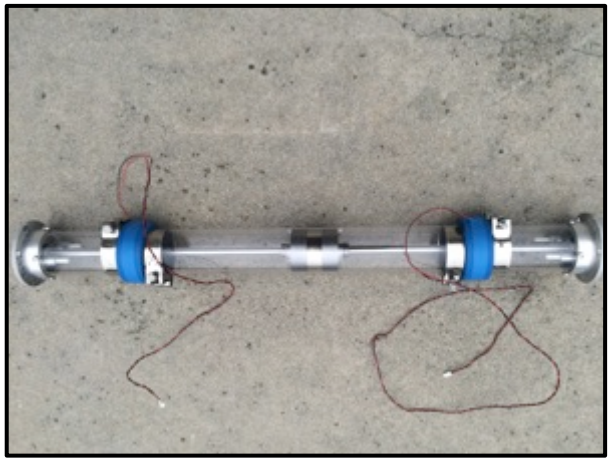
- Max. 1.05 W @ load of 40 Ω and speed of 19 rpm
- Experimental results were quite similar to simulation



Experimental results in comparison with simulation

Current Status of the System Development

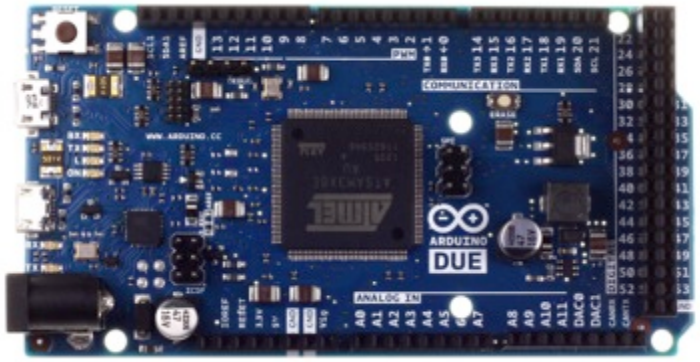




Current Status of the System Development

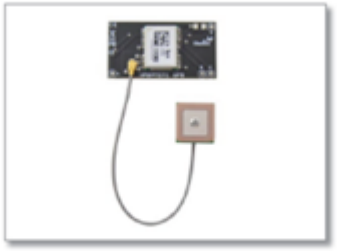
Moball-Buoy's Electronic Boards

Onboard Computing & Avionics:



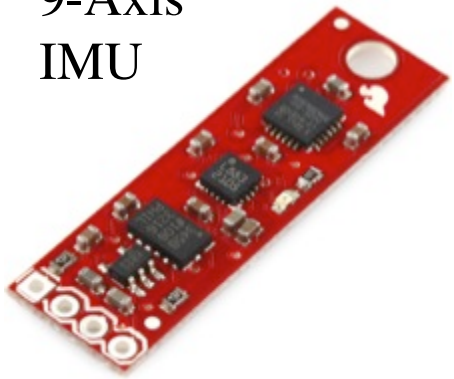
5-500 mW

GPS



Waspmote GPS module

9-Axis IMU



Initial Onboard Sensing Suit:

CO_2

CO_2 sensor

Methane

Gases Board

& more

Gases (CO, H_2S, O_2, O_3, H_2, NH_3, NOx, VOC)

Temp, pressure, humidity

Humidity sensor

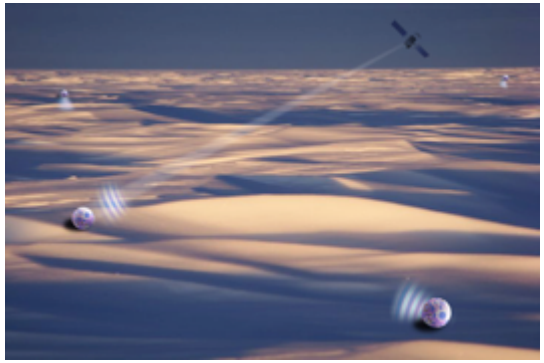
Water quality

Environ-mental

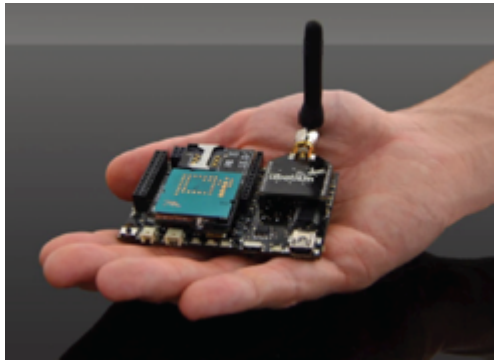
Video Camera Board

Optical & Camera

~1 watt



Moball-Buoy's Peer-to-Peer Communications Plan



Connection will be via Spread Spectrum Modems from Libelium for Waspmotes

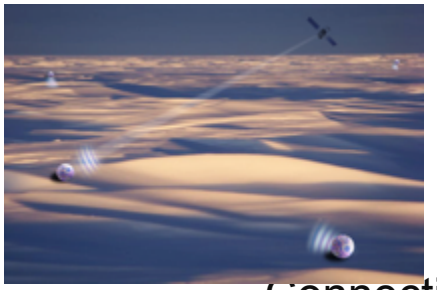
Waspmote works with different communication protocols (ZigBee, Bluetooth and GPRS) and frequencies (2.4GHz, 868MHz, 900MHz) and create links up to 12Km.

Initial selection for Moball is Highlighted.

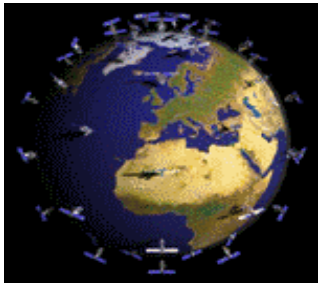
Communication radio	Frequency	Use zone	Protocol	SMA [A) B)]		On-chip [C)]	
				Power	Distance [1]	Power	Distance [2]
802.15.4	2.4GHz	World Wide	802.15.4	1mW	500m	1mW	100m
802.15.4 - PRO				63mW	7Km	63mW	360m
ZB			ZigBee - Pro	2mW	500m	2mW	100m
ZB - Pro				50mW	7Km	50mW	360m
868	868MHz	Europe	RF	315mW	12Km	-	-
900	900MHz	USA & Canada		50mW	10Km	-	-

Waspmote 802.15.4-PRO SMA 5dBi	W802P-SMA5	$194

From left to right: 0dBi, 2dBi, 4.5dBi, 5dBi antennas



Moball-Buoy's Satellite Communications Plan



Connection will be via Iridium 9603 SBD Modem

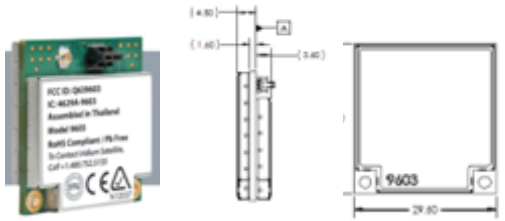
Recent advances in low-power communications using the new Iridium data capabilities now available (SBD, SMS) has allowed the development of systems that can stream transmit data (and receive commands) reliably in real time from very remote locations.

- Controller for Iridium® 9603 SBD transceiver
- 48 channel SiRFstarIV™ chipset based GPS
- 6 axes eCompass, providing tilt compensated orientation and acceleration information
- Serial interface for 3rd party equipment or PC control
- Wide supply voltage range (7 - 20 VDC)
- Fused 5V switched power output for external devices
- Two 12 bit Analog to Digital (ADC) inputs
- Four Digital I/O's (configurable as panic input)
- Digital temperature sensor
- Ultra-low standby power consumption (< 5 µA)
- Reverse polarity and transient voltage protection
- Extremely small package (2.1L x 1.75W x 1.25H inch enclosure)
- Easy integration into OEM products with a convenient DB15 interface

Cost: ~$450 + $100 for Dual Mode Antenna

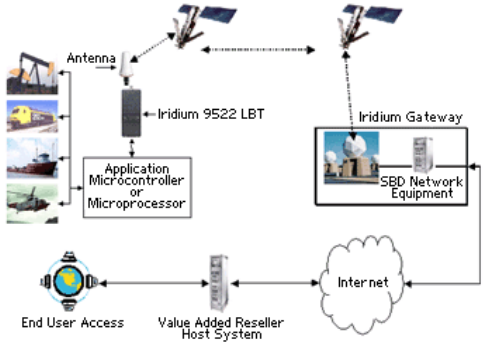
New Short Burst Data (SBD) Modems now Available

- Two Way Communication
- Data via Direct-IP socket to host computer or email
- Data delivery verification at remote (sending) site
- Cost: ~$250 Modem + $100 for (GPS/Iridium) Antenna



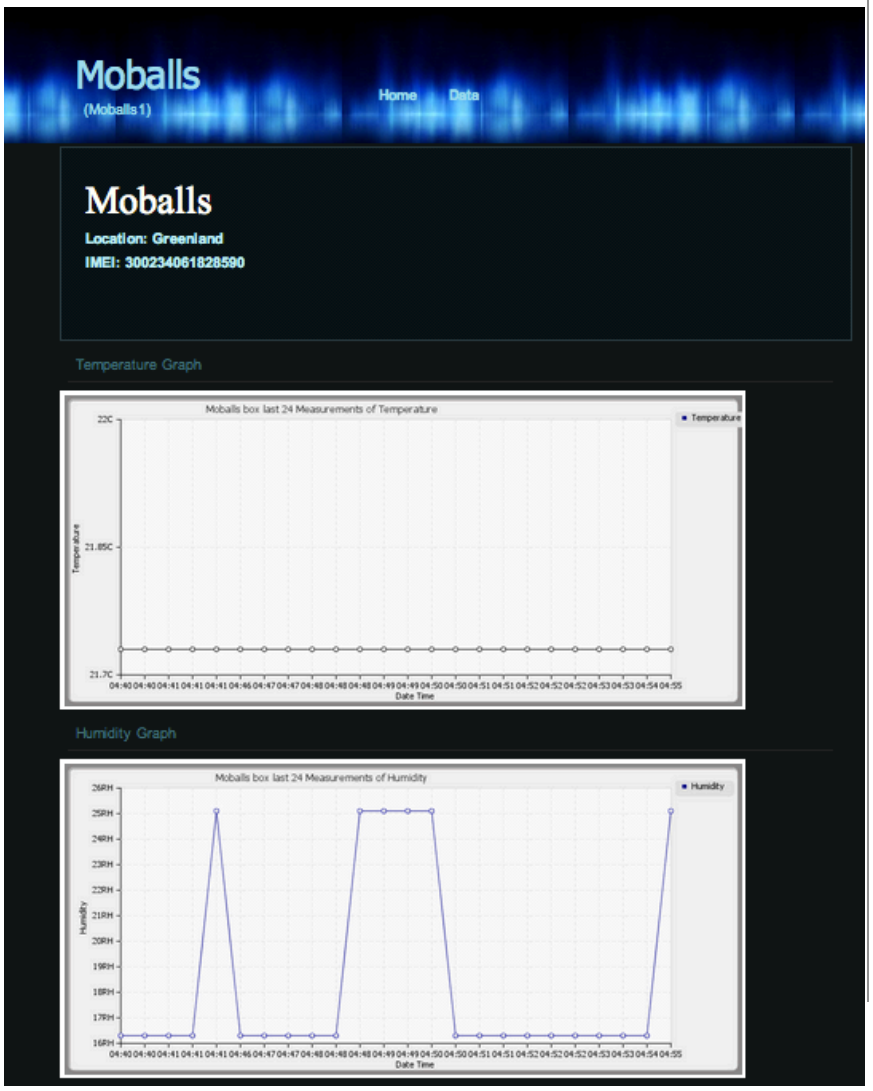
Global Coverage

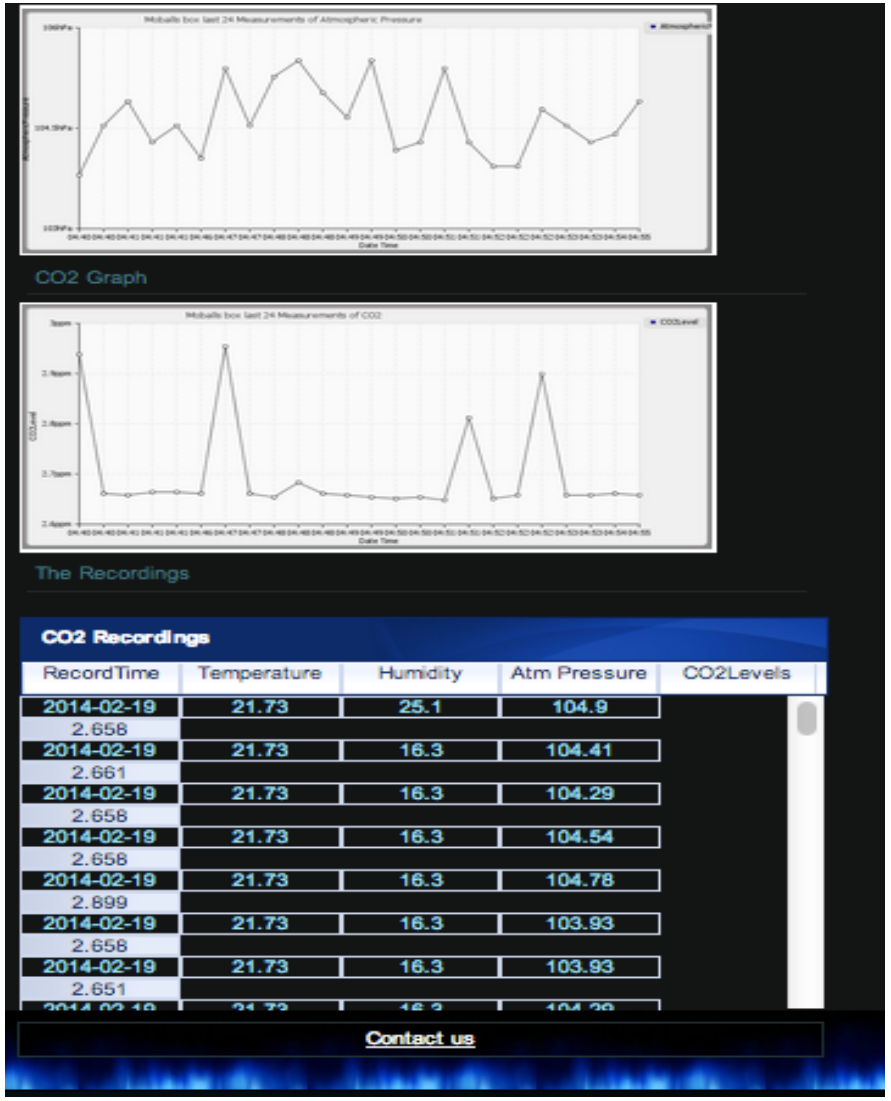
DOD SBD Modem Costs (Available to NSF/NASA/NOAA)		
Plan	*Monthly USAGE*	*Rate per Month*
Tier I	Unlimited	$138.21
Tier II	100 kb	$69.10
Tier III	30 kb	$26.59
Tier IV	Inactive	$10.63



Moball-Buoy Network's User Interface

(JPL/Alberto Behar)





Moball-Buoy's Transfer of Sensory Data via Peer-to-Peer Communication Transceivers

(JPL/Alberto Behar)