TAGGING OF OIL UNDER ICE FOR FUTURE RECOVERY FINAL REPORT

CONTRACT # E14PC00028

Ben Schreib,[1] Alex Bostic,[1] Jarrett Mitchell,[1] Alin Nomura,[1] Manuel Sanchez,[1] Jason Lin,[1]

Sam McClintock,[2] Ted Hale,[2] Navid Yazdi,[3] David Rein,[3] George Meng,[3] Casey Wallace,[3]

Elizabeth Skinner,[4] Mark Hinders[4]

URS (AECOM)[1]

Midstream Technology[2]

Evigia Systems[3]

College of William and Mary[4]

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URS

Point of Contact: Ben Schreib, ben.schreib@aecom.com

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APPENDICES

EXHIBITS

°C	degrees Celsius
2D	two-dimensional
3D	three-dimensional
AC	alternating current
API	Application Programming Interface
BSEE	Bureau of Safety and Environmental Enforcement
cm	centimeters
C-PVC	chlorinated PVC
COTS	Commercial-off-the-shelf
CRREL	Cold Regions Research and Engineering Lab
GIS	Geographic Information System
GPS	Global Positioning System
GRF	Geophysical Research Facility
Hz	Hertz
ICEX	Ice Exercises
IFTS	Ice Floe Tracking System
INTR	interrupts
IP	Internet Protocol
JSON	JavaScript Object Notation
LDGRIDSAT	Lamb-wave Detection Geo-Referencing Identification Satellite
LPSM	Low Power Storage Mode
kHZ	kilohertz
MCU	Microcontroller Unit
mg/ml	milligrams per milliliter
MHz	megahertz

MM	millimeter
MM	Maintenance Mode
MO	Mobile Originated
OD	outside diameter
PP	polypropylene
PPS	pulse-per-second
PVC	polyvinyl chloride
PVC-M	modified PVC
RF	Radio Frequency
SBD	Short Burst Data
SPI	serial peripheral interface
URS	URS Corporation
USB	Universal Serial Bus
UTC	Coordinated Universal Time
UWID	Underwater Identification
V	Volts
VDC	Volts Direct Current

SECTION ONE: INTRODUCTION

The purpose of this project was to develop a system that could be used to mark and track ice floes with entrapped oil until such time it could be successfully recovered. URS Corporation (URS) along with its team members Midstream Technology, Evigia Systems, and the College of William and Mary, in coordination with BSEE, developed the Ice Floe Tracking System (IFTS) presented herein. The IFTS comprises the Lamb-wave Detection Geo-Referencing Identification Satellite (LDGRIDSAT) tag, Underwater Identification (UWID) tag, and associated cloud infrastructure and user interface.

The system was successfully designed, developed, and tested over the past 2 years. Tasks 1 through 5 highlight the team's work and accomplishments.

- Task 1: Kickoff meeting to present the system architecture and concept. Discussions were based on the available commercial-off-the-shelf (COTS) hardware and software that could be integrated or modified and ancillary services, such as the satellite network, to meet the system objectives. The conceptual design, hardware, software and services selection process was formalized through a COTS trade study.
- Task 2: Design of the LDGRIDSAT and UWID tag devices, network interfaces, and the cloud infrastructure data message format from the satellite gateway to the mapping user interface. This task resulted in a detailed design report.
- Task 3: Prototyping of the LDGRIDSAT and UWID hardware.
- Task 4: Development of the mapping user interface and implementation of the cloud infrastructure.
- Task 5: Unit and system testing and demonstration of functionality and capabilities.

The key novel developments included:

- Implemented a pinging lamb wave, acoustic-based communication system for use in an UWID tag.
- Developed a COTS-based LDGRIDSAT tag that is ruggedized for the Arctic environment and for a variety of deployment options, including air drops.
- Adaptive power management algorithms were implemented in conjunction with interfaced sensors to automatically stay dormant, when needed, to conserve power.
- Employed an adaptive system-level approach, along with an innovative packaging, material, and coating design that will mitigate the adverse effects of snow buildup and ice formation on the wireless links, presented in Appendix A.

These key novel developments enabled the URS Team, along with BSEE, to demonstrate a system to enhance situational awareness using near real-time and cost-effective tagging and tracking of ice floes, thereby contributing to enhanced safety and environmental protection during an extended oil spill response and recovery effort.

SECTION TWO: SYSTEM ARCHITECTURE

Once oil has been detected underneath an ice floe, the IFTS could be used to track that ice floe's movement so that the oil spill can be remediated at a later date. The IFTS consists of several distinct parts, summarized in Exhibit 1, that work in concert to track the ice floe target area:

- UWID Tag: The UWID tag is equipped with an acoustic transducer that projects sound at a critical angle to the ice to create Lamb waves and Rayleigh waves, collectively referred to as "guided waves." The UWID tag is deployed underneath the ice with sufficient buoyancy to float up through sea water and oil to the bottom surface of the ice. The UWID tag then projects a tone burst up into the ice. The guided waves propagate as a plate wave that travels horizontally within the ice floe, allowing surface detectors (the LDGRIDSAT tag) to detect the transponder.
- LDGRIDSAT Tag: The LDGRIDSAT tag can be delivered by hand or lodged by aerial drop into the ice. The LDGRIDSAT tag can be used by itself to mark a location, or it can be combined with an onboard guided wave detector that can locate one or more UWID tags placed under the ice. Three to five LDGRIDSAT tags placed around a complex spill may be able to identify and triangulate a number of UWID tags, and continue to track them if the oil shifts; new UWID tags added to ice floes can also be tracked.
- Cloud infrastructure and user interface: This backend system includes the satellite system needed for the LDGRIDSAT tag to communicate. Because of extreme latitudes for some of the target locations, the satellite system is the Iridium network. The server and database are hosted in the cloud, and GIS software incorporates the user interface for extracting and displaying the actionable information to stakeholders.

Exhibit 1 shows the overall architecture and each component within the IFTS. The messages passed between the UWID tags to the LDGRIDSAT tags and on to the satellite gateway are detailed in the design report, but are summarized as:

- UWID beacon signal to LDGRIDSAT: The message communicated is a single binary output. The communication between UWID and LDGRIDSAT tags is performed through a simple acoustic signal at low frequency. The communication has no overlying protocol; it is a simple detect mode by the LDGRIDSAT of the UWID broadcast acoustic wave. The detection is only one bit, 0 for no signal, and 1 for a signal.
- LDGRIDSAT message format to cloud infrastructure: The UWID tag beacons are aggregated along with the LDGRIDSAT tag message and sent from the LDGRIDSAT tag to the server over the Iridium satellite network to the cloud infrastructure for interpretation and further processing for final display on the mapping user interface.
- Multi-block packet header: When a LDGRIDSAT message is larger than the Iridium's Short Burst Data (SBD) message payload of 340 bytes, the LDGRIDSAT sends the message in multiple SBD packets. Each packet has a 3-byte block header followed by up to 337 bytes of the message.

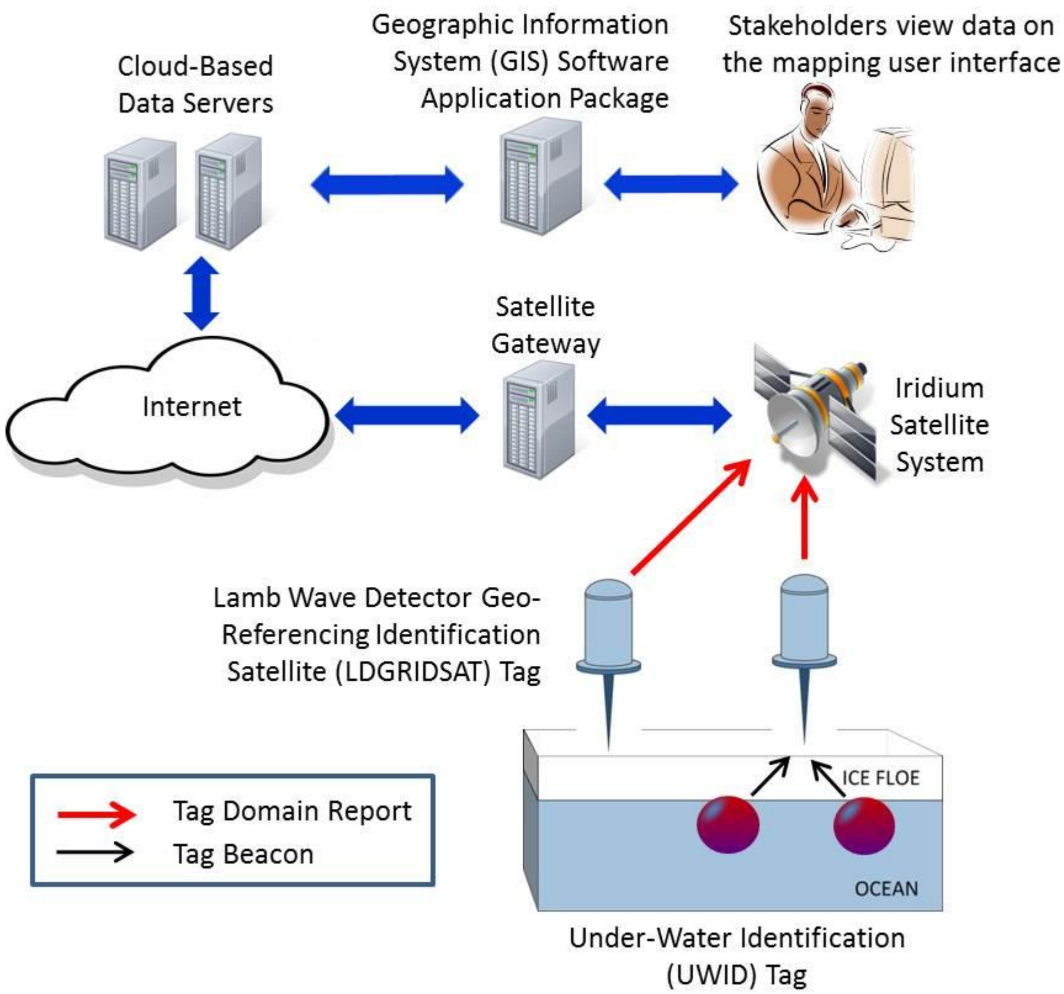


Exhibit 1: Block Diagram of IFTS Architecture

2.1 TRADE STUDY SUMMARY

The URS Team conducted a trade study and assessment of various COTS technologies and available components to determine the most feasible approach for designing and deploying the IFTS for tracking oil under ice floes in Arctic marine environments. Because there were no COTS devices with the functionality needed for the LDGRIDSAT and UWID tag, the trade study started a continuous-feature design exercise rather than a discrete comparison of available options.

We considered types, orientation, and frequency of transducers along with packaging and testing considerations for the UWID tag. The LDGRIDSAT tag components were based on previous satellite-enabled tracking tags; the trade study, which included radio frequency modules; GPS modules; antennas; accelerometers; batteries; and support infrastructure, such as the satellite gateway, cloud server, and software tools for the user interface. Additional emphasis was placed on functionality in extreme arctic and marine environments where the tag would have to be saltwater- and corrosion-resistant, and be able to function to -40 degrees Celsius (° C). The trade study found the best components, as well as alternate components in the case of integration or product idiosyncrasies discovered during the design, production, and testing phases.

2.2 DESIGN SUMMARY

The URS Team submitted an IFTS design report that outlined and described the Team's methodology for developing and analyzing the system requirements. This included a house of quality that ranked functional and engineering requirements. The UWID tag's acoustic beacon and the LDGRIDSAT tag's satellite communication had the highest technical priority. The team developed a failure modes, effects, and criticality analysis that identified possible failure modes throughout the system, an analysis of power budgets, potential reliability, and network interfaces. These exercises culminated in the team's selection of components, initial design, and integration for the major subsystems that included the LDGRIDSAT tag, UWID tag, cloud infrastructure, and user interface.

The LDGRIDSAT tag was based on a satellite-enabled tracking tag, but also included:

- An air-droppable format and enclosure sufficient to survive terminal velocity impact into the ice
- An additional accelerometer used as the sound sensor for the Lamb waves
- Software heuristics to pull the Lamb wave or guided wave acoustic signal from the background noise

The UWID tag design included:

- A transducer to generate low-frequency guided-waves for detection by the LDGRIDSAT tag
- An enclosure design for transducer orientation against the bottom of an ice floe

The cloud infrastructure and user interface design included:

- An interface with the satellite gateway to accept the incoming LDGRIDSAT tag domain reports
- Storage and interpretation of the data for display on the user interface

There were several design iterations and versions of each system component, the latest versions are described in the following section.

SECTION THREE: SYSTEM OVERVIEW

As described in the system architecture, the system has three primary subsystems: the LDGRIDSAT tag, UWID tag, and cloud infrastructure, which includes data acceptance from the satellite gateway, data processing, and display on the mapping user interface.

3.1 LDGRIDSAT TAG

This section summarizes the design elements, components, and protocols of the LDGRIDSAT tag. The LDGRIDSAT is designed to detect the guided wave signals from the UWID and report the collected information through a satellite gateway back to the cloud infrastructure and user interface.

3.1.1 Device Architecture Design

As shown in Exhibit 2, the LDGRIDSAT tag hardware includes the primary device microcontroller unit (MCU), motion sensor, satellite modem, GPS module, and high-capacity batteries. Additionally, a second, signal detection MCU and accelerometer are used for UWID beacon detection. The firmware for the device MCU was developed to improve power management and communicate with the signal detection MCU. Descriptions of the modules are presented in the following sections. The LDGRIDSAT hardware uses existing communication standards and interfaces, including serial, interrupts (INTR), analog, pulse-per-second (PPS), and serial peripheral interface (SPI).

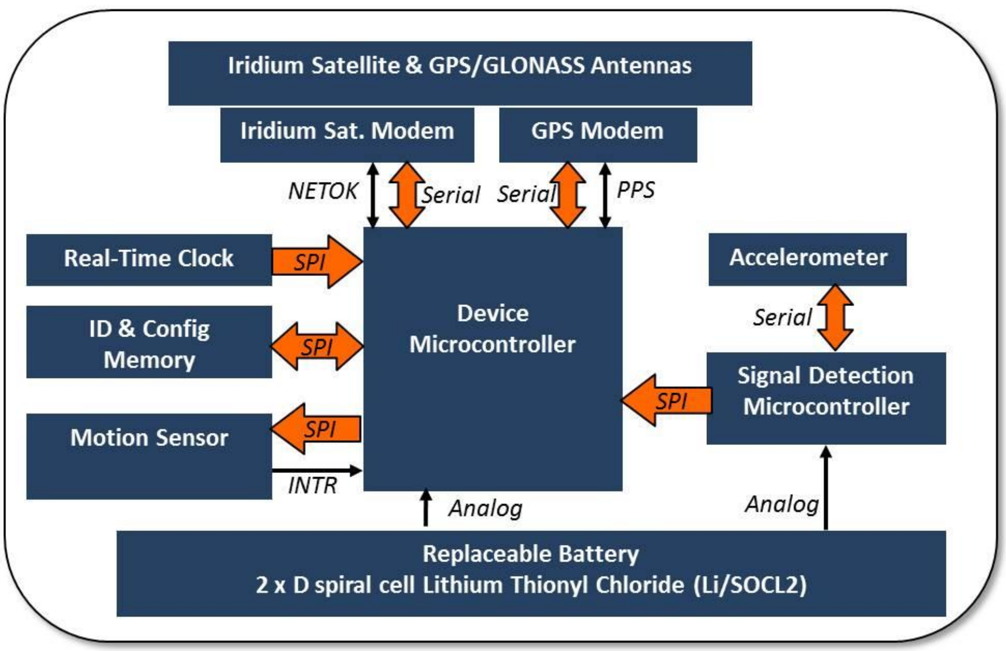


Exhibit 2: LDGRIDSAT tag architecture

3.1.1.1 Device Microcontroller Unit

The LDGRIDSAT tag architecture includes a device MCU to act as a border router host, providing the gateway between external communications and the signal detection MCU. It directly interfaces with the LDGRIDSAT tag GPS and Iridium modem. Exhibit 3 shows the LDGRIDSAT internals and primary hardware components.

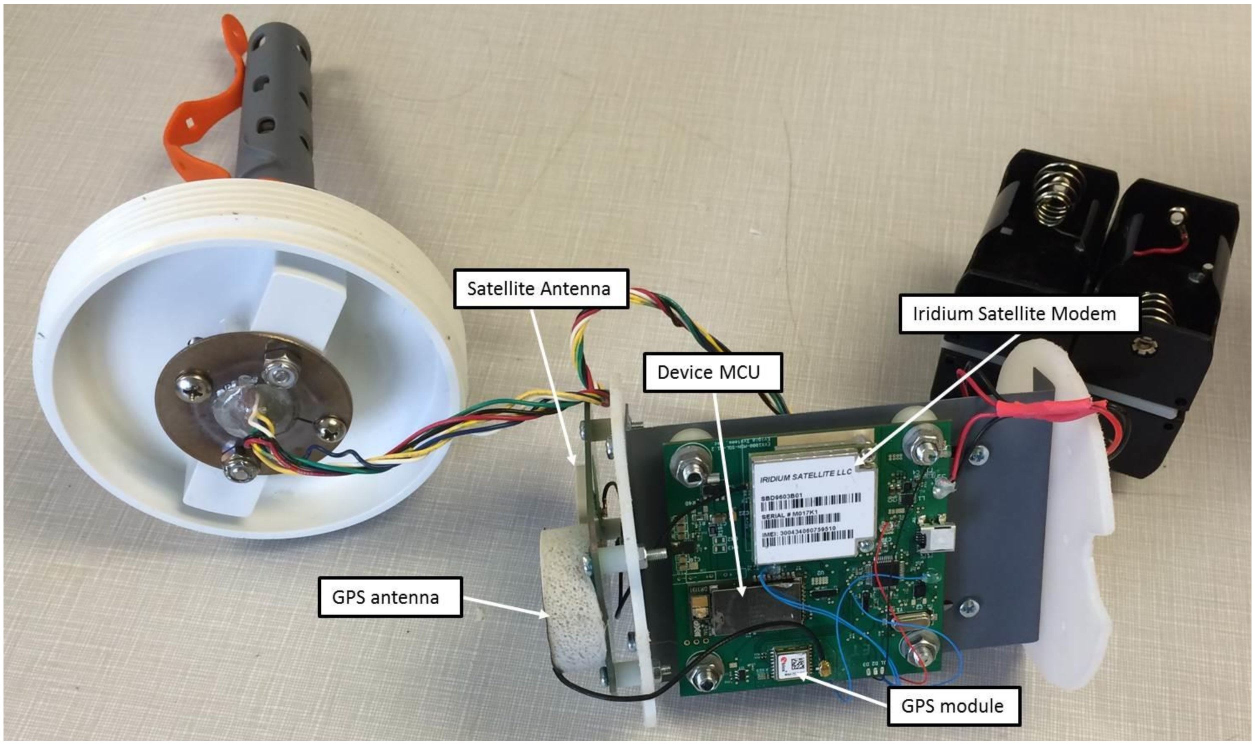


Exhibit 3: LDGRIDSAT components and packaging – Device MCU side

3.1.1.2 Signal Detection Microcontroller Unit

The signal detection MCU directly interfaces with the accelerometer to detect, collect, and analyze guided-waves produced by the UWID tag. Exhibit 4 shows the LDGRIDSAT internals on the opposite side from what is shown in Exhibit 3.

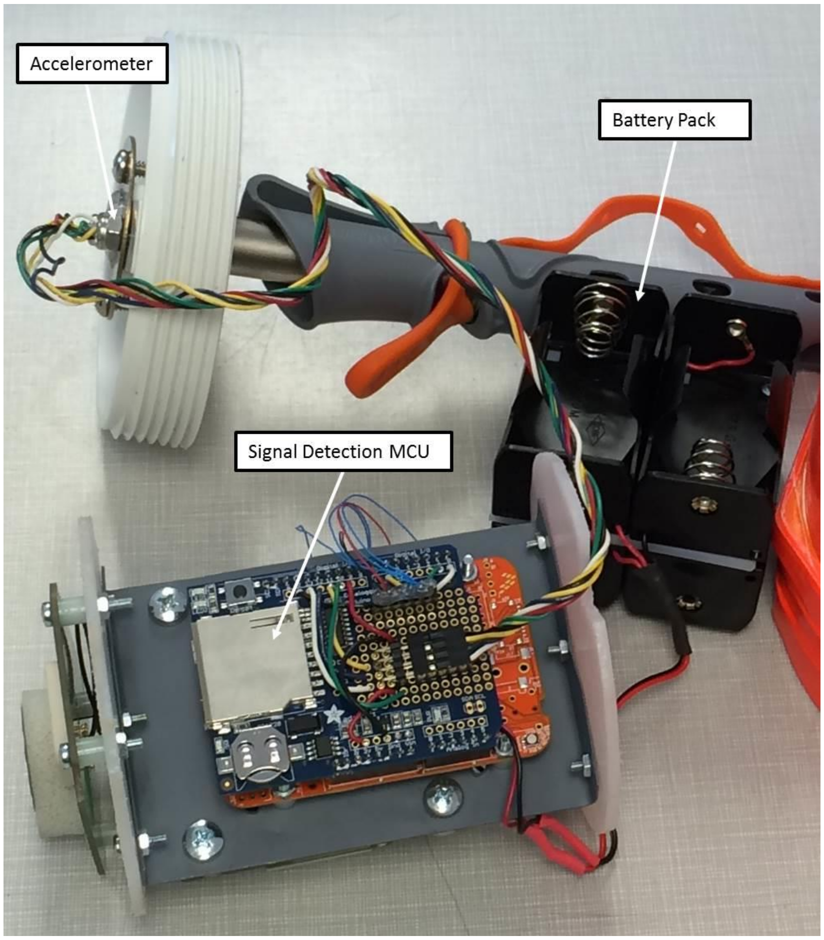


Exhibit 4: LDGRIDSAT components and packaging – signal detection MCU side

3.1.1.3 Accelerometer

The 3-axis accelerometer collects data at a rate of 3.2 kHz and acts as the acoustic signal detection sensor.

3.1.1.4 Iridium Modem

The LDGRIDSAT tag uses the Iridium 9603 modem module for communications with the cloud server and GIS interface, periodically sending LDGRIDSAT tag domain reports. The satellite modem operates in the frequency range of 1616 to 1626.5 MHz and implements the SBD protocol with a message payload size of 340 bytes.

3.1.1.5 Sensors

The LDGRIDSAT tag's MCU directly interfaces with the included sensors: GPS, motion, and battery. User settings define polling rates for each sensor and the calibration/conversion coefficients.

3.1.2 Firmware and Algorithms

Firmware on the LDGRIDSAT tag was modified and enhanced to implement the satellite communication, power management, and UWID signal detection.

3.1.2.1 Device MCU Functions

The device MCU sleeps most of the time, but wakes to process messages from the signal detection MCU and for periodic server update cycles. The server update cycle is activated when the device MCU gathers the information needed to create the LDGRIDSAT tag domain report, including checking system status and waiting for a GPS fix.

- Device MCU handling of messages from the signal detection MCU – Receives processed UWID detection notification, then updates information in table
- Device MCU incoming signal from motion sensor – Receives motion detection, then initiates timer to determine state change
- For each server update cycle, the MCU performs the following operations:
  - Powers on GPS and waits for a stable fix, then powers off GPS
  - Generates LDGRIDSAT tag domain report
  - Powers on Iridium modem, which then:
    - Waits for satellite detection
    - Connects to satellite and opens channel for communications
    - Sends LDGRIDSAT tag domain report using SBD protocol
    - Waits for packet acknowledgment
  - Powers down Iridium modem
  - Sleeps until the next server update cycle or signal from motion sensor

3.1.2.2 Signal Detection MCU Functions

The UWID signal detection MCU has the following functions:

- Ingests raw accelerometer data by the signal detection MCU
- Applies guided-wave detection algorithms to the data
- If the algorithm output determines a UWID beacon is detected, passes the information to the device MCU for inclusion into the LDGRIDSAT tag domain report

3.1.2.3 Time Synchronization

The LDGRIDSAT tag uses the GPS Coordinated Universal Time (UTC) time to set and maintain its real-time clock, which is GPS time plus the correction for leap seconds.

3.1.2.4 Firmware Segment for Controlling Iridium Modem Module

The device MCU communicates with the satellite modem over an asynchronous serial interface. Data packets are sent as SBD messages to the Iridium system. The Iridium gateway sends the messages to the cloud server and GIS interface as Mobile Originated (MO) direct Internet Protocol (IP) transfers.

The payload for SBD messages is 340 bytes. If a LDGRIDSAT tag domain report has more than 340 bytes, then the LDGRIDSAT message is sent as a multi-block message.

3.1.3 Enclosure

Exhibit 5 below shows the enclosure, in ice spike and ice screw configurations to meet the specific deployment requirements. The ice spike is for aerial deployments and the ice anchor to screw in by hand. All surface tags were painted in fluorescent green and fluorescent orange for aerial and ice anchor tags, respectively.

Exhibit 5: LDGRIDSAT enclosures in ice spike and ice screw configurations

Several materials were tried for tag housing, and in almost all cases the Team opted for piping of approximately 90 mm / 3 inch to 110 mm / 4 inch outside diameters (ODs) as these were easily obtained COTS products. The team worked with three variants of polyvinyl chloride (PVC): standard PVC, modified PVC that has an impact modifier (PVC-M), and chlorinated PVC (C-

PVC). PVC-M showed the most promise, but PVC-M flanges still failed side impact tests at a height of 35 meters. One chemical weld of standard PVC also failed at temperatures below freezing, which also weighed in eliminating PVC and its variants for housing material.

The team finally settled on polypropylene (PP) pipe material in both 90 mm and 110 mm ODs, and 80 mm and 99 mm inside diameter, respectively. The PP material was harder to work with and required thermal bonding at 250 °C instead of chemical bonding, but the PP material had excellent resilience to impact and temperature. PP flanges and caps were also used to complete the electronic payload housing.

The tag's electronic payload was affixed to a vertical, steel back plane, with PP disks at the top and bottom to keep it properly oriented in the PP piping. The standard integrated circuit boards were not changed, but attached to the back plane, with epoxy re-enforcement of critical connections. The Iridium satellite antenna and GPS antenna were affixed to the top PP disk. The team used four D-cell lithium thionyl chloride batteries for all surface tags.

3.1.3.1 Aerial Ice Spikes Tag

The aerial tag design needed to include the ability to maintain an upright profile on landing, absorbing some of the impact, and maintaining contact with the ice so the on-board accelerometer would be able to detect guided waves emanated from subsurface UWID tags. Other design challenges included the fact that dropping from any height onto ice was similar to impacting on concrete, that the ice floe had a variable layer of 5 to 15 cm of snow and fine grain ice on the surface, and that any spike impacting the ice tended to create a small crater.

The final design incorporated copper strips that were folded to make 1.25 cm broad spikes, with three spikes on the outside, and the other ends to make one central spike. This design enabled a certain amount of tag stability, and the copper was thin enough that it would bend and crumple on impact. After some external testing on dirt and sand, the team chose two common thicknesses of copper, 1/16 inch and 1/8 inch, to use in two different variants, type A and type B, respectively, of the aerial tag. These copper spikes were bolted to the bottom of a PP flange at the bottom of the aerial tag and cut to provide approximately 5 mm to 10 mm impact surfaces at the point of each spike.

Exhibit 6: Aerial Ice Spike LDGRIDSAT Type A (left) and Type B (right)

To maintain a vertical profile for impact onto the ice and slow the descent slightly, the team employed drogue streamers attached to the top of the tag. Streamers were used instead of a small parachute so that the tag would remain stable on impact. With the high winds on the ice floe, using a parachute that did not detach on impact would eventually cause the tag to fall over and be dragged. For these tests, the team used three strands of 2 meter by 2.5 cm by 0.05 mm PVC tape. The thin PVC tape was fluorescent green and pink and was attached by knotting one end of all strands around a metal wire attached at the top of the tag.

3.1.3.2 Ice Anchor Tag

The primary difference between the ice anchor and aerial drop LDGRIDSAT tags is that the ice anchor tag is meant to be deployed by hand onto the ice surface. To accommodate this, the team selected a 17 mm long steel ice anchor commonly used for ice climbing. The Team cut the end of the ice anchor off, welded a washer to the end, and potted the accelerometer in the top of the ice anchor. Then, the ice anchor with accelerometer was bolted to the bottom of the LDGRIDSAT tag. The ice anchor LDGRIDSAT tag is easily screwed into the ice floe by hand with no special tools needed.

3.2 UWID TAG

This section summarizes the design elements, components, and protocols of the UWID tag. The purpose of the UWID tag is to generate low-frequency guided waves in the ice floe, enabling the LDGRIDSAT tag to detect these vibrations at the top surface as they spread out in a circular fashion.

3.2.1 Device Architecture Design

As shown in the UWID tag architecture block diagram (Exhibit 7), the design includes a device controller, power supply, transducer driver, and signal generator and acoustic transducer. There are two versions of the UWID tag, a tethered version using an AC power supply and analog controls, with the untethered version using batteries and an MCU. The tethered version was needed for its flexibility in different testing scenarios, such as varying operating voltages and increasing the number of acoustic pulses available, which maximized the limited amount of time available at each test site.

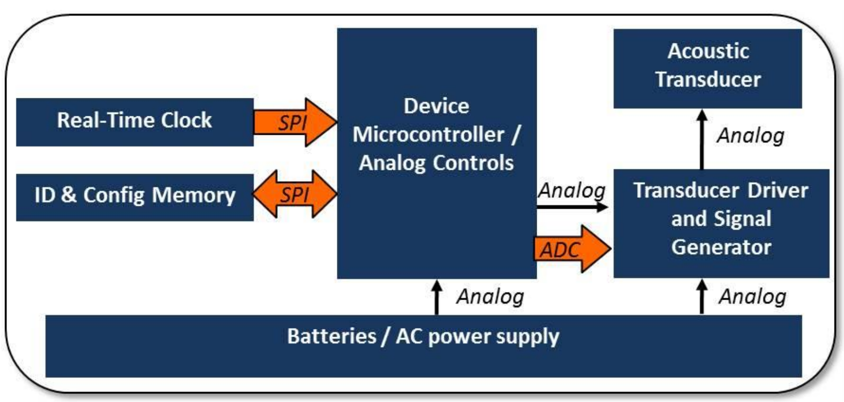


Exhibit 7: UWID tag architecture

3.2.2 Tethered Version

As shown in Exhibit 8, the final design fell to an elongated “kayak” type configuration that could easily be inserted in a 12-inch hole in the surface ice and float up to the bottom surface of the ice, as well as allow for easy extraction of the UWID after the test was over. The transducer was encased in a plywood frame and then the assembly was filled with a polyurethane two-part emulsion that expanded into a floatation foam casing, which was then shaped and painted.

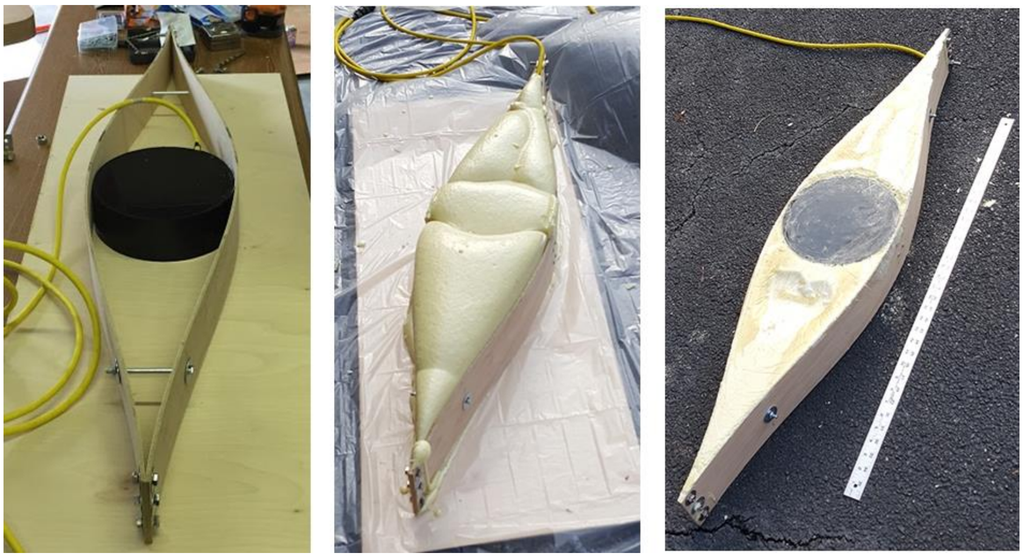


Exhibit 8: Manufacture of UWID tag

The UWID tag was modified to utilize an umbilical cable connected to the transducer driver and signal generator, to power and send instructions to the tag. The power provided to the transducer for the acoustic shot simulated the same power, as if where being powered by batteries. The use of the umbilical allowed for a large number of shots as we did not need to be concerned about battery power and energy levels, and allowed for adjustment of power levels to simulate various battery configurations. The transducer is from Airmar in a potted 2 kHz configuration. The UWID tag tether was attached to a transducer driver and signal generator. Exhibit 9 shows the painted enclosure ready for testing.

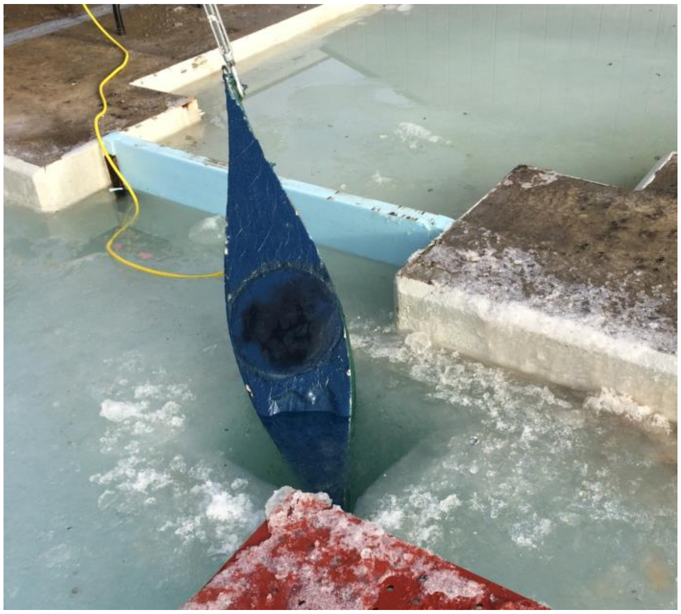


Exhibit 9: Tethered UWID tag being inserted under the ice

Exhibit 10 shows the transducer driver and signal generator built to power the UWID transducer for testing. The system as built has a power supply working at +/- 0 to 190 VDC and a potential output of 400 VDC. The system used an Apex PA92 4.0 amp amplifier and was current limited to 3.25 amps. The transducer was drawing 1.0 amp for all voltage settings.

NOTE: The high-power transducer driver and signal generator is a dangerous high-voltage piece of equipment and should never be operated by untrained personnel. The transducer driver is waterproof inside the Pelican case; however, during operation when the case is open, it is not waterproof and must be protected from moisture.

Exhibit 10: UWID transducer driver and signal generator

The amplifier used a tone burst type of pulse signal to drive the underwater transducer. The tone burst consists of a number of cycles of a 2 kHz sinusoidal wave. A longer tone burst will result in a narrower frequency content and more acoustic energy for the topside tag, but too long will make it difficult to detect (differential) arrival time(s) with our topside measurements. Precise identification of arrival times from the UWID to three or more topside tags may allow triangulation to localize the UWID. Exhibit 11 depicts the test settings and output voltages for the transducer driver, of which the first four settings would mimic possible battery configurations of a free-floating, untethered UWID tag.

Exhibit 11: Amplitude setting vs actual voltage for transducer driver

Amplitude Setting	Measured Voltage (V)
0.5	16.6
1.0	30.8
2.0	66.3
3.0	94.7
4.0	123.2
5.0	155.3
6.0	185.7
7.0	217.9
8.0	255.8
9.0	279.5
10.0	312.6

3.2.3 Untethered Version

The purpose of the UWID tag is to generate low-frequency guided waves in the ice floe. One purpose of the LDGRIDSAT tag is to detect these vibrations at the top surface of the ice floe as they spread out in a circular fashion. The LDGRIDSAT tags can then validate the rough location of the UWID. Lower frequencies are desirable because they are less sensitive to heterogeneities in the ice, but require larger or a greater number of transducers. Consequently, the size of the UWID should be kept manageable.

To optimally couple the acoustic waves into the ice from below, the team used Snell's law in various forms to back-calculate the angles of reflection and refraction. For thinner floes, we expected to generate lowest-order extensional Lamb wave modes, and by matching the phase velocities we found that an incident angle of 25 to 30 degrees is optimal. For thicker floes, the desired guided wave mode is a Rayleigh surface wave, which has its maximum vibrational energy near the top surface of the ice. For this mode, the refraction and mode conversion across the water-ice interface underneath the floe must be considered to obtain the appropriate wave modes inside the ice, which are incident upon the top surface beyond the critical angle for

Rayleigh wave generation. Based on this analysis, an incident angle of 22 to 28 degrees in the water below the ice is needed. The current design parameter of the inside deflection cone is to guide waves at 26 degrees total cone angle, or 13 degrees from vertical to each side, so the incident angle of reflection is 26 degrees.

The most compact UWID design, as pictured in Exhibit 12 has an inner diameter of approximately 240 mm. It uses a single, large, circular transmitting transducer that transmits vertically and is oriented by the buoyancy of an air-filled conical reflector, which redirects the acoustic beam toward a range of angles somewhat less than 30 degrees from vertical. Note that for low frequencies, the transducer will be relatively small compared to wavelength, so it will naturally transmit a range of angles. That makes the self-orienting design more robust, because there is no need to have the transmitter oriented precisely, which is also important because the bottom surface of the ice floe may be irregular.

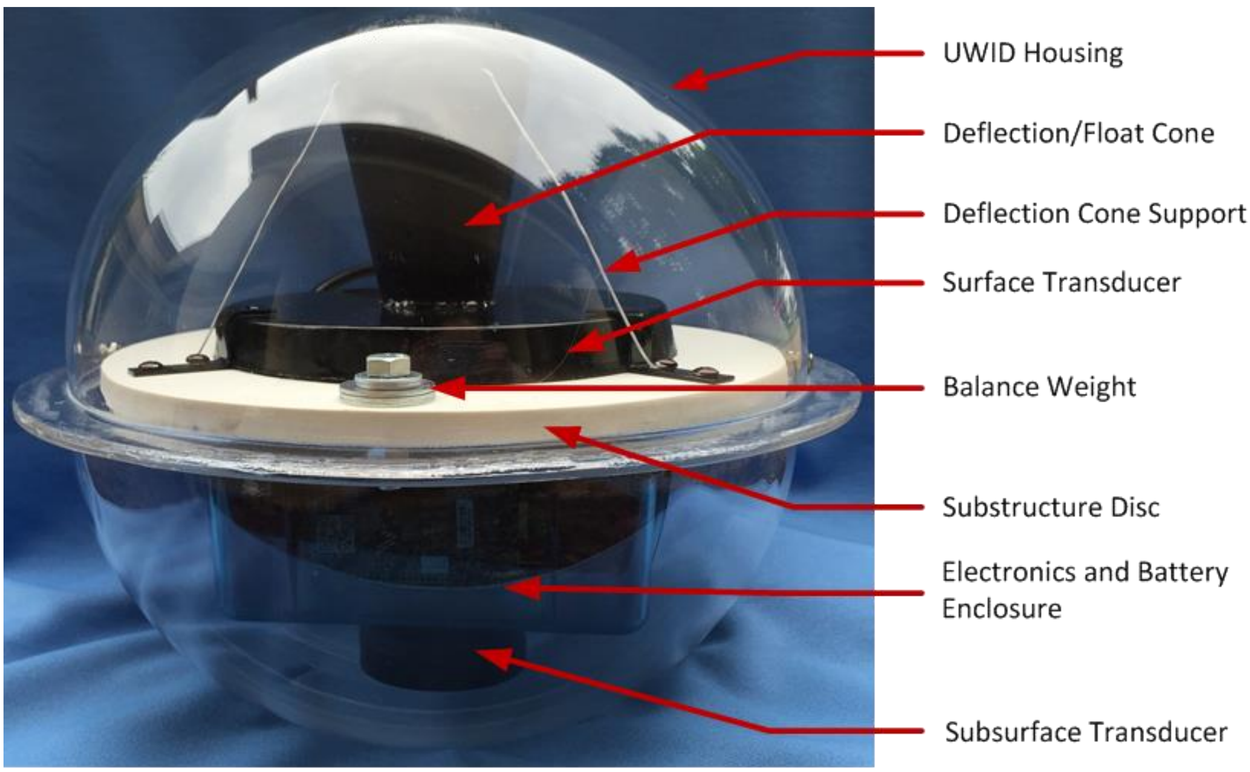


Exhibit 12: Components of the UWID tag

The enclosure is constructed of an approximately 10 mm thick walled shell that is sealed via low-temperature epoxy and lip, with a small hole to add the couplant. The internal cone that serves as both directional float and reflector can be either milled nylon or rapid-prototype polymer and is filled with air.

The circuitry and batteries are contained in a separately sealed polymer enclosure shown in Exhibit 13. The couplant and enclosure have almost the same density as seawater. The circuitry float, battery casement, and reflector cone will be filled with enough air to displace the mass of solid components to give overall buoyancy of 0.8 mg/ml (enough to rise through a thick layer of light crude oil).

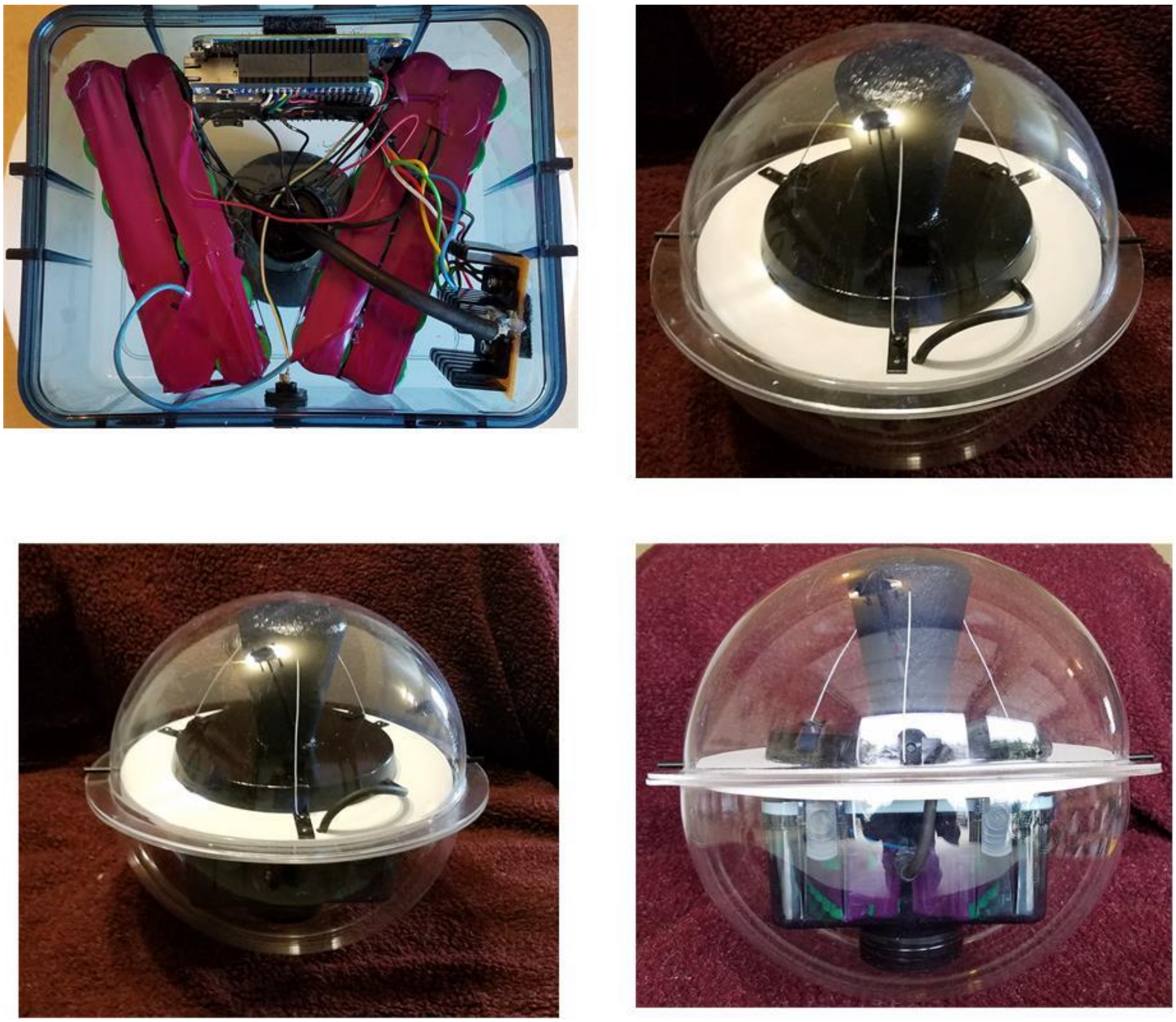


Exhibit 13: Untethered UWID battery, electronics and enclosure assembly

The untethered UWID tag can be made in a sphere or ogive (aka football) shape if additional buoyancy is needed, as found with the tethered UWID tag. The internal self-orienting mechanism is still part of the design, but the additional volume of the ogive outside of the central sphere is filled with buoyancy foam. Because the number of transmissions is determined by the battery size, we envision ogive form-function UWID tags for scenarios where more transmitted pulses are needed than can be accommodated by the batteries that can be incorporated into the spherical UWID tag.

3.3 CLOUD INFRASTRUCTURE AND USER INTERFACE

Cloud infrastructure provides the backend data acceptance from the satellite gateway, processing and interpreting key tag information such as location to a Web-accessible map displayed for the end user. Exhibit 14 diagrams the data flow within the cloud infrastructure.

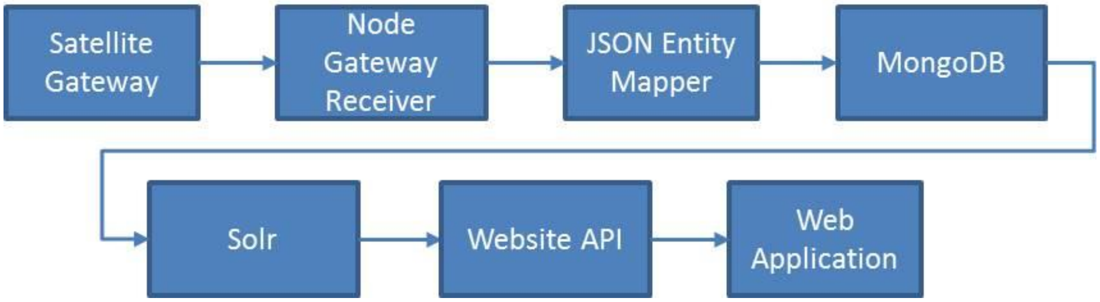


Exhibit 14: Cloud infrastructure schematic diagram

3.3.1 Software Employed

The cloud infrastructure consists of the software components listed below, which process the Tag Domain Reports requested from the satellite gateway. They are deployed and run on the Amazon Web Services cloud servers.

- NginX Reverse Proxy – Manages incoming requests from the gateway. It facilitates which ports are open and what systems can communicate through those ports. It works in tandem with the firewall.
- Node Gateway Receiver – Listens for packages sent by the satellite and, once received, starts the processing engine.
- JSON Entity Mapper – Translates messages into entities the database can use. This configuration file is used by the node gateway receiver. If the gateway changes protocols, or the gateway provider changes, the entity mapper will be updated, and the rest of the subsystem should be unaffected.
- Node Processing Engine – Receives incoming messages and translates them into MongoDB database entities.
- MongoDB Database – Stores the translated entities from the node processing engine. The database structure defines what the entities are and the formats of each of their attributes.
- Solr (indexing engine) – Provides fast search capabilities.
- Node Web Server –Provides a Web and Application Programming Interface (API) server for the mapping application, deployed on the same cloud instance.
- Koop (data translation engine) – Formats the database entities into a consumable format for Web-based systems.
- Turf.js (spatial data manipulation engine) – Conducts spatial queries and formats MongoDB data into GeoJSON.

- Leaflet (Web mapping application) – Displays interactive features that represent the tags in the field and the messages and status that they emit over time.

3.3.2 Cloud-Based Data Servers

The hardware chosen for this project is sufficient for prototyping and proof of concept. Because of Amazon's scalability, what is done on a small scale using its platform can be upgraded to support a larger, production-ready environment. The hardware is suitable to support all software components of this project, including NginX, the Node Ingestion server, MongoDB database, and the Web mapping application. The Amazon Web Services data centers are staffed 24/7 by trained security guards, contain environmental systems to minimize the impact of disruptions, and span multiple geographic regions to provide resiliency to manmade and natural disasters.

3.3.3 GIS Software Application Package

After the NginX reverse proxy accepts the incoming requests from the satellite gateway, the GIS software application package that consists of the node gateway receiver and processing server uses the JSON entity mapper to parse the LDGRIDSAT tag, produce Tag Domain Reports, and store the data in the MongoDB database deployed on the Amazon Web Services server. After the data are stored, they are immediately indexed and made available for search using the front end mapping application.

3.3.4 Mapping Application Programming Interface

The user interface is designed to provide all of the desired functionality while maintaining ease of use for novice users. Desired functionality is as follows:

- LDGRIDSAT tags viewable on a map
- Visible status indication of LDGRIDSAT tags
- Clickable LDGRIDSAT tags that display additional information about UWID tags
- Reviewable history details for the LDGRIDSAT tags

A user guide with detailed step-by-step instructions and screen captures to aid new users is included as Appendix B in this report. This application is best viewed in the latest desktop browsers (Firefox 15+, Opera 12.1+, Chrome, Internet Explorer 10+) and mobile platforms (Safari for iOS 3–7+, Android browser 2.2+, 3.1+, 4+, Chrome for Android 4+ and iOS, Firefox for Android, Other WebKit browsers [webOS, Blackberry 7+, etc.], and IE 10/11 for Win8 devices).

Leaflet is free to use but does not have map imagery. Map Box (a paid service that provides free base maps) is combined with Leaflet to obtain this imagery.

SECTION FOUR: TESTING

To ensure that the system operates as designed, the URS Team conducted initial modeling, simulation, and unit- and system-level tests detailed in this section.

4.1 GUIDED-WAVE MODELING AND SIMULATIONS

A key part of design optimization trade-off is exploring options via simulation. The College of William and Mary assessed a variety of options for simulating the Lamb wave propagation and scattering in ice floes and concluded that the most suitable software packages for modeling the acoustic interaction in the water and ice are Visco-Elastic Finite Integration Wave Solver, Geoacoustic_TDFD, and SoundSim.

The Applied Science Department has also implemented various two-dimensional (2D) and three-dimensional (3D) versions of the acoustic and elastodynamic finite integration technique, typically adapted to run large simulations on William and Mary's parallel computer cluster, SciClone. Another available simulation tool is the Visco-Elastic Finite Integration Wave Solver. This program uses MATLAB to run a C program that simulates the wave propagation using a finite integration technique. The software is designed to simulate both isotropic and anisotropic materials. More information is available at https://code.google.com/p/v-efit/.

The Geoacoustic_TDFD code published by Woods Hole Oceanographic Institute is well suited for these simulations and is widely accepted in the geoacoustics community. The MATLAB code was originally written to simulate the interactions between water and the sea floor using a finite-difference, time-domain technique. Adjusting the material properties allowed modeling of Lamb waves in the ice. More information is available at http://oalib.hlsresearch.com/Other/index.html.

SoundSim is a 2D code written by the Applied Science Department of William and Mary for simulating Lamb waves in structural materials. This code allows for adjustment in the material properties and the thickness of the material. More information is available at http://www.mathworks.com/matlabcentral/fileexchange/11838-soundsim-2d-elastic-wave-simulator.

The Nondestructive Evaluation Lab at William and Mary has been using Lamb waves to find flaws in thin layers of materials. The team leveraged this experience to predict how Lamb waves behave in sea ice and guide the development of the underwater tag. To better understand the wave propagation in sea ice the personnel from William and Mary modified the Geoacoustic_TDFD software from Woods Hole Oceanographic Institution to simulate the acoustic wave in a layer of ice. These simulations showed that relatively low frequency waves (1 to 3 kHz) would behave as expected through a layer of sea ice.

Exhibit 15 shows the Group Velocity Dispersion Curve for sea ice, something that provided the team with the necessary insight to the wave propagation at the Cold Regions Research and Engineering Lab (CRREL) and beyond. The dispersion curve allowed the team to determine which wave modes are present and their velocities in the ice. The x-axis is the frequency of the signal in hertz (Hz) times the thickness of the ice, and the y-axis is the group velocity of the guided waves in meters per second. The thickness of ice at CRREL was approximately 0.5

meters and the signal from the underwater tag is at approximately 2300 Hz. This gives us a frequency*thickness value of 1150 Hz*meters. The wave modes present at this frequency thickness are the A_1 and S_0 Lamb wave modes as well as the Rayleigh wave. Here the guided wave modes have similar velocities. This implies that all of these modes will arrive to the topside accelerometer at approximately the same time. For this test, the focus was on detecting any guided wave and mode produced by the UWID through the ice, not any specific mode.

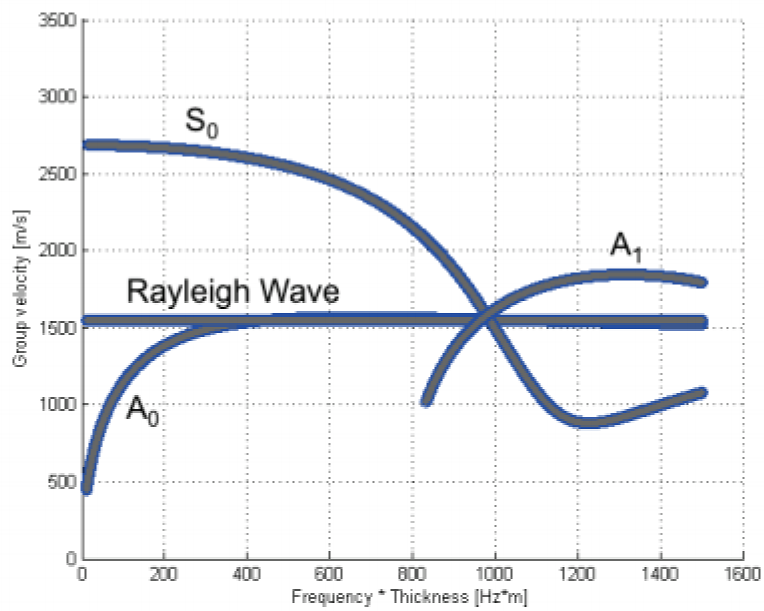


Exhibit 15: Group velocity dispersion curve for sea ice

For these simulations, the team used a simple, single pulse to show the propagation through the ice. In each of the simulations snapshots (Exhibits 16 through 18), the top half of the figure is the longitudinal wave modes and the bottom half is the shear waves. In both of these images, the top layer is air, the middle is ice, and the bottom layer is water. The underwater tag is simulated using a point source located directly under the ice layer on the y-axis. Exhibit 16 shows the simulation of the underwater tag in about 1-meter-thick ice. The initial signal can be seen propagating through the simulation space at about 20 meters away from the source. Here the guided waves can be seen developing in the shear mode plot. Exhibit 17 shows that a change in thickness in the ice floe does not significantly change the guided wave propagation. Exhibit 18 shows the waves interacting with a crack about half the depth of the ice. This simulation shows the guided waves will continue to propagate after interacting with a significant flaw in the ice.

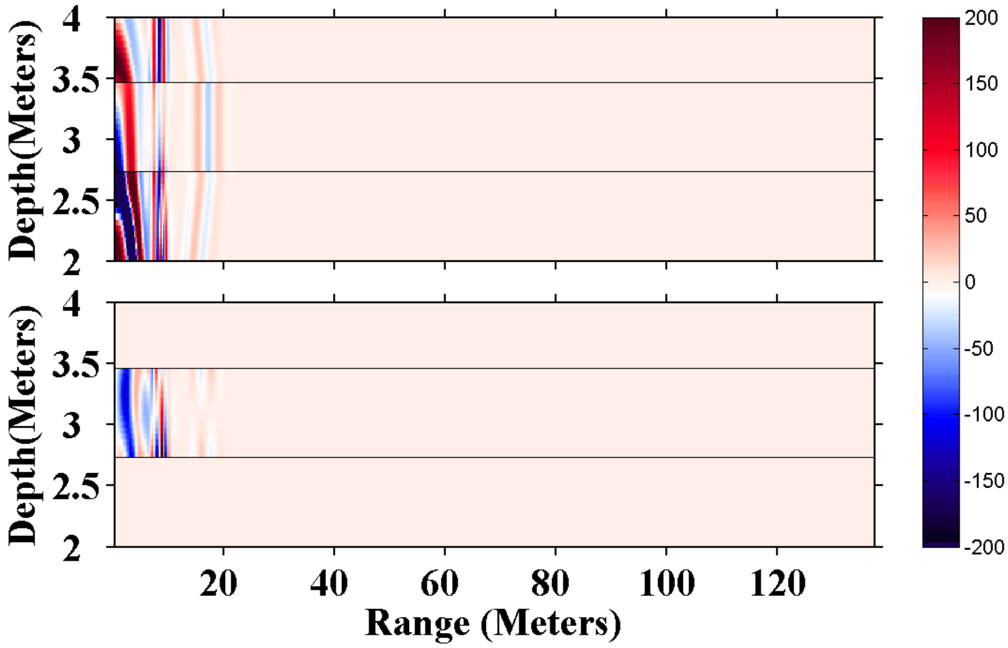


Exhibit 16: Simulated longitudinal wave modes and shear waves in 1-meter-thick ice

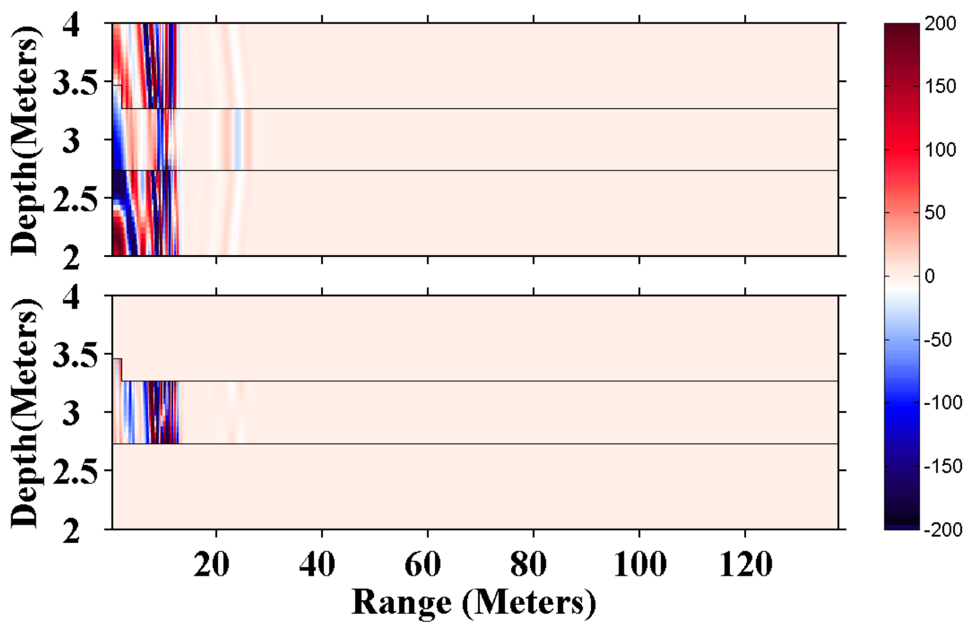


Exhibit 17: Simulated longitudinal wave modes and shear waves in 0.5-meter-thick ice

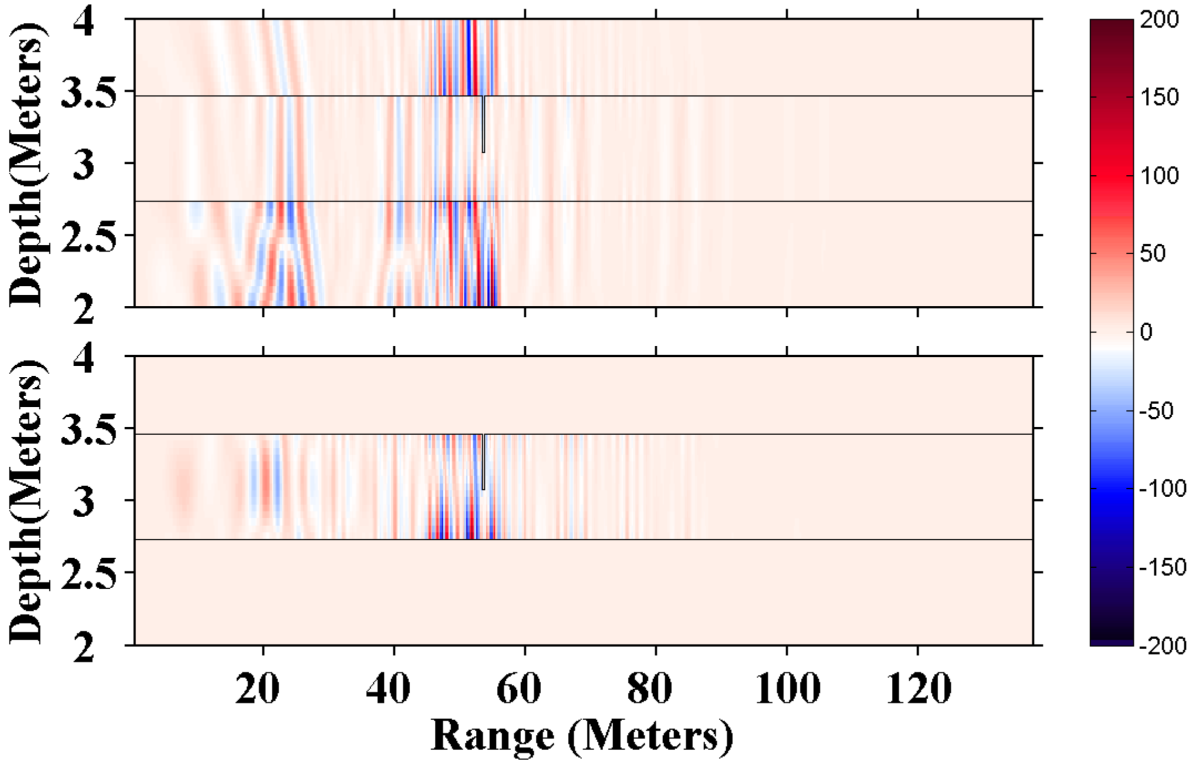


Exhibit 18: Simulated longitudinal wave modes and shear waves in 1-meter-thick ice with a 0.5-meter dislocation at approximately 55 meters from the source

4.2 CLOUD INFRASTRUCTURE AND USER INTERFACE

Both unit and system testing were performed during the development process to ensure proper operation and confirm that all functionality was implemented correctly.

4.2.1 Unit Testing

Unit testing tests individual unit functionality without depending on other parts of the architecture. One unit was tested at a time, and all other components were mocked:

- **Gateway Message Delivery.** The delivered messages were compared to the messages sent from the LDGRIDSAT tags.
  - ➢ Messages were mocked and sent to the gateway receiver. The mocked message package length was compared with the message received by the gateway receiver, node gateway receiver, and processing server. The received messages from the gateway were compared to the simulator data.
    - o A byte-by-byte analysis was used to ensure integrity was maintained.

    - The mocked messages parsed by the entity mapper were compared to a previous, correctly parsed message to ensure the processing engine was functioning properly.

- **Data Storage.** Storage was tested to ensure the data intended to be saved was actually saved.

- **Node Web API.** The interface was tested to verify that each API received and responded correctly to incoming requests.

    - The Mocha testing mock request was made, and the responses were compared to the previously determined expected responses. Mocha is a JavaScript unit testing framework and test runner. It facilitates the process for designing unit tests and running and providing the pass/fail results of each test. Mocha is the de facto unit test framework for Node.

- **Application Testing.** The Jasmine testing framework was used to unit test all application functionality.

    - Jasmine is a behavior-driven development framework used for testing JavaScript code. Jasmine does not require other JavaScript frameworks and uses clean, obvious syntax that allows application tests to be easily written.

4.2.2 System Testing

The Team set up a message signal relay system that sent mock messages to the Node Ingestion server.

- **Mock Messages.** The signal relay sent success and error message types so the system could test its response to both scenarios.

    - The Team created a LDGRIDSAT emulator and developed a simulator that dynamically manipulated LDGRIDSAT values and quantities.
    - The manipulated values were compared with the values ultimately stored in the database.
    - Errors were introduced in the emulators to ensure the system would fail gracefully.

        - Incorrect byte length was the primary failure technique.
        - Incorrect data types (e.g., latitude and longitude) were tested.

- **Payloads.** The simulator was used to mock the different messages that can be sent from the tags.

- **Security.** Tests indicated that only the gateway can send messages through the NginX reverse proxy.

- **Application Testing.** The Web application representation of the tags and the accuracy of the data sent were tested manually.

4.3 COLD REGIONS RESEARCH AND ENGINEERING LAB TESTING SUMMARY

The team conducted testing February 24 and 25, 2016 at the Geophysical Research Facility (GRF) within the CRREL in Hanover, New Hampshire. The primary goal of the CRREL testing was to demonstrate that the acoustic signals generated under the ice could be detected by the surface sensors (accelerometers) above the ice.

Testing at CRREL involved the deployment of a UWID tag underneath the test ice in a tethered mode and the placement of the Lamb wave detector portion, acoustic sensors, of the LDGRIDSAT tag on the surface of the ice. Once deployed, the UWID tag projected a series of acoustic shots into the bottom surface of the ice for detection by the acoustic sensors.

Exhibit 19 shows the GRF at CRREL, a 60- by 22- by 7-foot outdoor concrete basin of simulated sea ice. The ice thickness at the time of testing was approximately 20 inches. The salt water concentration was 29.4 parts per thousand at the ice/water interface and 32.6 parts per thousand at the bottom of the tank. CRREL cut an approximately 12- by 14-inch hole into the ice for access to insert the UWID tethered transducer and provided power for the signal generator and laptops.

Exhibit 19: CRREL GRF with simulated sea ice

4.3.1 Experimental Overview

Exhibit 20 depicts the experimental setup at CRREL. The UWID tag was deployed underneath the sea ice surface and tethered to the transducer driver and signal generator. Three acoustic sensors, the lamb wave detector portions of the LDGRIDSAT tag, were positioned at fixed internals away from the UWID tag. The UWID tag was placed at one side of the ice block to get maximum distance for an unimpeded sound wave. Once the signal generation from the UWID tag was initiated, the acoustic sensors were triggered to start recording data.

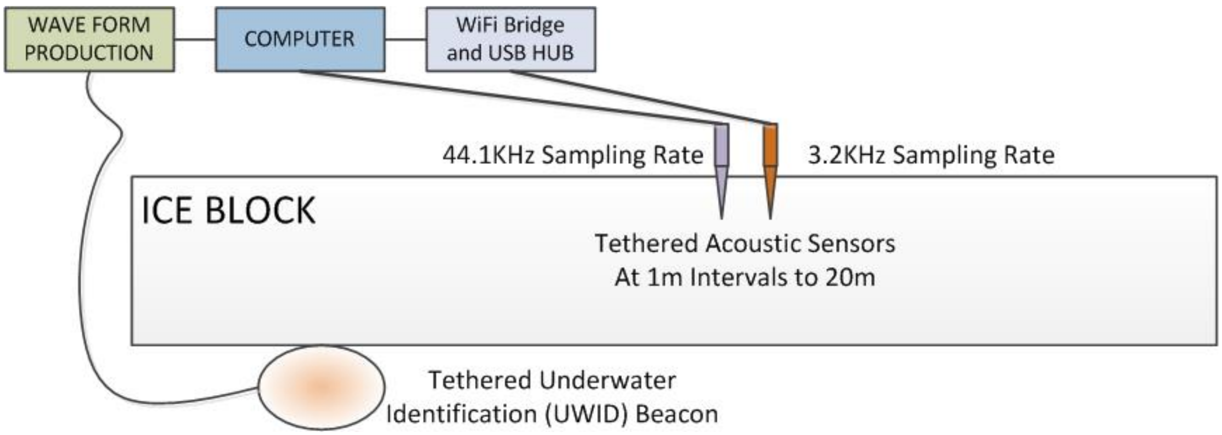


Exhibit 20: Schematic for subsurface to surface acoustic testing of simulated sea ice

4.3.2 Test Setup and Summary

The test team deployed a tethered UWID tag under the ice in the test facility as shown in Exhibit 21. As shown in Exhibit 22, we then marked the ice in 1-meter intervals out from the UWID tag as a reference.

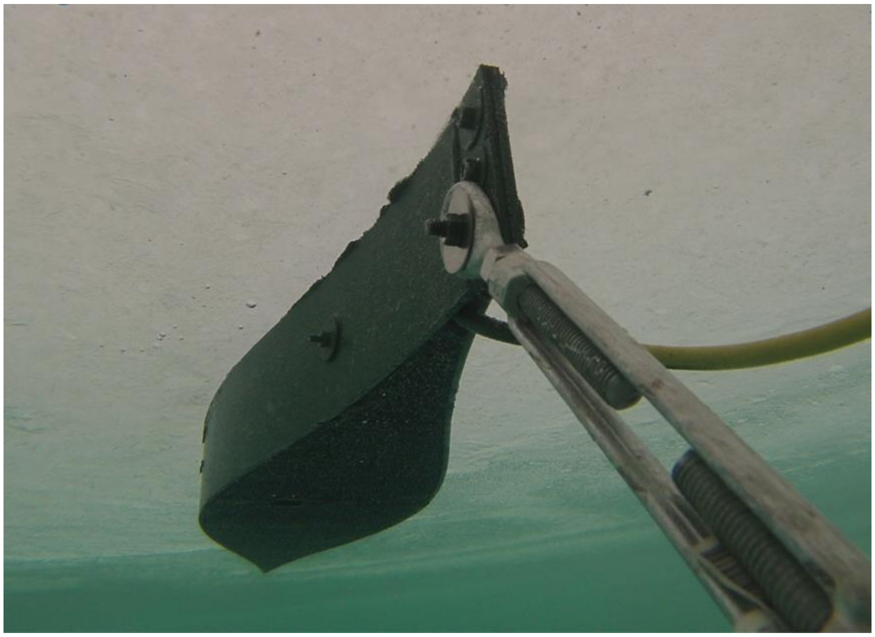


Exhibit 21: UWID tag under the surface of the CRREL sea ice

Exhibit 22: One-meter marking on the CRREL simulated sea ice

The team transmitted an acoustic pulse through the transducer driver to the UWID tag and into the ice. The team collected data at each point on the ice from the Digiducer accelerometer and at every third point from the other accelerometer. The pulses transmitted had a variation of 16.6V to 279.5V, all at a 1 amp draw by the transducer. The acoustic signal was a pulse of 12 cycles at 10 Hz of a 2 kHz sinusoidal wave. The acoustic pulses transmitted from 16.6V to 94.7V were meant to simulate possible voltage configurations of an untethered, battery-operated UWID. The Digiducer accelerometer was the primary data collection tool and a subset of the trails were recorded for comparison with the other accelerometer.

4.3.3 Data Analysis

The following sections describe the data collected, analysis and synthesis of filters and detection algorithms to implement within the LDGRIDSAT tag.

4.3.3.1 Algorithm Development for Signal Identification and Extraction

When the transducer is sampled at some distance, the signal is buried in a significant amount of noise. A narrow bandpass filter is applied to the data to enhance the transducer signal, which is then processed with a Fast Fourier Transform algorithm to obtain a power level for the transducer signal received. This method works well for the data collected using the Digiducer device because of the high sample rate at which data is collected. However, given processing power and memory constraints for a microcontroller as well as limitations on a low-cost deployable accelerometer sensor, another detection method was required.

The sensor deployed in the LDGRIDSAT tag is only capable of collecting data at a sample rate of 3200 Hz, far less than the Digiducer device. The transducer generates short bursts, 10 times per second, and while the LDGRIDSAT cannot detect the 2000 Hz tone, it is capable of detecting the bursts at 10 Hz. Therefore, the firmware in the deployed sensor device was programmed to search for this 10 Hz signal of the 2 kHz tone using the same filtering techniques.

4.3.3.2 Signal Detection and Results

Exhibit 23 shows the signal directly above the transducer. Here the tone burst can be seen as the signal with the peak amplitude of about 0.012. Immediately after the initial tone burst, we began to get reflections off the edges of the pond. These reflections are shown as smaller amplitude waves after about 0.008 seconds. Exhibit 24 shows the frequency response of the signal. This was calculated using a Fast Fourier Transform in MATLAB. The peak frequency was at 2242 Hz, with the next highest peak at 2325 Hz. From this, we designed a bandpass filter from 2.2 to 2.4 kHz to reduce the noise in the signal.

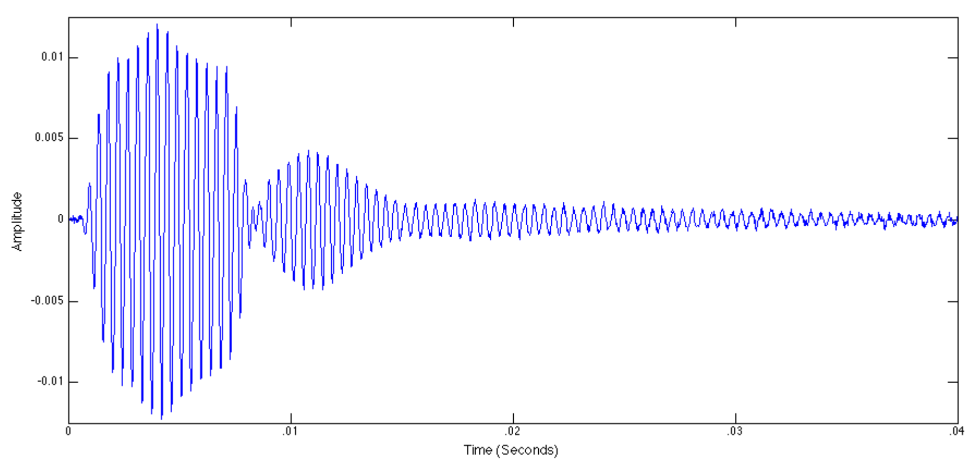


Exhibit 23: Zero-meter recording showing original signal and first reflection

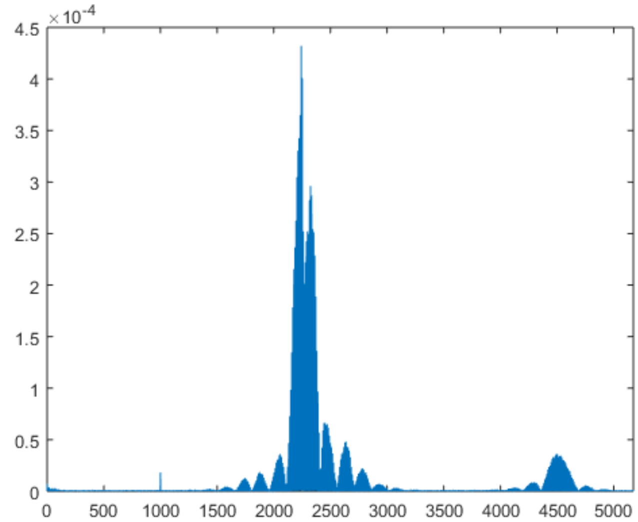


Exhibit 24: Frequency response of the UWID signal

Exhibit 25 shows the signal 10 meters away from the transducer at 155.3V before filtering. (Note: all figures are shown as microseconds on the x-axis versus amplitude on the y-axis). The signal is buried in the noise. Exhibit 26 is that same signal after filtering. There are clear peaks at the pulse repetition rate. Exhibit 27 is a plot of the raw data from a 30.8V signal, similar to what a battery-powered UWID tag would transmit. And Exhibit 28 is the same signal after filtering. Exhibit 28 clearly denotes the signal, but has several variances and interference, some of which were caused by reflections, and some of which were caused by noise from the GRF pool pumps, neither of which would be present in a real-world scenario. Exhibit 29 is an example of one of the signal captures by the LDGRIDSAT tag accelerometer.

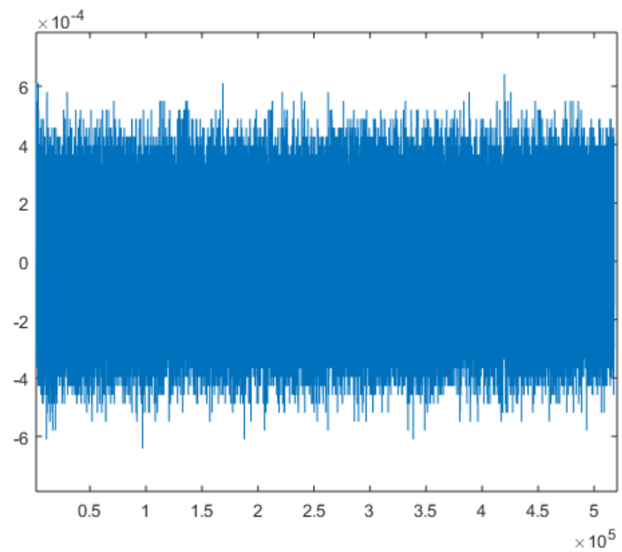


Exhibit 25: UWID tag signal of 155.3V at 10 meters before filtering

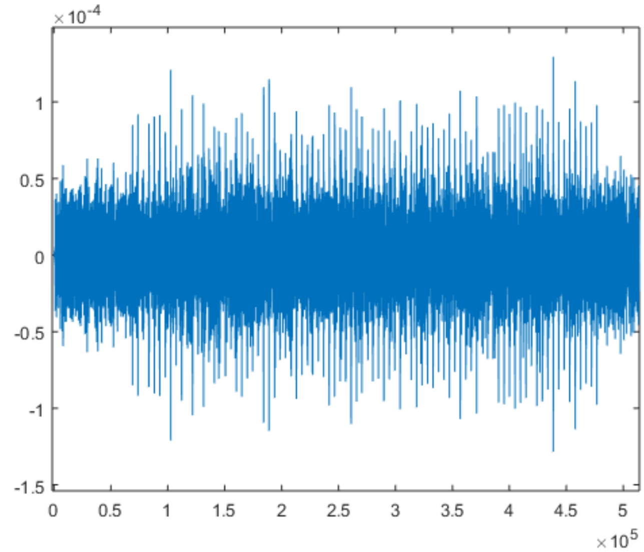


Exhibit 26: UWID tag signal of 155.3V at 10 meters after filtering

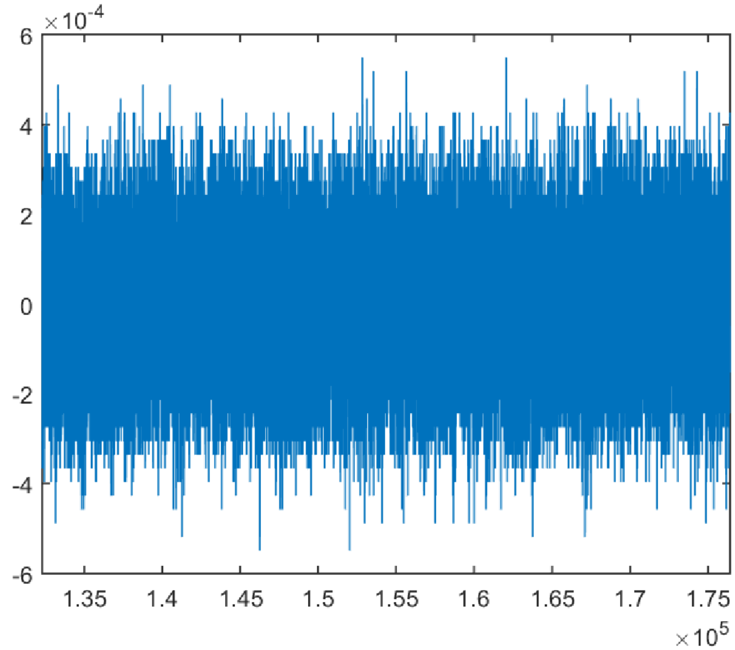


Exhibit 27: UWID tag signal of 30.8V at 15 meters before filtering

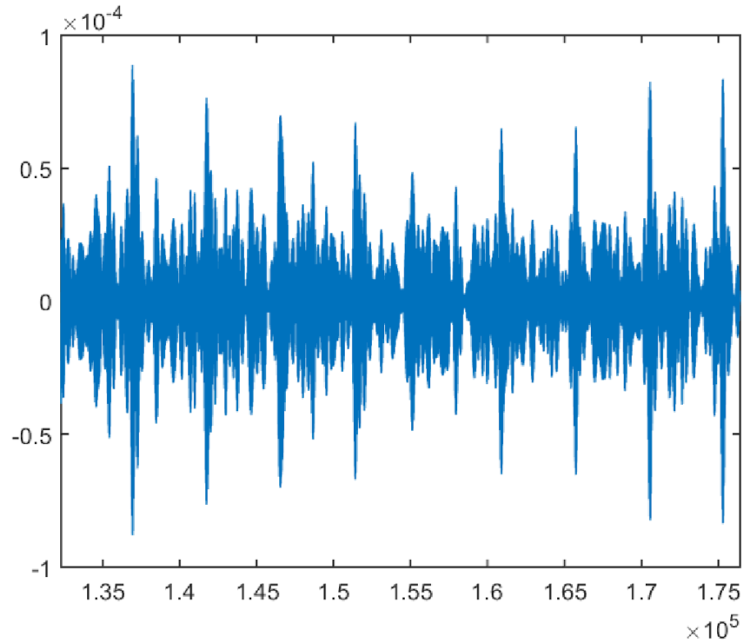


Exhibit 28: Zoomed-in plot of the UWID tag signal of 30.8V at 15 meters after filtering

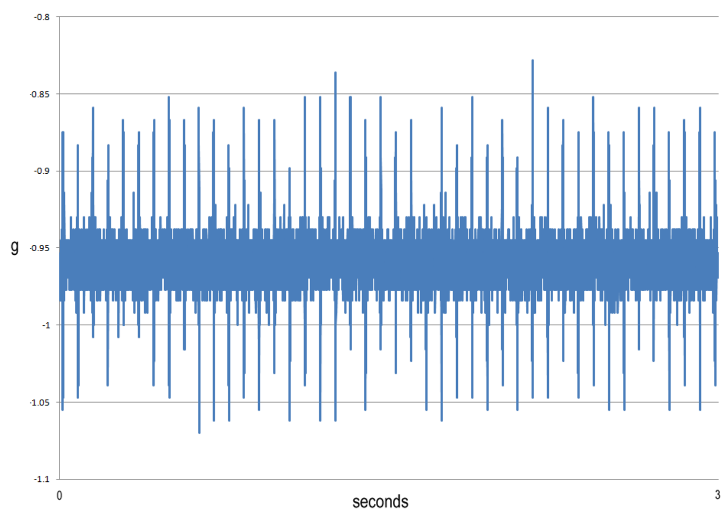


Exhibit 29: Example of signal capture using the LDGRIDSAT tag accelerometer

4.3.4 Cold Regions Research and Engineering Lab Testing Conclusions

The CRREL tests showed that top-surface accelerometers can detect acoustic signals generated from underneath the ice, and that filtering can be introduced to increase the sensitivity and positive signal detection as the sensors get farther away from the signal source, in this case the UWID tag. We were able to use both accelerometers as guided-wave sensors for successful detection of the UWID tag acoustic pulses up to 18 meters, the entire length of the GRF.

The UWID tag was inserted in a 12-inch hole, maintained position against the lower surface of the ice, and was easily extracted. The UWID tag was buoyant enough to keep contact between the transducer and the bottom surface of the ice. The transducer driver and signal generator was able to produce burst tones at varying voltages, allowing for a series of tests, some of which mimicked what signals could be expected from battery-powered UWID tags. All of the accelerometers were able to detect signals generated under the ice.

All the accelerometers used were able to detect the signal both directly near the source and through the guided wave products of the signal through ice. The team used the post analysis of the sound files from the higher-sampling rate accelerometer to construct filters that allowed for the detection of low-voltage/low-power signals at varying distances. Some of these files also showed the interference from other sources, such as the GRF pool pumps, but the signal was still clearly evident in almost all files. These filters were used to set up pre-processing filters in surface sensors for real-time detection of acoustic signals from the UWID tags.

While over 300 sound files were collected as part of this testing, the limited ice surface combined with the GRF's containment walls, upward sloping edge of the pool at the far end, and relatively shallow depth meant that the sounds generated by the transducer were constantly reflected from multiple surfaces. So while the sounds could be detected, the sound files show no degradation beyond a few meters because of the reflections and the team was unable to extrapolate behavior beyond the confines of the test surface and length of the GRF.

4.4 ICE EXERCISES TESTING SUMMARY

The primary goal of the 2016 Navy Ice Exercises (ICEX) testing was to demonstrate the efficacy and survivability of aerial and manually deployed surface LDGRIDSAT tags. The ICEX testing conducted on March 23 and 24, 2016 involved the aerial deployment of four LDGRIDSAT tags. All four housings and payloads survived the aerial drop, and the two type A tags imbedded properly in the ice floe.

4.4.1 ICEX Setup

The aerial drop was supported by a Bell helicopter and flight team contracted by the U.S. Navy's Arctic Submarine Lab for ICEX. The test team deployed four tags, two (type A) were equipped with 1/16-inch semi-rigid copper spikes on a 90mm polypropylene payload housing, and two (type B) were equipped with 1/8-inch semi-rigid copper spikes on a 110 mm polypropylene payload housing. We dropped these tags from a helicopter at approximately 100 meters above the ice floe, and moving at approximately 20 kilometers per hour "sideways" so that the door where the tags were thrown from was located at the trailing edge of movement, with a wind speed of approximately 20 knots per hour. The tags were observed on their drop to the ice, and then the helicopter landed for the retrieval of all tags. A second aerial drop was considered, but cancelled because of the evacuation of personnel from the camp after the ice floe opened up. One ice-anchor LDGRIDSAT tag was deployed at the edge of the ICEX camp.

4.4.2 ICEX Tests

The aerial tags were thrown from the helicopter in a variety of positions (see Exhibit 30). In all cases, even when the tag was thrown out spike first in an almost ideal flight path, it took approximately 50 to 75 meters for the tag to stabilize in non-wobble, spike down flight path to ice floe impact. Some of the initial wobble of the tag was caused by wind, air turbulence around the helicopter, and the downwash from the helicopter blades.

Using this type of drogue streamers, regardless of aerial platform used—helicopter, plane, or drone—the team recommends a minimum drop height of 100 meters above the ice floe. The only other consideration for an aerial drop is to avoid hitting ice ridges on the ice floe. The ice ridges with snow drifts can easily reach 2 meters, and an aerial drop into the drift may prevent the LDGRIDSAT tag from contacting the ice. This would negate the use of the onboard accelerometer. An aerial drop into the drift could also bury the tag in snow, preventing satellite and GPS communication.

Exhibit 30: Deploying LDGRIDSAT tag from helicopter

4.4.2.1 Aerial Tag Impact with the Ice Floe

The type A aerial tag with 1/16-inch-thick copper blades impacted almost perfectly with the ice floe. One tag impacted through slightly thick snow and crust of about 12 cm, and the copper spikes made solid contact with the ice floe with only minor buckling (see Exhibit 31). The other type A tag hit in only about 8 cm of snow and crust. This tags' copper blades buckled as was hoped for, absorbing the impact, keeping the tag upright and allowing the copper spikes to make solid contact with the ice floe (see Exhibit 32). The buckling also aided in providing a type of anchoring in the snow and crust cover, and it took two members of the drop team to pull the tag from the ice floe.

Exhibit 31: Type A LDGRIDSAT tag on impact

Exhibit 32: Type A LDGRIDSAT tag spikes after stable impact

The two type B aerial tags bounced from the impact and landed on their sides. Upon inspection, the tags hit the ice correctly, but the 1/8-inch thick copper did not buckle, but only bent at the flange area (see Exhibit 33). The lack of buckling caused the tag to just hit the ice and bounce up a half meter or so before landing on its side.

Exhibit 33: Type B LDGRIDSAT tag after impact

4.4.2.2 Aerial Tag Housing and Payload

All of the PP housings of the type A and type B tags survived the aerial drops, including those type B tags that just bounced off the ice, with an outside temperature of approximately -40 °C. The electronic payloads also survived impact. However, there was a slight bend in the steel backplane of the integrated circuits. The test team recommends that the backplane be constructed so it has greater flexion in the middle to absorb more of the shock without bending, either through two steel panels instead of one with a sleeve or friction screw between them or corrugation in the middle of the backplane.

The tag batteries also survived impact, but the PVC bracket for the batteries chipped in several places. The test team recommends that future battery brackets be constructed of polypropylene, nylon, or similar material that is not quite as brittle as PVC.

4.4.2.3 Aerial Tag Drogue Streamers

The tags' drogue streamers did keep the tags oriented correctly for the drop. However, in all cases one or more of the three strands of PVC tape broke at some point on the way down. The team recommends that the next design incorporate 4 mil to 6 mil biodegradable tape (a readily available COTS product) instead of 2 mil PVC tape.

4.4.3 Ice Anchor LDGRIDSAT Tag

One ice anchor LDGRIDSAT tag was deployed towards the edge of the ICEX camp. The ice anchor tag was easily screwed into the ice floe by hand, and anchored properly with the base just above the ice (see Exhibit 34). However, the camp was evacuated that same day because of a large fissure in the ice floe with encroaching sea water (see Exhibit 35). The LDGRIDSAT tag stopped operating the next day, but no one was present to inspect the tag. The team assumed that it fell into the sea, or was damaged during the hasty evacuation, or experienced some malfunction.

Exhibit 34: Ice anchor LDGRIDSAT tag deployed on ice floe

Exhibit 35: ICEX Camp Sargo near ice floe fissure and sea

4.4.4 ICEX Testing Conclusions

The ICEX test did prove that the LDGRIDSAT tag can be deployed from an aerial drop without damage to the payload, remain oriented correctly for satellite communication, and maintain contact with the ice to utilize the onboard accelerometer. Only minor modifications as noted in this report are recommended for subsequent drops, and follow-up testing of a final design can be performed anywhere on ice floes. The design is robust enough that other government agencies have already expressed interest in adopting the tag for other research initiatives on glacier ice and in polar areas.

4.5 BARROW, ALASKA TESTING AND SYSTEM DEMONSTRATION

The Barrow testing conducted on March 25 and 26, 2016 involved the deployment of an UWID tag underneath the ice floe in a tethered mode and the placement of the LDGRIDSAT tag and other accelerometers on the surface of the ice. The primary goal of the Barrow testing was to demonstrate the survivability of the ice anchor surface tag, and demonstrate that acoustic signals generated under the ice floe by the UWID tag could be detected by a surface tag above the ice floe and then relayed through a satellite network to a cloud infrastructure for display on a user interface.

Once deployed, the UWID tag projected a series of acoustic shots into the bottom surface of the ice for detection by the tags and sensors. All test equipment worked as expected, the UWID tag floated correctly to the bottom surface of the ice, and the accelerometers in use picked up the immediate high-voltage signals. However, UWID detection at long ranges was compromised as a result of the sampling rate of the surface sensors. The URS Team also deployed an ice anchor LDGRIDSAT tag on March 26 at a separate location on the ice floe, with its last report captured on May 22, 2016.

4.5.1 Test Setup

The Barrow testing was supported by UIC Science, a native Alaskan science company that was the outfitter for test, providing the snowmobiles, sleds, ice augers, cold weather gear, all the necessary permits, and a guard for polar bears. During the first day of testing, the test team bored a hole in the ice flow approximately 3 kilometers northwest of Barrow and lowered in the UWID tag, then screwed in two LDGRIDSAT tags to test the accelerometers ability to pick up the UWID tag. The depth of the ice floe at this location was approximately 1.3 meters. The cold temperature caused computer issues and the team was forced to curtail the testing an hour early. The second day of testing included repeating some of the tests at the same location, then subsequent testing of a single LDGRIDSAT tag deployed approximately 10 kilometers northeast of Barrow.

4.5.2 Data Analysis

Exhibit 36 shows the test setup off the coast of Barrow. The UWID tag signal was detected by the LDGRIDSAT tag at approximately 10-meter distance. This showed that the LDGRIDSAT tag can detect acoustic signatures of the UWID tag using the onboard accelerometer. The LDGRIDSAT tag then successfully transmitted the tag domain report to the cloud infrastructure and reported the information on the GIS user interface.

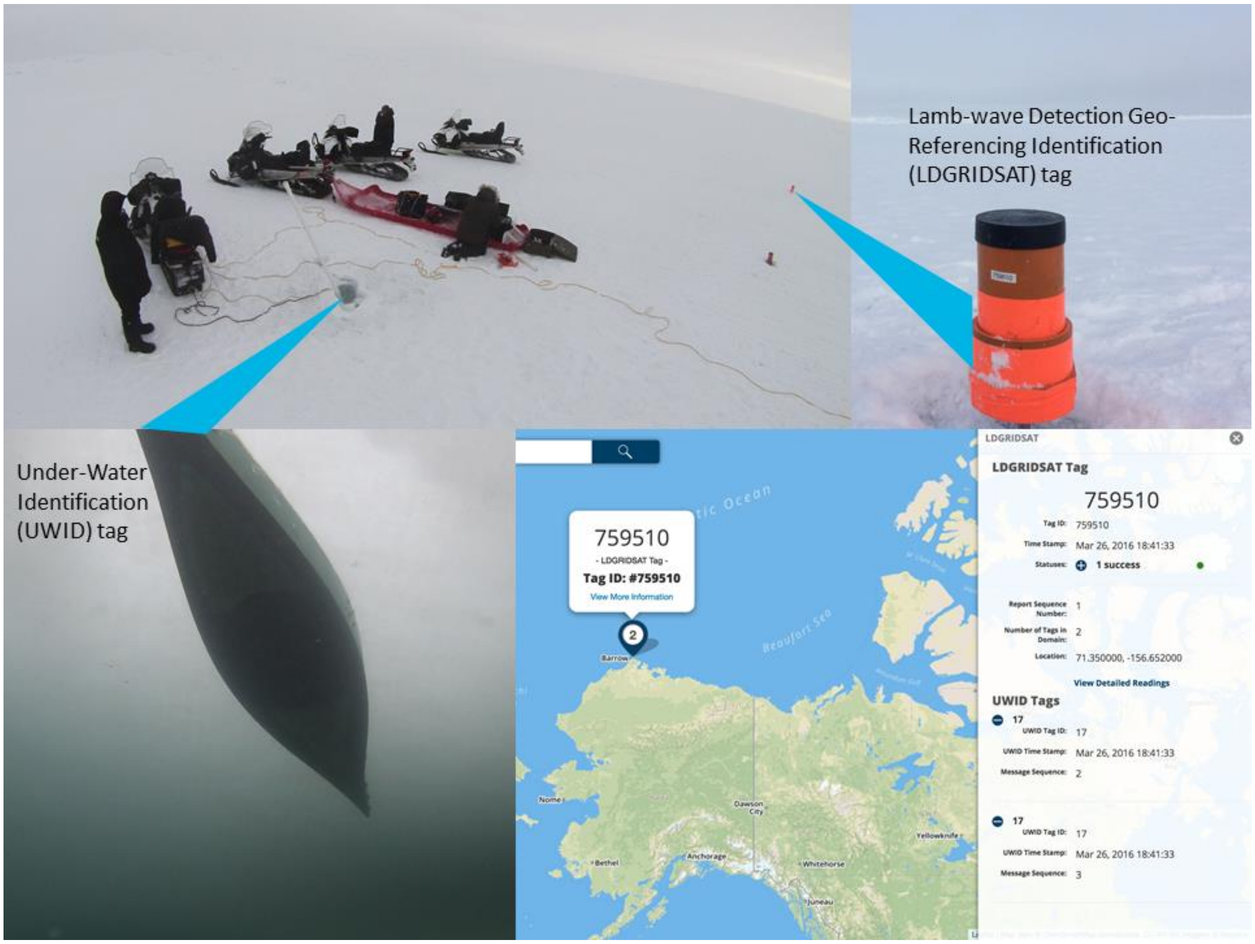


Exhibit 36: Barrow test setup – A LDGRIDSAT successfully detected the UWID acoustic beacon and transmitted its data through the satellite gateway for display on the user interface

The acoustic profile was the same for short distances out to 10 meters regardless of voltage. Further distances proved inconclusive, as the guided waves of the UWID tag could not be seen. The team analyzed the findings and concluded that the 3.2kHz sampling rate of the accelerometer originally chosen for the LDGRIDSAT tag was too small to accurately record and use onboard post-processing to detect the UWID's acoustic signature. The accelerometer board and connections were too tightly integrated with the LDGRIDSAT tag to make changes in the field. Additional testing will need to be conducted to determine at what distance and how much information can be transmitted through the ice to the LDGRIDSAT tag with an accelerometer with a higher sampling rate.

4.5.3 Barrow Ice Anchor LDGRIDSAT Tag Deployment

An ice anchor LDGRIDSAT tag was deployed approximately 10 kilometers northeast of Barrow on March 26 (see Exhibit 37).

Exhibit 37: Ice anchor LDGRIDSAT tag deployed on an ice floe near Barrow by the URS Team

Exhibit 38 shows the most recent screenshot of the LDGRIDSAT with its last report on May 22, 2016. UIC Science reported that the LDGRIDSAT tag was bent over and postulated that a polar bear had been playing with it. Through weeks of warmer weather, and given its tilted position, the tag likely fell all the way over on its side with the antennas pointing at the horizon and unable to successfully transmit to the satellite network.

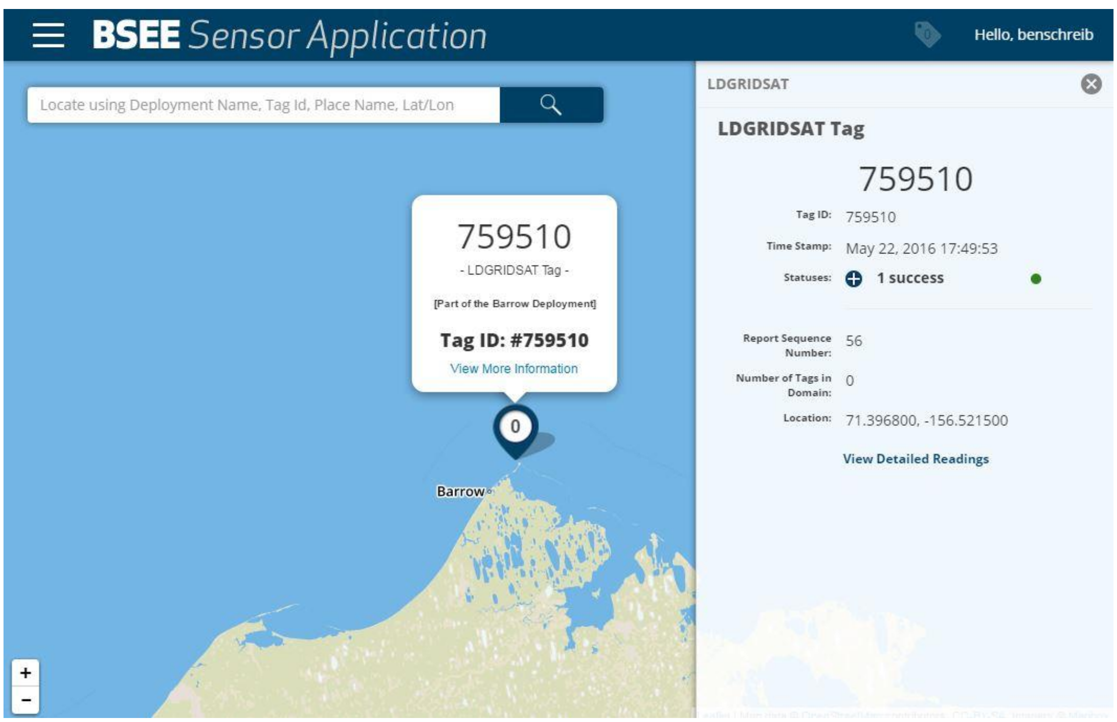


Exhibit 38: Last reporting location of LDGRIDSAT 759510

4.5.4 Barrow Testing Conclusions

The Barrow test showed that the LDGRIDSAT tag can be deployed manually by use of an ice anchor at the base of the tag and that the LDGRIDSAT tag can operate for extended periods in the Arctic environment. LDGRIDSAT tag 759510 was able to continuously report for 57 days. The UWID tag was a success in that the LDGRIDSAT tag detected the UWID acoustic signature out to 10 m. However, the LDGRIDSAT tag could not detect the UWID tag at larger distances. This was likely due to a low sampling rate of the accelerometer used in the LDGRIDSAT tag, and can be corrected with the use of a more expensive accelerometer with a higher sampling rate.

Our team consulted with UIC Science, the outfitter for the Barrow testing, and concluded that the surface tags should be coated with a pepper-based deterrent on the final coat of paint to discourage polar bears from handling the LDGRIDAT tag.

SECTION FIVE: OPERATIONS, MAINTENANCE, AND TRAINING

5.1 SETUP, CONFIGURATION AND OPERATION

The following sections summarize the components, procedures and settings for operation of the LDGRIDSAT tag.

5.1.1 Setup

Before using the systems, the user activates the satellite data service plan on the LDGRIDSAT units through an authorized service provider. The modem number (IMEI) will need to be provided. The satellite data are routed to the pre-defined cloud infrastructure server IP address and port number.

5.1.2 Startup

To install or replace the battery, the bottom cover of the LDGRIDSAT tag must be unscrewed to expose the battery compartment as shown in Exhibit 39. Once the battery is installed and the cover is replaced, the tag will start functioning autonomously; the tags do not have an external power button. Tag IDs are assigned as factory default and are imported into the cloud infrastructure database as part of the standard tag messages.

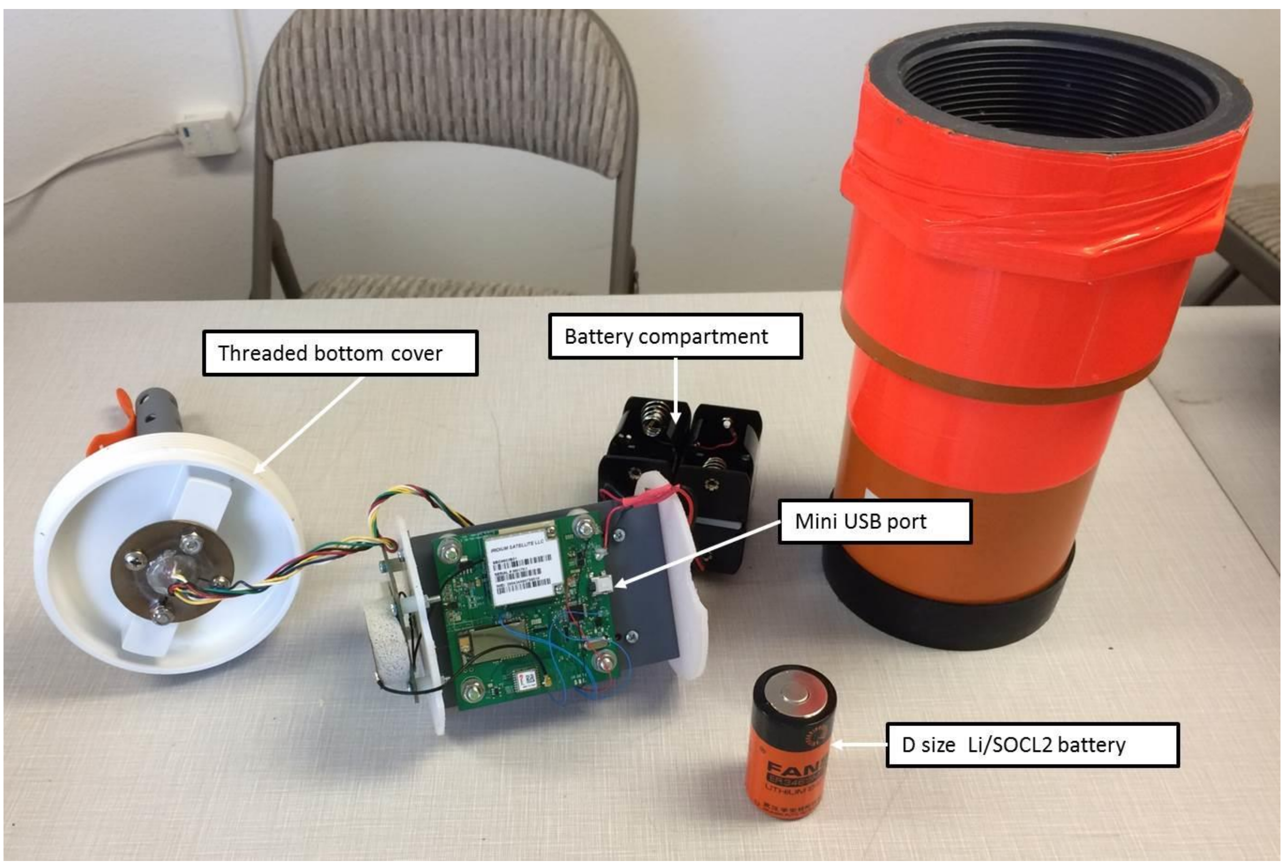


Exhibit 39: LDGRIDSAT tag startup and configuration component parts

5.1.3 Configuration

The LDGRIDSAT tag does not have any external buttons and it operates autonomously. The UWID tag does not have any external buttons and operates in an active mode. In this mode, the tags produce an acoustic beacon for detection by the LDGRIDSAT tags in active mode.

The LDGRIDSAT tag operates in three different modes:

- **Low Power Storage Mode (LPSM)**. This mode is designed for the tags to have minimum power consumption during storage. The motion sensor is monitored during LPSM.
- **Active Mode**. This is the mode in which the tags operate during deployment. In this mode, the LDGRIDSAT tag acts as a network-coordinator host to receive acoustic beacons and process data to ascertain the presence of UWID tags. The LDGRIDSAT tag also establishes the satellite communication link and runs the server update cycle with GPS fix.
- **Maintenance Mode (MM)**. This mode can be initiated by issuing an addressed maintenance command message to a target LDGRIDSAT tag through the USB interface (Type-A Male USB to Mini type-B Male USB cable required). In this mode, the configuration parameters on the tags can be retrieved and set using commanding messages.

MM is used to configure tag parameters. To enter into MM:

1. Plug in the USB cable
2. Insert the batteries
3. Deploy TeraTerm, a terminal emulator for communications, on the computer
4. Hit “Enter” on the keyboard to start
5. Type “?” and hit “Enter” on the keyboard to see the menu
6. Start entering commands

The configuration parameters, debug output parameter definitions, and the screen shot of the maintenance software tool are presented in Exhibits 40 through 42.

Exhibit 40: LDGRIDSAT configuration parameters

Command	Description	Parameter
P (shift p)	Sets the LDGRIDSAT automatic reporting period.	Valid range: 0 – 10080 minutes 0 disables the automatic reporting to manual.
r	Starts a LDGRIDSAT report in manual mode (when P=0)	N/A
m	Motion Parameters:	
	Storage To Active Event Window:	Valid Range 1 – 65535

Command	Description	Parameter
	• Event window started at first motion event while in storage mode. Runs until the end of the window period and the tag remains in storage mode. Or the threshold number events occur and the tag switches to active mode.	Time in seconds
	Storage To Active Event Threshold: • Number of motion events to detect within the event window to switch from storage to active mode.	Valid Range: 1 – 255 events
	Active to Storage No Event Window: • Window reset after each motion event. If window period times out without any motion events, tag switches to storage mode.	Valid Range: 1 – 65535 Time in seconds
	Motion Event Active Threshold: • Minimum motion magnitude to initiate motion detect.	Valid Range: 10 – 65535 (1.0 g – 6553.5 g) Units: 0.1 g
	Motion Event Active Period: • Minimum period for motion magnitude to be above active threshold to qualify as motion event.	Valid Range: 0 – 255 (25.5 s) Units: 100 ms
	Motion Event Inactive Threshold: • Maximum motion magnitude to initiate end of motion event.	Valid Range: 10 – 65535 (1.0 g – 6553.5 g) Units: 0.1 g
	Motion Event Inactive Period: • Minimum period for motion magnitude to be below inactive threshold to end motion event.	Valid Range: 0 – 255 (25.5 s) Units: 100 ms
D	Enable debug output	
d	Disable debug output	

Exhibit 41: LDGRIDSAT debug output messages

appTagHandler: Tag Report Message		
Command	**Description**	**Parameter**
tag [value]	Tag serial ID in hexadecimal	Valid Range: 0 – 0xffffffff
cyc [value]	Network cycle of received report message. Used to detect duplicate reports.	Valid Range: 0 – 255 Wrap around from 255 to 0
Status [value]	Tag status word	Bitmap of tag statues
appStatusHandler: End of Network Cycle		
Command	**Description**	**Parameter**
cyc [value]	Network cycle of received report message. Used to detect duplicate reports.	Valid Range: 0 – 255 Wrap around from 255 to 0
tags [value]	Number of tag reports received	Bitmap of tag reports

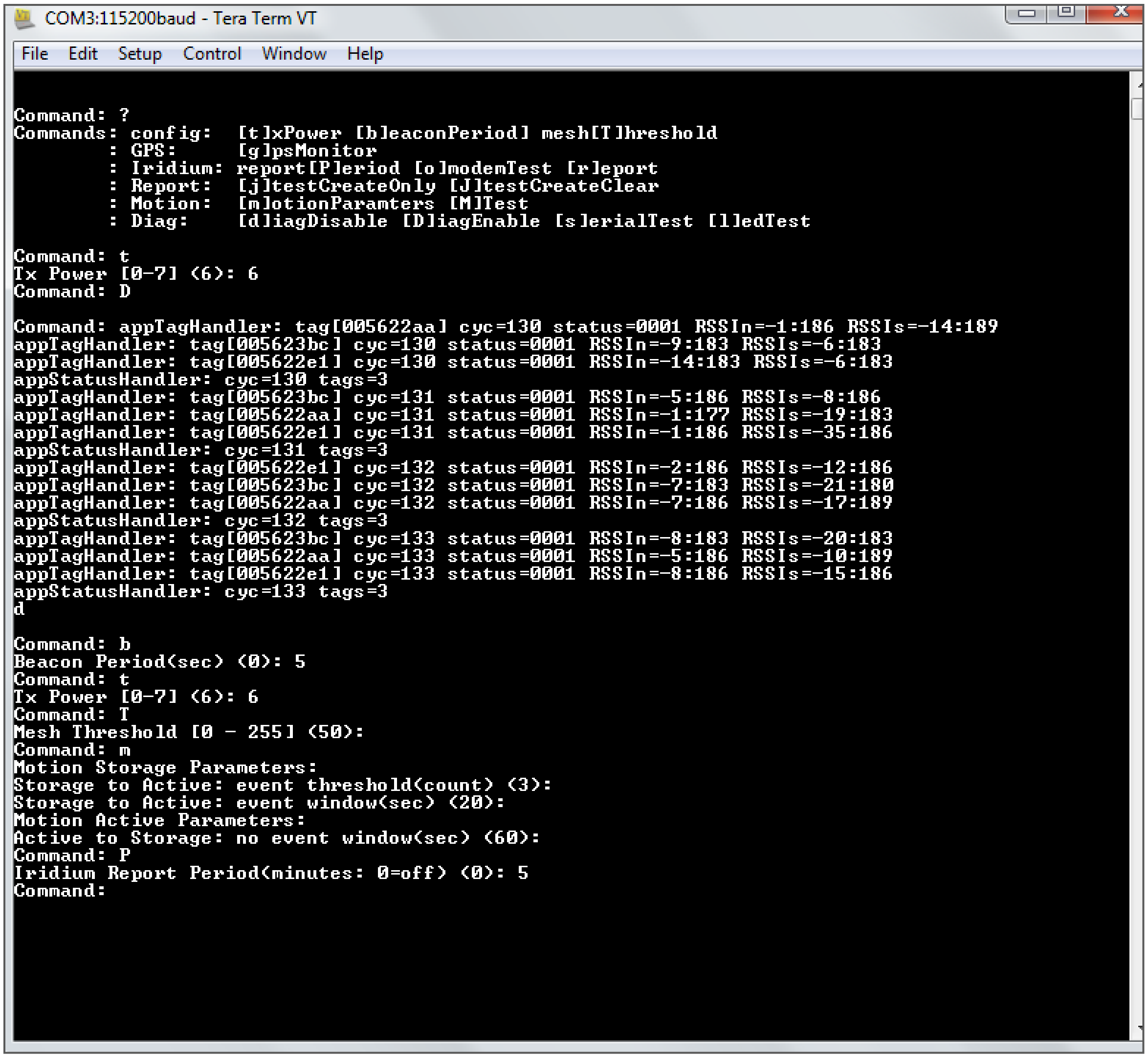


Exhibit 42: TeraTerm command line interface to configure tags

To disconnect and power down from MM:

1. Go to TeraTerm File tab and click disconnect or close TeraTerm
2. Disconnect the USB cable
3. Remove LDGRIDSAT tag batteries

5.2 MAPPING USER INTERFACE USER GUIDE

Included as Appendix B.

SECTION SIX: CONCLUSION

The URS Team initiated this project with the original objectives as outlined by the Broad Agency Announcement and refined them during the kickoff meeting with BSEE to develop the goals, functions, and objectives of the system. The URS Team derived and analyzed the system performance requirements to form a conceptual design of the system, identifying the necessary components needed for the desired functionality. The team used data from a COTS assessment, analysis of alternatives, and trade study to find the components, software, hardware, services, and subsystems to use as part of the design. The components that were selected for the system were inspected to validate that they met the performance requirements and provided the interoperability required at each of the network and data interfaces. The team presented the design details for each major subsystem: LDGRIDSAT tag, UWID tag, cloud infrastructure, and user interface. The system components were then prototyped, and functionality was validated by subsystem unit testing and full system testing at CRREL, ICEX, and in Barrow, AK.

Through open discussion and an iterative and flexible design process, the URS Team has demonstrated the capabilities of this prototype IFTS. We successfully implemented our original, key novel developments of a pinging Lamb wave sensor for use in an UWID tag and developing a COTS-based LDGRIDSAT tag ruggedized for the Arctic environment and for a variety of deployment options, including air drops, with adaptive power management and material enclosure designs to mitigate adverse effects from the environment.

Our tests at CRREL showed that the UWID tag could be used to transmit guided waves from underneath the ice to the surface. ICEX testing demonstrated the resilient design of the LDGRIDSAT tags to be deployed from the air and survive the harshest Arctic environments. The demonstration in Barrow, AK proved that the end-to-end data transmission works, from UWID acoustic beacon to surface LDGRIDSAT tag detection to transmission through a satellite network for display on the mapping user interface with extended times on station in extreme environments for long-term monitoring and stakeholder action.

The URS Team plans to continue this work by refining the UWID and LDGRIDSAT tag designs, including a new accelerometer and detection firmware to extend detection distances between the UWID and LDGRIDSAT tags.

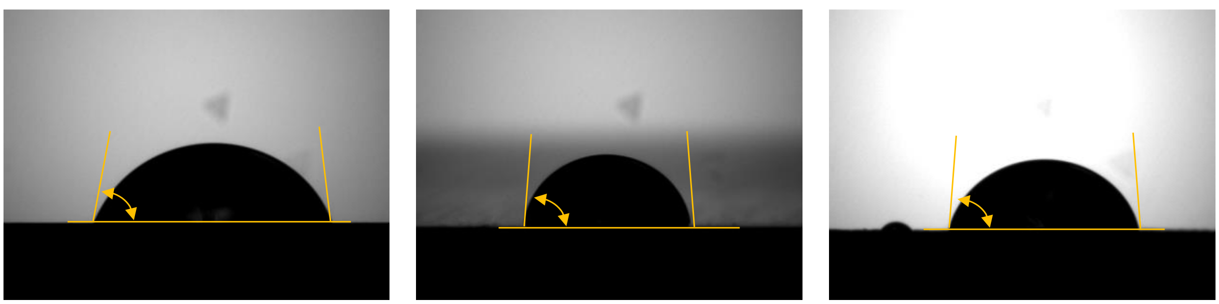
Appendix A:

Enclosure Ice Prevention Study

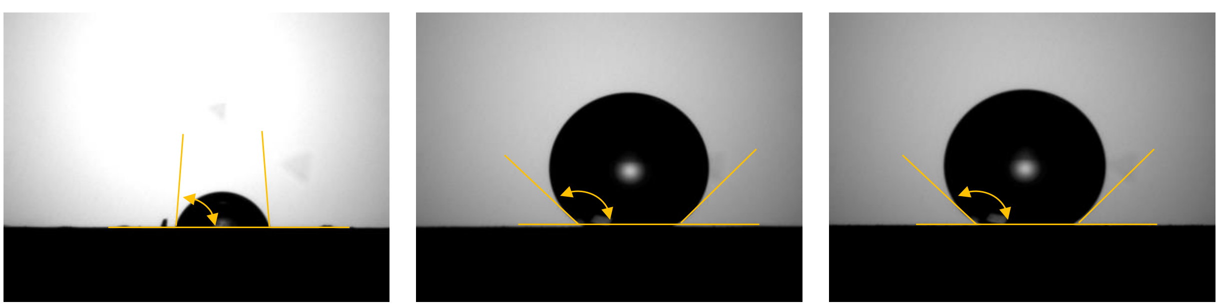
Because the LDGRIDSAT tag would be deployed in cold weather regions, ice could form on the surface of the enclosure, weakening or blocking the radio frequency signal from the tag's antenna. To reduce or eliminate ice formation, the antenna enclosure surface could be covered with a hydrophobic material. The more hydrophobic the surface, the more slowly ice will form.

Evigia has conducted extensive tests on different materials that can coat or be taped onto the top of the enclosure near the antenna. The angle at which water contacts the surface is an indicator of how hydrophobic the material is. Typically, the steeper the angle, the more hydrophobic the material. Exhibit 43 shows the measured contact angle of water on the surface with different material coatings using a Rame-Hart goniometer.

The tag enclosure itself was polished to form a relatively hydrophobic surface. The URS Team first compared the original hydrophobic enclosure surface to black tape, Parylene C coating, and polyimide coatings. The water contact angles of these materials did not significantly differ from one another; all of them were between 86 and 89 degrees. We then explored two different commercially available superhydrophobic coatings applied directly to the enclosure: Water Beader™ and Hydrobead©. Both of the coatings can be sprayed on and are easy to apply in multiple layers on most clean surfaces. Exhibit 43 shows the water contact angles of these two superhydrophobic coatings; the contact angles are very similar and both are greater than 110 degrees.



(a) Enclosure w/o coating: 86.2° (b) Black Tape: 88.4° (c) Paralyne coating: 87.6°



(d) Polyimide Tape: 87.9° (e) Water Beader™ coating 112.6° (f) Hydrobead© coating 111.0°

Exhibit 43: Water contact angle measurement of the surface with different material coatings for ice prevention

As indicated in Exhibits 43e and 43f, the water droplet forms into a ball on a superhydrophobic surface and does not cling to the surface. If the surface has a slight tilt, the water ball will drift off. This indicates that a tilted (or upside-down) mounting of the tag may promote water removal from the surface because it will be more hydrophobic. Exhibit 44 illustrates the water test on a coated enclosure compared with the uncoated area and black tape, which has a similar water contact angle. The enclosure is tilted at 45 degrees from horizontal. As shown, the black tape and original enclosure surface can still trap water on the surface, but water droplets slide away from the surface coated with Water Beader™.

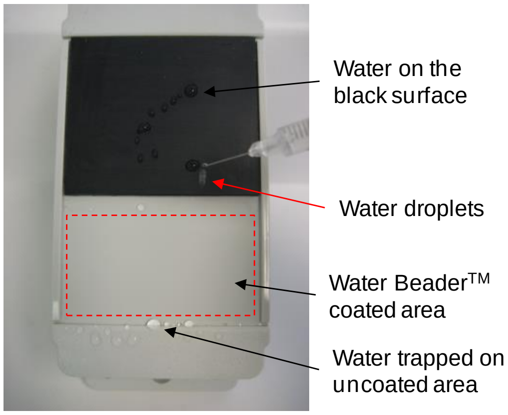


Exhibit 44: Water droplet test on the surface of enclosure

Note that the hydrophobic surface can slow ice formation, but if large water droplets remain on a horizontal surface, ice can still form. Exhibit 45 shows the water droplets on our test surfaces have frozen into an ice ball below 0 degrees Celsius (°C) in a BTRC environmental chamber. Both areas sprayed with superhydrophobic coating are similar and have ice balls that remained on the surface.

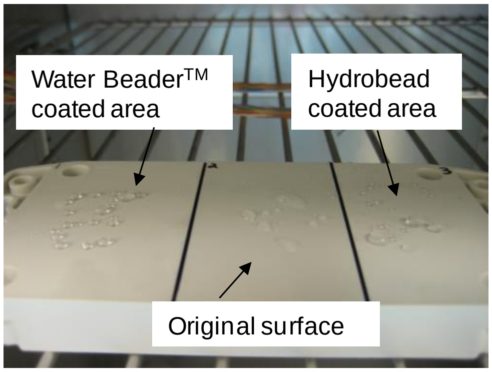


Exhibit 45: Water droplet freezing test in a BTRC environmental chamber

The durability of various hydrophobic coatings in a rugged field environment due to aging and/or being scratched off is projected to be limited (about 1 year). Evigia's goal is to provide an easy and low-cost solution for the ice prevention. Therefore, we continue to employ enclosures with smooth and polished surfaces to provide hydrophobic properties. In addition, we can develop a tape coated with durable superhydrophobic coating materials, such that the tape can be attached to and peeled from the enclosure surface (near the antenna) during maintenance. Finally, the tapes or spray-on superhydrophobic coating in the antenna area could be employed just prior to deployment of the tags in arctic regions.

Appendix B:

User Guide

BSEE Sensor Application

User Guide

Verison 1.7 • July 5, 2015

user guide (n.)

A user guide or user's guide, also commonly known as a manual, is a technical communication document intended to give assistance to people using a particular system.

A

Add Tags

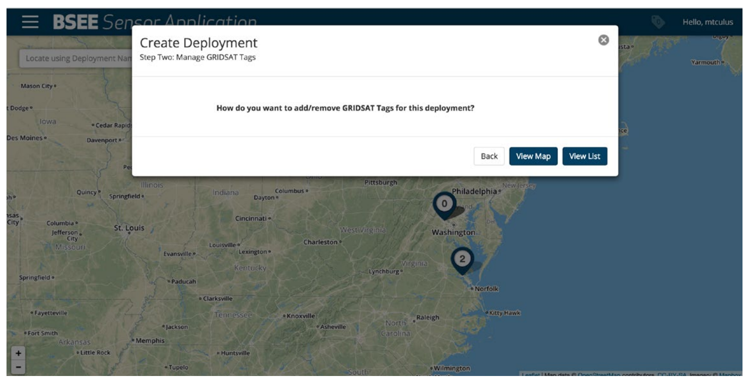
Only **Administrators** can add **GRIDSAT Tags** and subsequently **GRID Tags** to the system. Only **Administrators** can add **LDGRIDSAT Tags**.

Add to Existing Deployment

To add to an existing deployment, click the **Menu**[1] Button and select **Edit Deployment** from the menu. Then the select the deployment you wish to edit. Next the user can review the **GRIDSAT Tags** and **LDGRIDSAT Tags** in the deployment. Then the user must choose if they want to **Visualize Tags** or Manually Enter **Tags**[2]. Once the user has added tags to the **Deployment**, they will be asked again to review the added **GRIDSAT** or **LDGRIDSAT Tag(s)**.

01

02



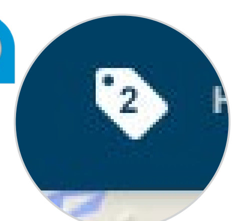
Administrator

Administrator is the highest user setting in the BSEE Sensor Application. An administrator can see all **Tags** and **Deployments**, add **GRIDSAT Tags** and **LDGRIDSAT Tags** to the system and assign **GRIDSAT Tags** and **LDGRIDSAT Tags** to users. To learn your permission level, click **Settings** in the main menu. At the bottom of the list you will see the category **Role**. Your permission level will be listed below.

Assign GRIDSAT Tag and LDGRIDSAT Tag

Administrators and **Super Users** can assign **GRIDSAT Tags** or **LDGRIDSAT Tags** to users. Once assigned, a **Notification**[3] will be displayed to the user.

03

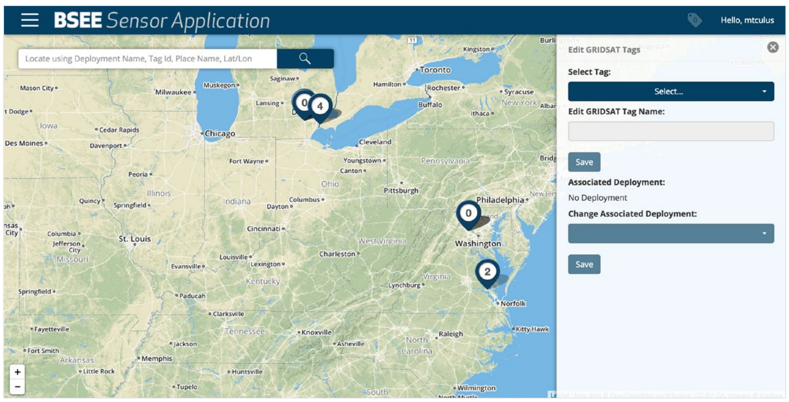


C

Change Associated Deployment

The user can change the deployment associated to a **GRIDSAT Tag** or **LDGRIDSAT Tag**. The user can complete this task by clicking Edit **GRIDSAT Tags** in the main menu. Next, the user simply needs to select the **Tag ID** and then a new **Deployment** from the dropdown under **Change Associated Deployment**[4]. When you are done, click the save button.

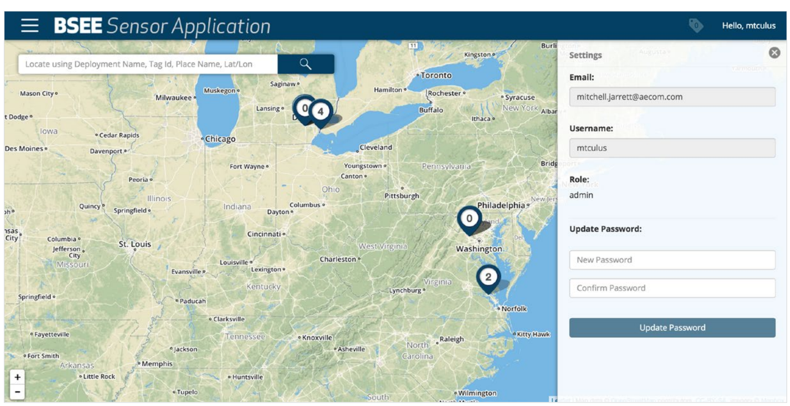
04



Change Password

You can change your **Password** by clicking the **Settings**[5] link in the main menu. Type a new password and confirm that password. When you are done, click the update password button.

05



Close Drawer

To close the information drawer on the right side of the application, click the circular **"X" icon**[6] in the upper right of the sliding **Drawer**.

06

URS

Create Deployment

To create a new **Deployment**, click the menu button and select **Create New Deployment** from the menu. The first action of creating a deployment is to name the deployment. Next the user must choose if they want to **Visualize Tags** or Manually Enter **Tags**. Once the user has added tags to the deployment, they will be asked to review added **GRIDSAT** and **LDGRIDSAT Tag(s)**.

D

Deployment

A **Deployment** is a group of **GRIDSAT** and **LDGRIDSAT Tags**.

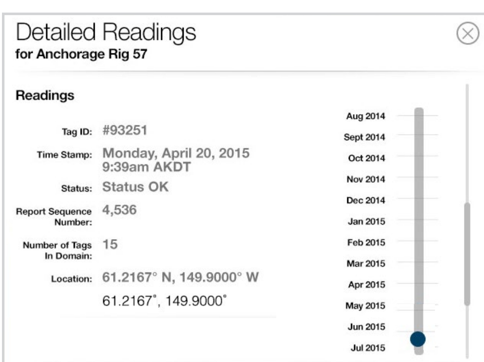
Detailed Readings

Detail Readings contains two categories: Readings and Location. The **Readings**[7] section shows the following readings: **Tag ID**, **Time Stamp**, **Status**, **Report Sequence Number**, **Number of Tags in Domain**, and **Location**. There is a scrub slider that allows the user to see all of the aforementioned readings at different times over the life of the **GRIDSAT Tag** or **LDGRIDSAT Tag**.

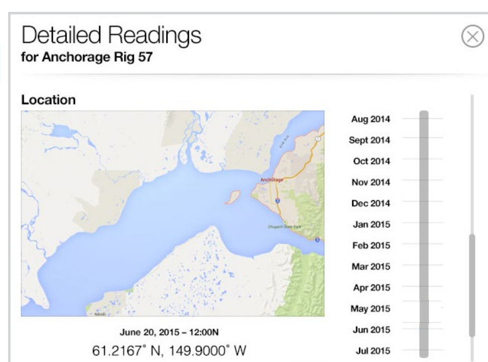
The **Location**[8] section shows the position (Visually and Numerically) over time. There is a scrub slider that allows the user to select a particular point in time and thus the position of the **GRIDSAT Tag** or **LDGRIDSAT Tag**.

To access the Detailed Reading section, click on a **GRIDSAT Tag** or **LDGRIDSAT Tag** pin. A Tooltip will appear and at the bottom you will find a **View More Information** link. This link will open the **Deployment** drawer with more information about that particular **Tag**. You will find a **View Detailed Readings** at the bottom of the corresponding **Tag** entry.

07



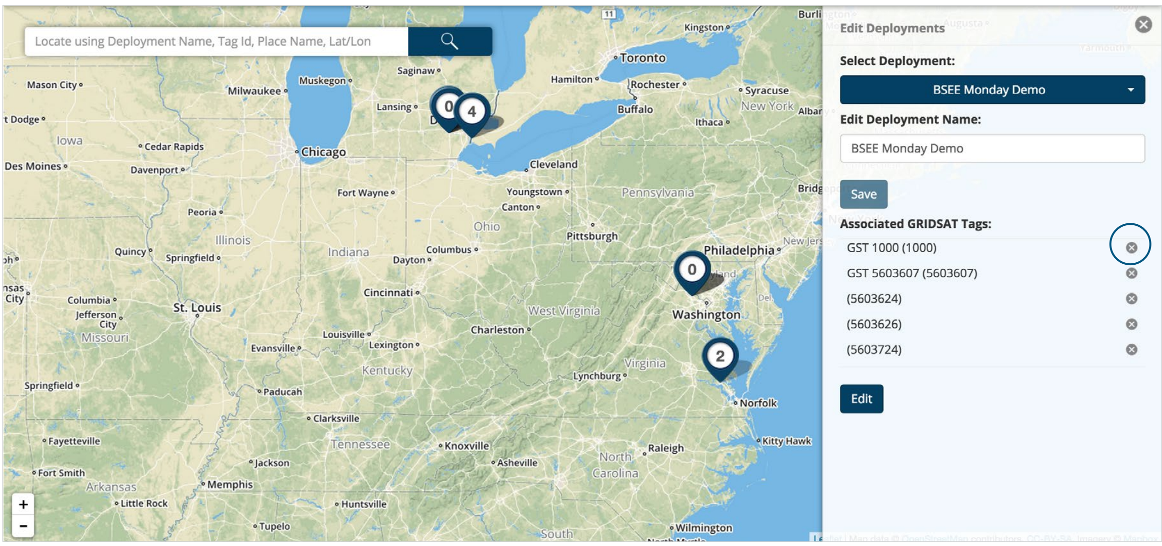
08



Disassociate GRIDSAT Tag

A **GRIDSAT Tag** or **LDGRIDSAT Tag** can be associated and disassociated with **Deployments**. If the user would like to disassociate a **Tag**, select Edit Deployments from the main menu. Next simply click the **"X" Icon**[9] next to the **Tag** you would like to disassociate at the bottom of the **Edit Deployments** drawer.

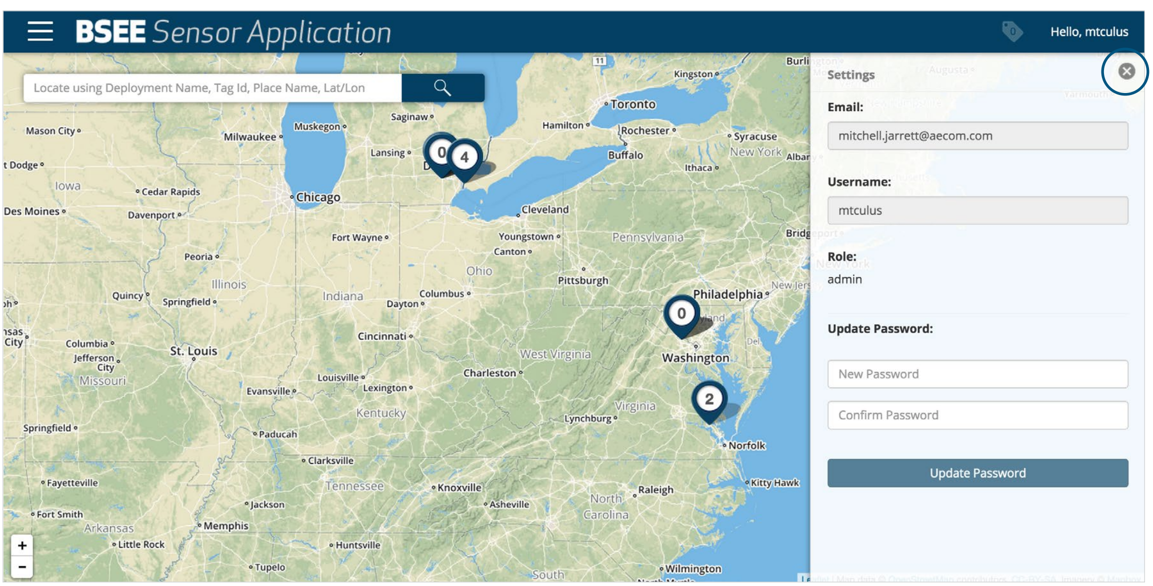
09



Drawers

Drawers refer to the container which slides in from the right side of the application. Clicking the **"X" Icon**[10] found in the upper right can retract the drawer.

10



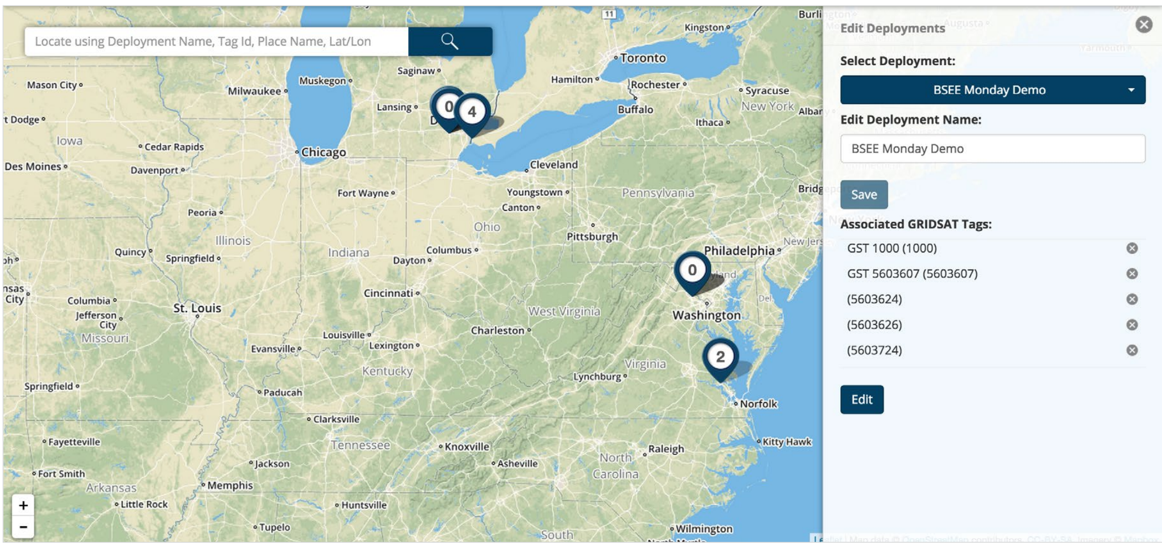
URS

E

Edit Deployment Name

Click **Edit Deployments**[11] from the main menu and the second item in the **Edit Deployments** drawer is **Edit Deployment Name**. Simply type in a new deployment name and click the save button when you are done.

11



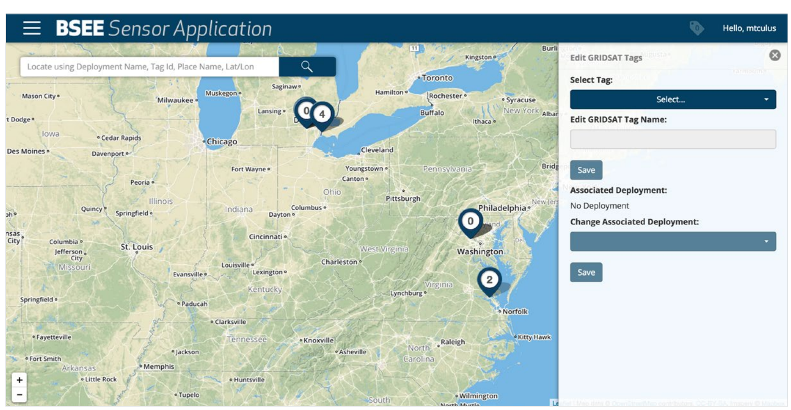
Edit Deployments

To find this action, click **Edit Deployments** found in the main menu. Within this **Drawer** you will be able to **Edit Deployment Name** and see which **GRIDSAT Tags** or **LDGRIDSAT Tags** are associated to a particular **Deployment**.

Edit GRIDSAT Tag or LDGRIDSAT Tag

To find this action, click **Edit GRIDSAT Tags** found in the main menu. Within this **Drawer**[12] you will be able to select a **GRIDSAT Tag** or **LDGRIDSAT Tag**, edit the **Tag** Name, **Change Associated Deployment** and see which **GRID Tags** are associated to a particular **GRIDSAT Tag**.

12



URS

Edit GRIDSAT Tag or LDGRIDSAT Tag Name

To find this action, click **Edit GRIDSAT Tag** found in the main menu. Next click the Edit Icon next to **Edit GRIDSAT Tag Name** and enter the new name. When you are done, click the save button. (See inset number 12.)

G

GRIDSAT Tags

Geo-Referencing Identification Satellite (**GRIDSAT**) tag is a Global Positioning System and satellite modem enabled radio-frequency device that acts as a gateway for all **GRID tags** to communicate tag identification, time, location and status information to the BSEE sensor application.

GRID Tags

Geo-Referencing Identification (**GRID**) tag is a radio-frequency enabled device that communicates through a mesh network of other **GRID tags** to a **GRIDSAT tag** for asset identification and tracking.

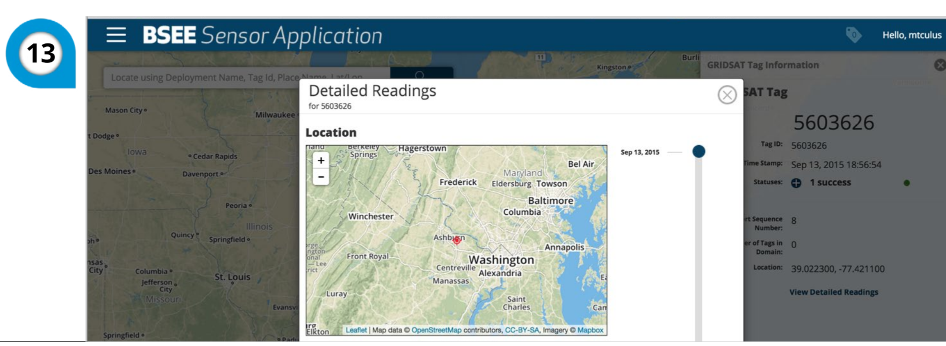
L

LDGRIDSAT Tags

Lamb-wave Detection Geo-Referencing Identification Satellite (**LDGRIDSAT**) tag is a Global Positioning System and satellite modem enabled radio-frequency device that detects signals through guided waves generated from **UWID Tags** and acts as a gateway to communicate **UWID Tag** identification, time and sequence number information to the BSEE sensor application.

Location

The **Location**[13] section shows the position (Visually and Numerically) over the course of time. There is a scrub slider that allows the user to select a particular point in time and thus the position of the **GRIDSAT** or **LDGRIDSAT Tag**.



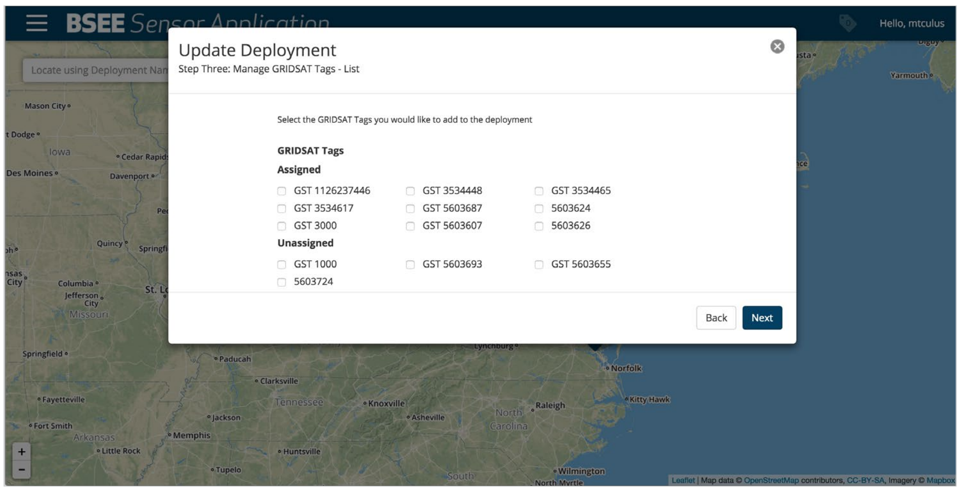
URS

M

Manually Enter Tags

Manually Enter Tags[14] means the user can select **GRIDSAT Tags** or **LDGRIDSAT Tags** to add/ associate to a **Deployment** by checking boxes next to the desired **Tag**. You can reach this action by selecting **Create New Deployment** or **Edit Deployments** both of which are found in the main menu.

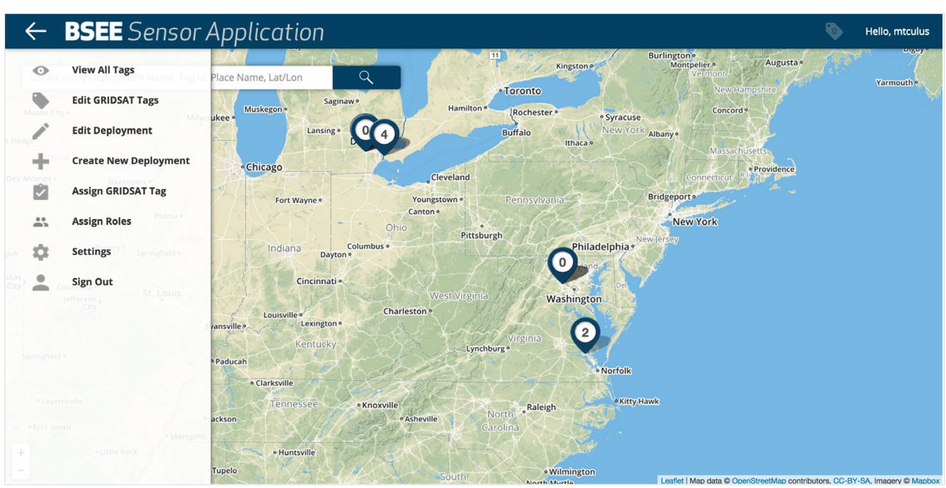
14



Menu

The **Main Menu**[15] of the BSEE Sensor Application will be accessible using the menu icon (three horizontal lines). The user can access the following actions from the menu: **View All Tags**, **Edit GRIDSAT Tags**, **Edit Deployment**, **Create New Deployment**, **Assign GRIDSAT Tags**, **Settings**, and **Sign Out**.

15



Message Sequence

Message Sequence is the number of consecutively detected signals by the **LDGRIDSAT Tag** from a **UWID Tag** since the **LDGRIDSAT Tag** was powered on.

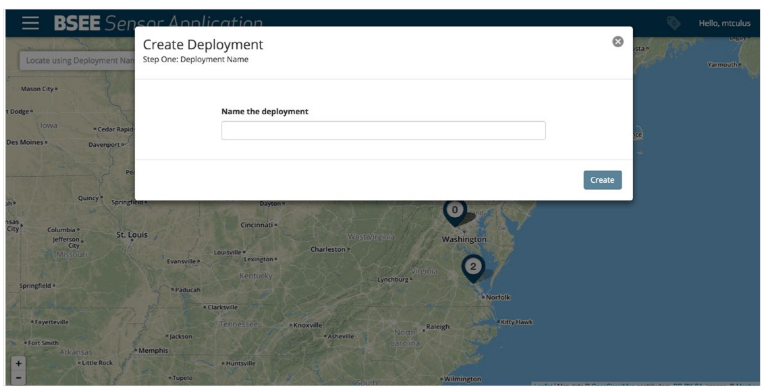
N

Name Deployment

There are two ways to name a **Deployment**. You can (1) name a deployment when you initially **Create New Deployment** or (2) you can **Edit Deployment Name**.

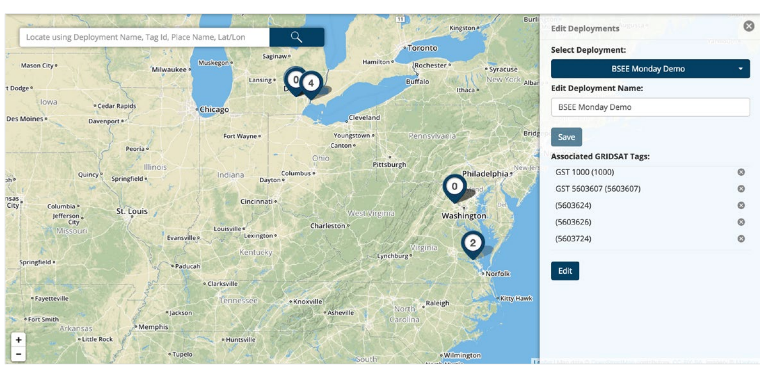
1. Simply click **Create New Deployment** from the main menu and **Name Deployment**[16] is the first step.

16



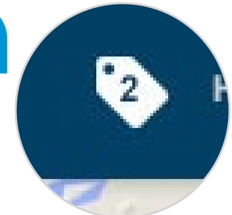
2. Click **Edit Deployments** from the main menu and the second item in the **Edit Deployments** drawer is **Edit Deployment Name**. Click the Edit Icon[17], type in a new deployment name and click save when you are done.

17



Notification

18



The BSEE Sensor Application will notify the user when **GRIDSAT** or **LDGRIDSAT Tags** have been assigned to the user. **Notifications**[18] will persist in the top navigation bar. **Notifications** will reset after the user views the All Tags page.

Number of Tags in Domain

The **Number of Tags in Domain** simply refers to number of **GRID Tags** associated to a given **GRIDSAT Tag** or the number of **UWID Tags** detected by a given **LDGRIDSAT Tag**.

P

Password

Passwords for the BSEE Sensor Application must be at least 8 characters long and must use 3 of the following 4 when creating password: Upper Case, Lower Case, Number, Special Character (i.e. !@#$...). You can change your password by clicking the **Settings** link in the main menu. See **Change Password**.

R

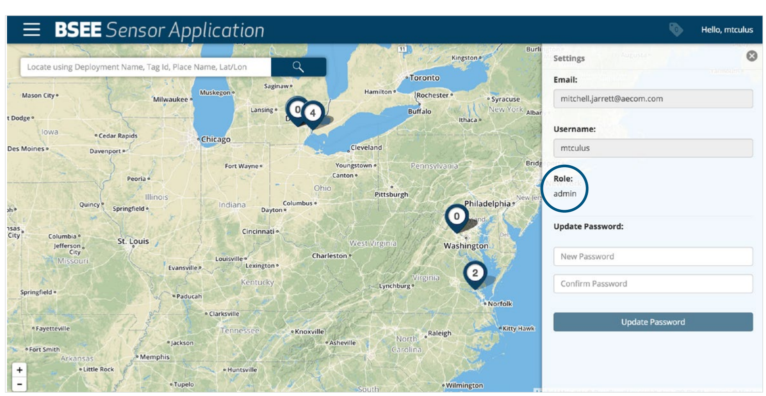
Register

The BSEE Sensor Application requires users to be signed into the application in order to access any and all parts of the program. To register an account, click the link beneath the **Sign In** button on the Sign In page. The registration process requires an Email Address, User Name, and **Password**.

Regular User

Regular User is the lowest user setting in the BSEE Sensor Application. A Regular User can only see the **Tags** an **Administrator** or **Super User** has assigned to the user. To learn your permission level, click **Settings** in the main menu. At the bottom of the list you will see the category **Role**[19]. Your permission level will be listed below.

19



Report Sequence Number

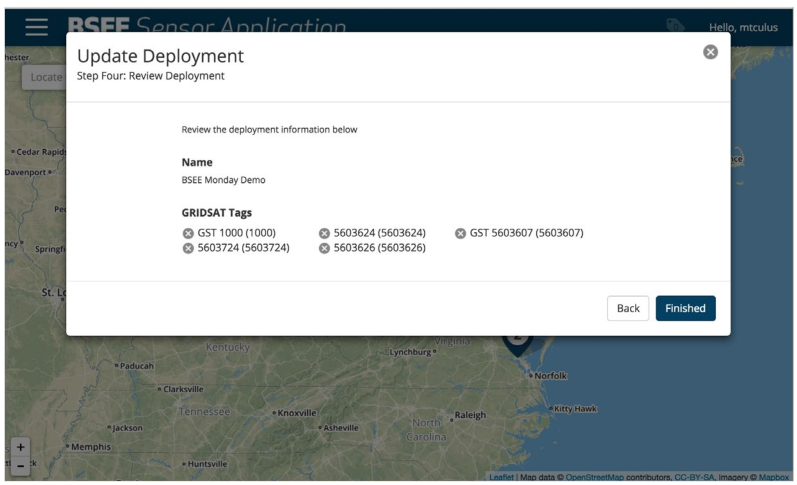
Number of consecutive reports transmitted to the BSEE sensor application from a **GRIDSAT Tag** or **LDGRIDSAT Tag** since powering on.

Review Deployment

Review Deployment[20] refers to reviewing the **GRIDSAT Tags** and **LDGRIDSAT Tags** associated to a particular **Deployment**. There are three ways to review the **Tags**:

1. After the user has created a new deployment.
2. Before and after the user edits a deployment
3. The user can see all of the **GRIDSAT Tags** and **LDGRIDSAT Tags** associated to a specific **Deployment** in the **Edit Deployment** Drawer.

20



Role

There are three roles with three distinct permission levels within the BSEE Sensor Application. The three roles are **Administrator**, **Super User**, and **Regular User**.

S

Search

The search box will allow users to search the BSEE Sensor Application using Longitude & Latitude, Places of Interest, **Tag ID**, Tag Name, or **Deployment** Name.

Settings

The program settings for the BSEE Sensor Application can be found at the bottom of the **Main Menu**[21]. The **Settings** drawer will contain the four following actions: **Edit Email**, **Edit Username**, **Edit Password** and **Role**.

21

Sign In

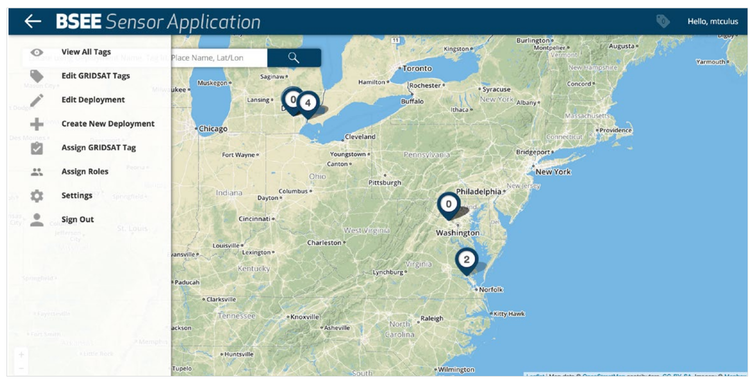
The BSEE Sensor Application requires users to be signed into the application in order to access any and all parts of the program. To sign into the BSEE Sensor Application the user will need to enter an Email Address and a **Password**.

Sign Out

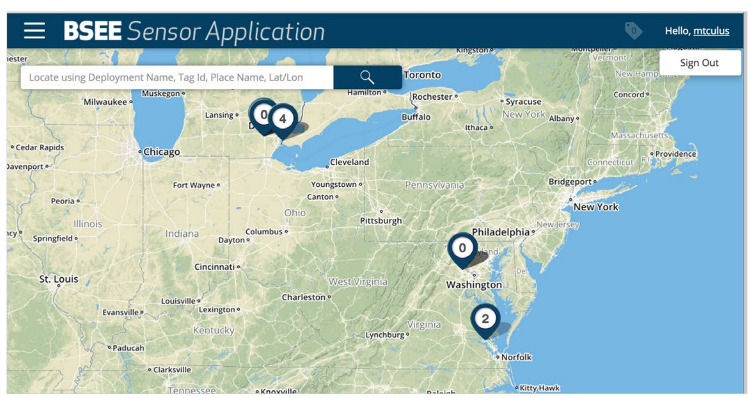
There are two ways to sign out of the application.

1. The user can find the **Sign Out link**[22] at the bottom of the main menu.
2. The user can also sign out by clicking the **Username**[23] in the upper right corner of the navigation bar.

22



23



Status

Tags can show the following status messages: Status OK, Battery Low, GPS Fault, No GPS Fix, RF Module Fault, Stationary, and Reserved.

Super User

Super User is the middle user setting in the BSEE Sensor Application. A Super User can see all **Tags** and **Deployments** and assign **GRIDSAT Tags** and **LDGRIDSAT Tags** to users. The only operation a **Super User** cannot perform is adding **Tags** to the system. To learn your permission level, click **Settings** in the **Main Menu**. At the bottom of the list you will see the category **Role**. Your permission level will be listed below.

T

Tag ID

This is a unique ID for **GRIDSAT Tags**, **LDGRIDSAT Tags**, **GRID Tags** and **UWID Tags**. **Administrators** use these **Tag IDs** to add **GRIDSAT Tags** and **LDGRIDSAT Tags** to the BSEE Sensor Application and distinguish unique IDs for associated **GRID Tags** and detected **UWID Tags**.

Tags

A physical device used to identify, locate and track assets that it is attached to. The **GRID**, **GRIDSAT** and **LDGRIDSAT** are defined as **Tags**.

Time Stamp

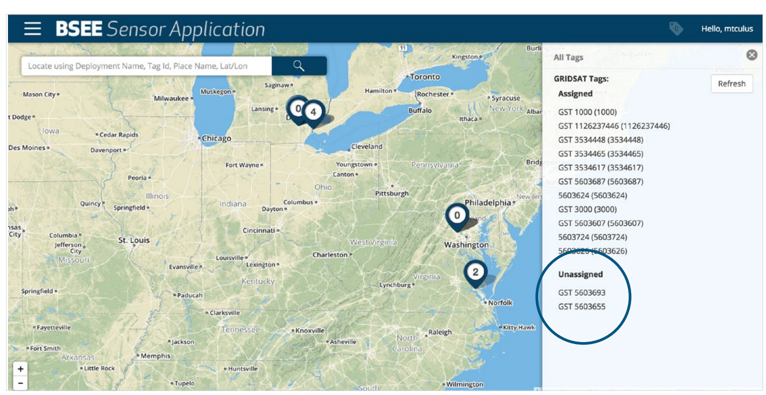
The **Time Stamp** is the time when the **GRIDSAT Tag**, **LDGRIDSAT Tag** or **GRID Tag** last collected or transmitted data.

U

Unassigned GRIDSAT Tags

Unassigned GRIDSAT Tags[24] are any tag that have not been associated to a **Deployment.** The user can find which **GRIDSAT Tags** and **LDGRIDSAT Tags** are unassigned by clicking **View All Tags** in the **Main Menu**. There will also be an indicator to show which unassigned **GRIDSAT Tags** and **LDGRIDSAT Tags** have been assigned to the user by an **Administrator** or **Super User**.

24



UWID Tags

Under-Water Identification (**UWID**) tags are acoustic generating devices deployed beneath the ice for detection by the surface **LDGRIDSAT Tags**.

V

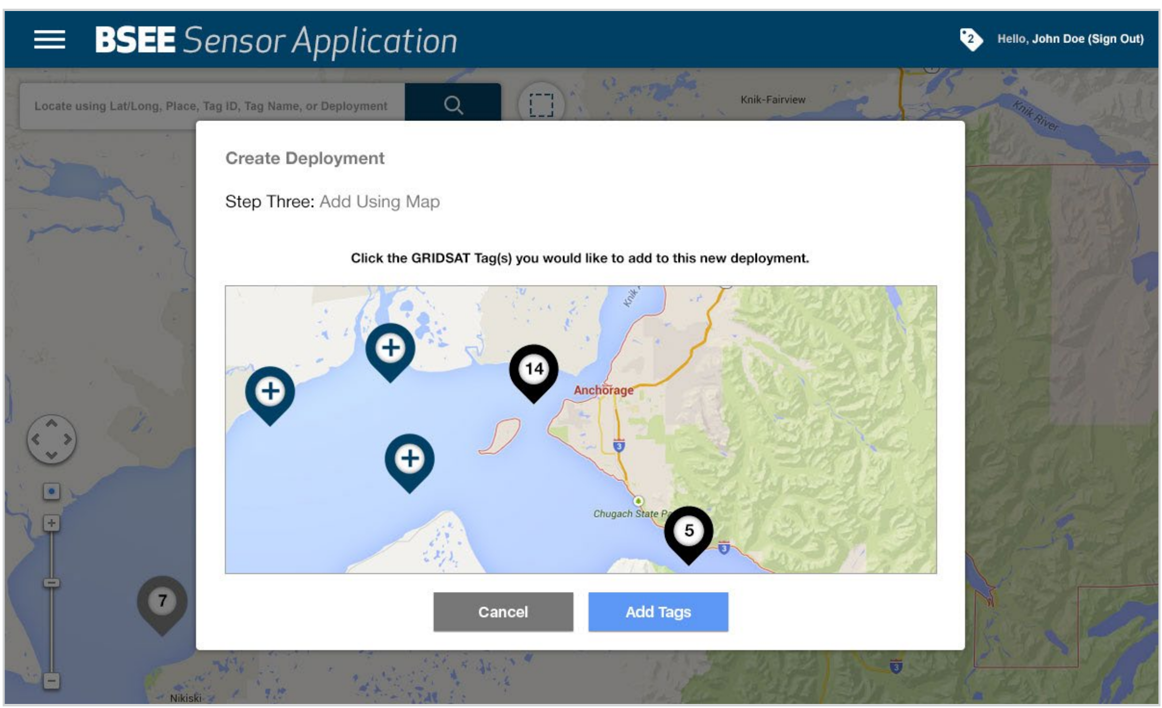
View All Tags

This action will allow the user to see all of the **GRIDSAT Tags** and **LDGRIDSAT Tags** assigned to a user. The All **Tags** drawer will have two distinct sections: **Assigned GRIDSAT Tags** and **Unassigned GRIDSAT Tags**. (See above example image.)

Visualize Tags

Visualize Tags[25] means the user can select **GRIDSAT Tags** and **LDGRIDSAT Tags** to add/associate to a **Deployment** by clicking **GRIDSAT Tag** or **LDGRIDSAT Tag** Pins located on a map. You can reach this action by selecting **Create New Deployment** or **Edit Deployments** both of which are found in the **main menu**.

25



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