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A Remote Release Device for Marine Mammal Electronic Tags

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LONG-TERM GOALS

This new technology aims to provide researchers with a safe and reliable method for retrieving and reusing data-logging tags deployed on marine mammals. The RRD and handheld controller use the internationally-accepted Argos wireless-protocol for line-of-sight communication. Once interrogated with a unique command, the RRD activates its release mechanism's electrically-degradable epoxy. The RRD is separated from its baseplate within 10 seconds of being activated. Once retrieved, the RRD can be refurbished with a new 'cartridge' and baseplate for subsequent deployment of payload devices.

The tasks completed in this period focused on building and testing the RRD and its system components, which helped to identify assembly tasks and production costs associated with manufacture. Custom-built electronics have been integrated into the hardware of the RRD and the handheld controller. While their functionality has been verified, these devices contain embedded processors and their native applications continue to be written and tested. Mechanical housings and fixtures for assembling the RRD's release mechanism have been iteratively developed and tested for applicable bond strength and release time. Lastly, the current form of the RRD is L: 4.2" x W: 2.5" H: 0.8" and was achieved using in-house vacuum casting techniques.

In collaboration with Russ Andrews and the Alaska SeaLife Center, refinements to the design have been incorporated so that typical applications of this technology will be better served. Field trials are slated for deployment on free-ranging pinnipeds within the next 6 months.

OBJECTIVES

The objectives of this program are to further develop and field test a prototype Remote Release Device (RRD) and its handheld Remote Release Controller (RRC) for retrieval of payload data-logging tags. This contract includes four main tasks:

1. Design and manufacture 20 RRDs suitable for deployment on large and small pinnipeds and 1 handheld RRC.
2. Test the system and its components in a laboratory-controlled environment.
3. Test and demonstrate the system's capabilities in a realistic study scenario without animals.

4. Test the system on free-ranging pinnipeds carrying payload data-logging tags.

APPROACH

A handheld RRC sends a release command to a listening RRD (see Figure 1). The RRD interprets incoming messages and decides whether or not it should initiate its release mechanism. Upon doing so, the RRD sends a reply message verifying that it has successfully detached from its baseplate.

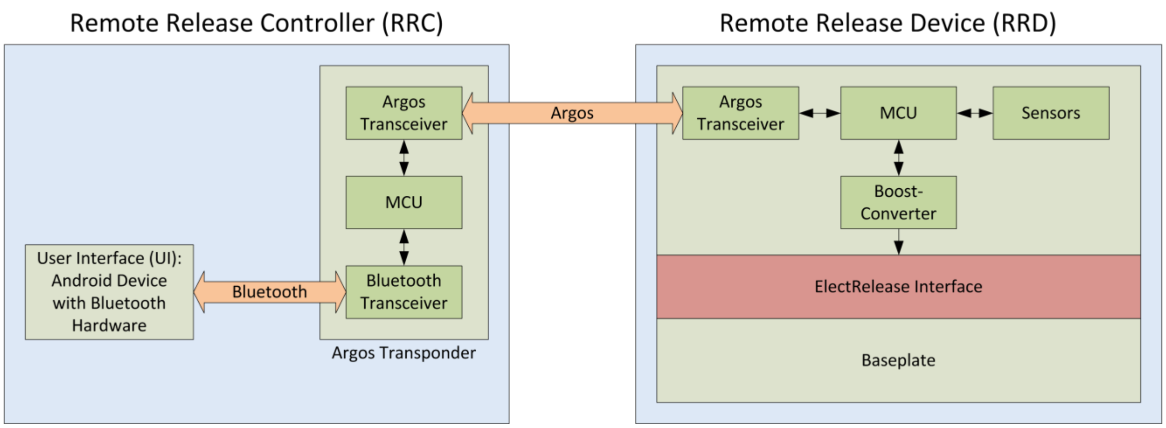

Figure 1: Block diagram of the major system components are highlighted in blue: The RRC is geographically represented "at-the-user" while the RRD is located "on-the-animal." Long-range communication (< 3.5 km) is accomplished through Argos modulation and depicted by the orange "Argos" arrow. Physically distinct components of these systems are shown in light green: The RRC is comprised of an Android mobile device and an Argos transponder. These components communicate using short-range (< 15 m) Bluetooth modulation that synthesizes a bi-directional serial-data transfer (shown by the orange 'Bluetooth' arrow). The RRD is comprised of a baseplate (secured to the study animal) and a reusable platform (that includes its internal electronics and carries a payload). A release mechanism uses ElectRelease epoxy to hold these components together when in deployment mode. When requested to release from the baseplate (release mode), the ElectRelease interface is broken down and the reusable platform is separated from its baseplate. The sub-systems of these components are highlighted in dark green. Both the RRC's transponder and the RRD's platform utilize Argos transceivers under autonomous control of microcontrollers (MCUs) running embedded algorithms.

The RRC is comprised of an Android mobile device that is paired with an Argos transponder through a Bluetooth link. The Android device runs a native application that allows a user to initiate a release command and visualize its successful completion. This application utilizes internal (Bluetooth) hardware to transfer serial data to and from the transponder. Subsequently, the transponder relays messages to and from the RRD through a low-powered signaling scheme that uses the Argos protocol message structure. The Argos transponder is comprised of a microcontroller (MCU) running embedded code that autonomously controls its Bluetooth and Argos transceivers.

The RRD is optimized to conserve its limited energy supply (a single AA battery) for brief (~1 s) and infrequent (1-2 times per deployment) communication before releasing from its baseplate. It is comprised of a low-powered MCU that utilizes its sensors for monitoring calendar events and environmental variables. Before deployment, the user can program the times of day, week, month, and/or season that they expect to retrieve the RRD. The RRD's MCU then autonomously runs embedded code that frequently senses if it is "wet" or "dry." When the MCU senses that the RRD is "out of water" for a reasonable period of time, it runs an algorithm that optimizes its average power demand when receiving Argos messages. Once a valid release message has been received, the MCU initiates a Boost-Converter that draws current through electrically-degradable epoxy (ElectRelease) within its release mechanism. This mechanism contains a spring that helps to overcome the bond strength of the ElectRelease epoxy as it breaks down. Concurrently, the MCU is monitoring the release event. Once released from the baseplate, the MCU sends an Argos message back to the RRC telling the user that the release event was successful.

WORK COMPLETED

Electronic (Hardware and Software) Development

The RRD and the Argos transponder share many of the same electronic components. Therefore, a single PCB for controlling the functionality of these two devices was designed and manufactured. In production these PCBs would be populated with only the necessary parts and their processors would be uploaded with applicable code. In addition to the release circuitry, the RRD utilizes hardware for sensing time and water immersion. Conversely, these components would be omitted from the production run of the Argos transponder, while a Bluetooth transceiver would be included. Both the RRD and the Argos transponder use the same Argos transceiver. The Argos transceiver is comprised of an Ultra-High Frequency (UHF) receiver, a Transmit/Receive (T/R) switch, an Argos transmitter, and a low-powered MCU for signal processing and control of the peripheral circuitry. For test and development a single PCB populated with all the circuitry was manufactured (Figure 2). This PCB included breakaway portions for code development (JTAG port) and data collection (pushbutton and additional headers). The Argos transmitter was manufactured on a separate PCB and Figure 2(C) shows this hardware interfaced with the control board.

Energy conservation is critical for extending the lifespan of battery-powered devices. Over a given deployment duration, receiver electronics will proportionately account for the largest average power demand. Therefore, the RRD is embedded with code that reduces the energy consumed by receive operations uncorrelated to possible collection events. The RRD uses two sensors to power-down its electronics: a user-programmable calendar and a wet/dry sensor. A Super Real-Time Clock (SRTC), calibrated for temperature effects in timing circuitry, ensures that the calendar of the RRD will stray less than one second a year. Therefore, a user is able to preprogram hours, days, weeks, and/or months that might correlate with the re-collection event. Times uncorrelated to those programmed by the user will allow the MCU to shut-down most functions of the device. Since radio waves do not propagate efficiently in water and because the platform will not float, the RRD periodically measures the conductivity of seawater to determine whether it is underwater and "wet." This "wet" condition causes the MCU of the RRD to keep its receiver powered-down. When the platform is determined to be "out of water" and its calendar is "scheduled on," the RRD runs an algorithm that periodically checks for an in-band Argos carrier and subsequent modulation. When modulation is detected, the message is decoded. Valid messages contain a preprogrammed (known) ID and a command. A command that initiates release also instructs the RRD when to send its verification message.

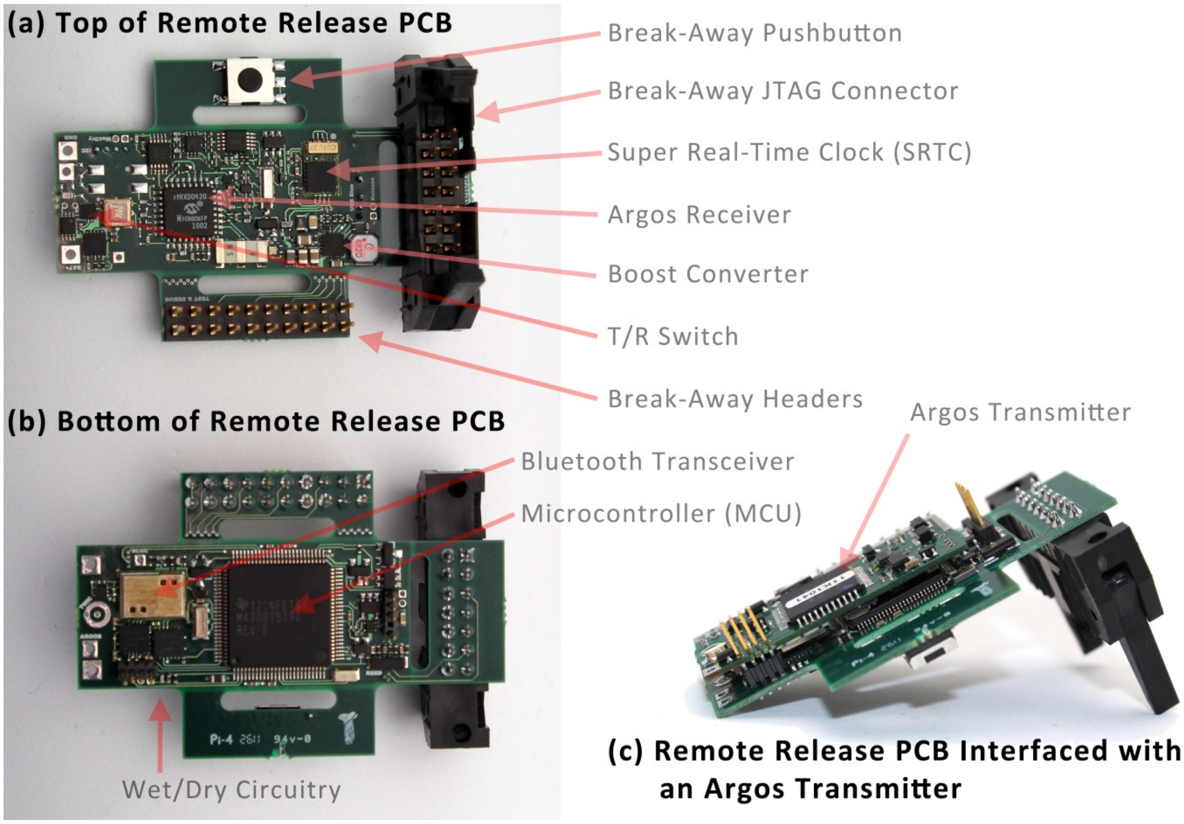

Figure 2: For test and development, the common controller PCBs for both the RRD and the Argos transponder were populated with all components. Additional break-away portions of the board allowed for debugging the functionality of the embedded code. The top (a) and bottom (b) of the control PCB are annotated with their respective components while (c) shows how the design is interfaced with the Argos transmitter.

The Android device is the interface from which the user decides to initiate a release command. Because cellular electronics require high-power infrastructure that is not readily available in remote locations, an Argos transponder was developed for long-range communication between the Android User-Interface (UI) and the RRD. Physical cables are susceptible to corrosion over time, especially in harsh marine environments, so a Bluetooth solution was developed. A Bluetooth transceiver was integrated into the Argos transponder design. The Argos transponder establishes a Bluetooth pairing with the Android and autonomously relays messages to and from the RRD. When the transponder is not communicating with the Android UI, its Argos receiver is decoding messages sent from possible sources. If decoded messages are determined to be from the same source and occur at regular intervals, then the transponder estimates when that message will be sent again. Subsequent to a user-initiated release command, the transponder will transmit its Argos message only when it believes that Argos messages will not be sent by other sources.

The code developed over the last 12-month period substantiated the PCB and hardware designs and verified functions related to the technology. This period was integral in determining the constraints of the technology and resulted in development of embedded functions to be ported to the RRD and RRC applications.

The Release Mechanism
The release mechanism is an electromechanical device that, when actuated, allows the RRD to separate from its baseplate. Figure 3 illustrates the various phases required to assemble this device. The puck is first bonded to the base using ElectRelease epoxy (Figure 3a). A middle-plate is then assembled with an inner O-ring (not shown) sealing the bottom half of the design. A plastic spacer and Belleville washers are then slipped over the puck and held in place with a C-clip (Figure 3b). The C-clip fits into a machined groove of the puck. Another O-ring then sits in the machined groove of the top-plate (Figure 3b) and seals the top half of the design. A small spring (not shown) sits within the cavity of the puck and provides electrical contact for subsequent circuitry. The upper O-ring gets press-fit and screwed to the top-plate. The top-plate is then interfaced with the electronic controller of the RRD (Figure 3c). The central puck is electrically isolated from the outer pieces of the design (top, middle, and bottom plates) because the positive conductor (red wire) is connected to a cylindrical metal tab that is surrounded by an insulating washer. This structure is shown glued into the top-plate (Figure 3c).

Iterative production and design changes were made to the release mechanism over the past 12 months. Through production feedback from the first redesign, the release mechanism is now assembled using fixtures for (1) gapping the epoxy interface between the base and the puck and (2) preloading the spring force of the flattened Belleville washers and assembling the C-clip into the puck's groove. These fixtures significantly improved construction time and variability of the design. Release times of a previous prototype were long and variable, so the redesign of the release mechanism included a larger (and tunable) spring force. A 100 lb. spring force preloaded the bond strength of the cured epoxy thus, when actuated, provided a reliable de-bond event. User feedback requested that the design have the ability to be refurbished in the field. This redesign allowed for the difficult-to-manufacture parts to be assembled in-house and be packaged as a single cartridge. This allows for a few easily-assembled parts to be put together by the user without jeopardizing the performance of the device. As shown in the next section, this redesign also allowed for integration of the release mechanism into the vacuum cast RRD shape.

In-house testing of the tensile-strength of the ElectRelease epoxy was performed on the current design. A test fixture was constructed to pull apart the puck from the base of the release mechanism. A hydraulic press provided the force while a load cell and indicator captured the forces exerted on the glue joint. Figure 4 shows the test set-up used to collect tensile strengths of the ElectRelease epoxy.

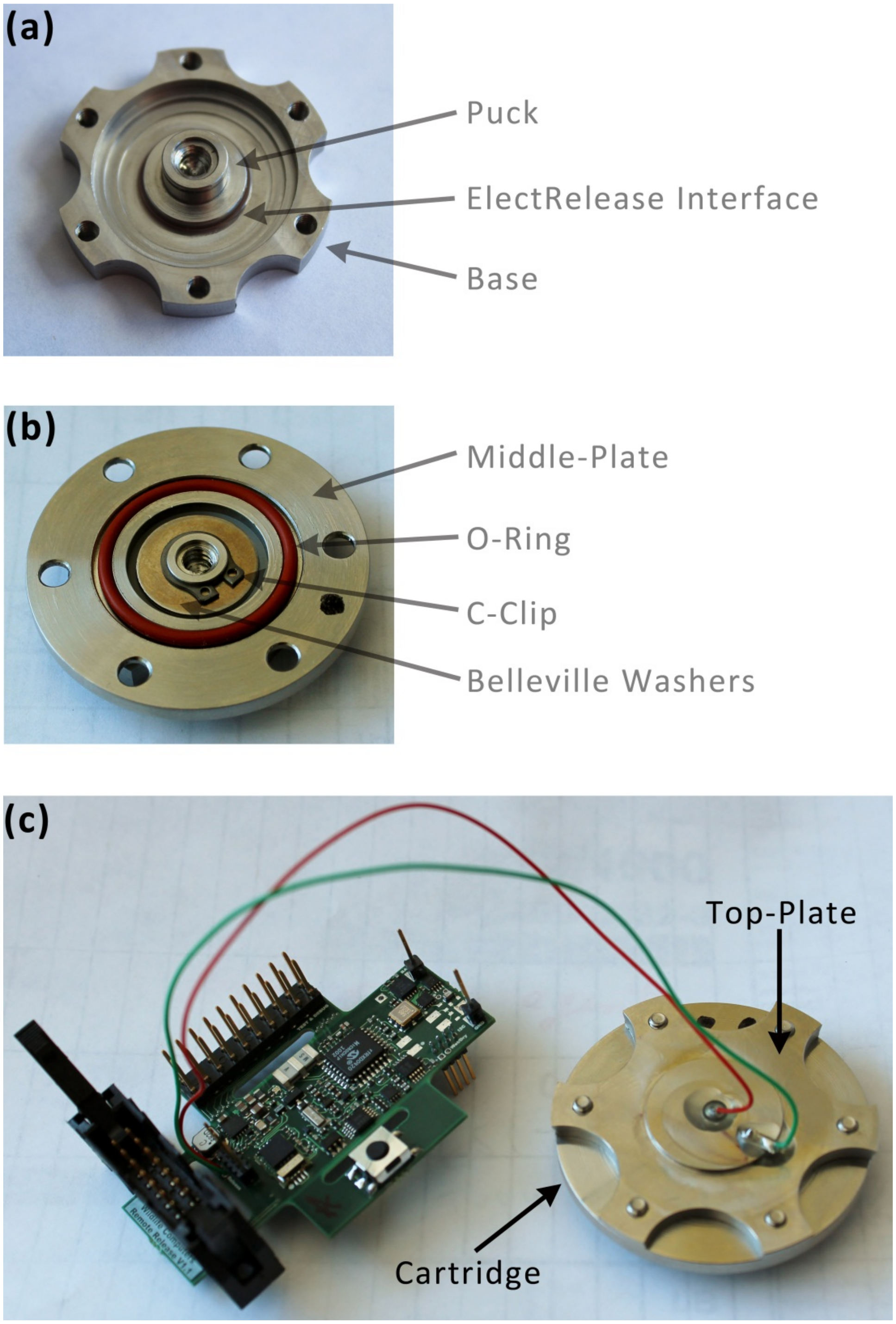

Figure 3: The release mechanism is shown in its various phases of assembly: (a) Bonded Central Structure, (b) Assembled Replaceable Cartridge, and (c) Interfaced with the Electronics.

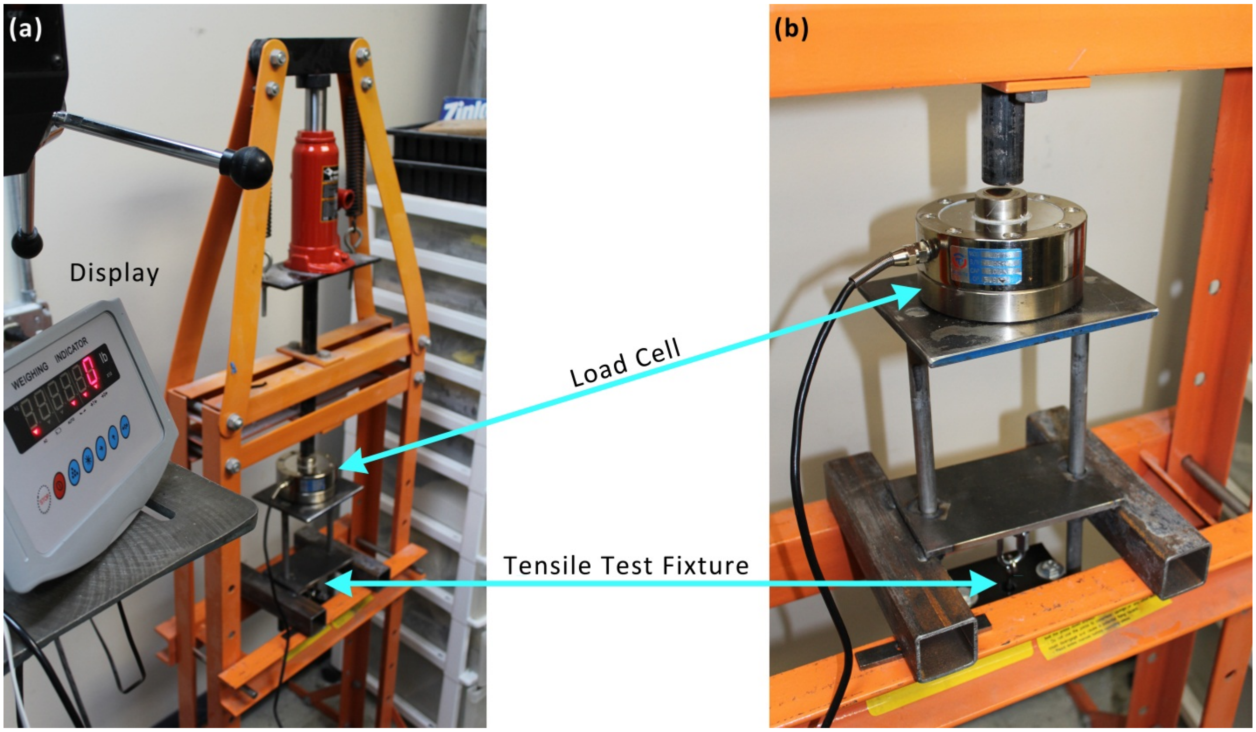

Figure 4: Tensile Test Set-up: showing (1) the fixture and the hydraulic press used to stress the ElectRelease epoxy interface and (2) the load cell and display indicator used to capture the results.

Cured ElectRelease epoxy bonds provided typical tensile strengths of ~230 lbs. Although results varied from batch to batch and part to part, these tests helped to identify production-type problems with manufacture. Subsequent redesign of the release mechanism calls for a larger surface area for bonding the puck to the base. Solutions for better bonding these surfaces are being explored, because delamination at the ElectRelease interface has been observed.

Vacuum Cast RRD Shape

The recoverable RRD and its baseplate were designed and manufactured using in-house vacuum casting techniques. The top-plate and cabling of the release mechanism were first cast into the recoverable RRD shape. The cartridge was then attached to the top-plate using six hex screws. Next, a fiberglass plate was machined and sealed by casting its shape into epoxy. This provided additional strength and rigidity to the design. Lastly, a wave spring preloaded the ElectRelease epoxy bond with another 50 lbs. and was positioned between the RRD and its baseplate. The baseplate was hand-assembled and secured to the release mechanism's base by six additional hex screws. When actuated, the wave spring would provide enough throw for the RRD to launch from its baseplate, thereby releasing the two halves of the RRD. Figure 5 shows these parts: (a) fully-assembled and (b) released.

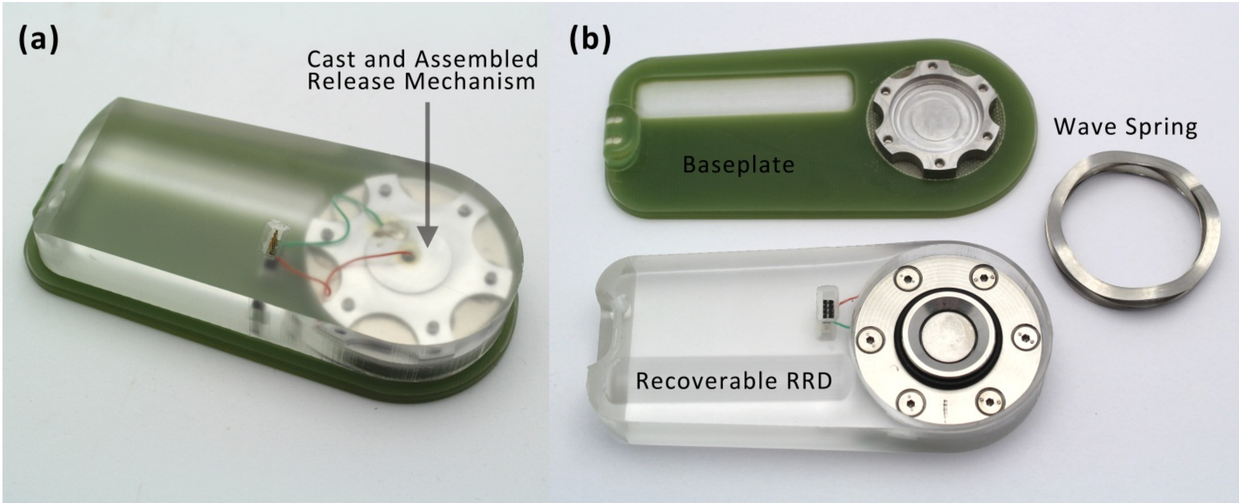

Figure 5: Cast parts of the RRD (omitting circuitry for simplicity) are shown in their (a) fully-assembled or deployed state and (b) in their separated or released state. Note that the base of the release mechanism, the wave spring, and the baseplate will be lost when the RRD is released.

Cast and assembled RRDs were stressed and electromechanically released to verify the functionality of the design. For these tests, the electronic design was interfaced with the cast and assembled RRD. The electronics ran a native application that would drive current through the ElectRelease epoxy by activating a constant voltage source (boost converter) when its pushbutton was pressed. During this event, the circuitry would monitor the instantaneous power demanded by this operation through a measurement made by the processor's analog-to-digital converter. This measurement was captured and saved for subsequent data analysis. Figure 6 shows a typical de-bond event as captured by the circuitry of the RRD.

The data collected and analyzed from release tests of the prototype show that release times vary between 3 and 9 seconds at room temperature. Subsequent tests aim to characterize temperature effects on the release times and bond strength on the device.

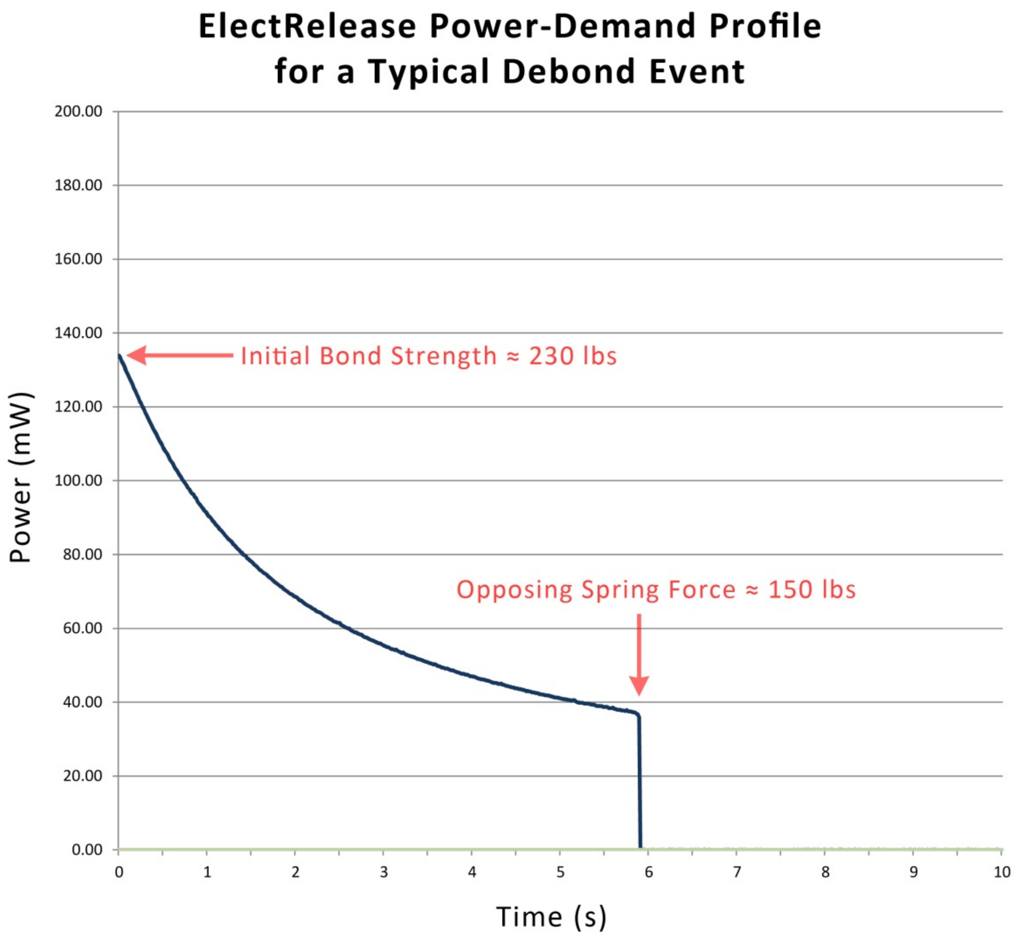

Figure 6: Because it is driven by a constant voltage source, the resistance of the ElectRelease epoxy is shown to monotonically increase as the bond strength is electrochemically degraded. This plot shows the bond strength of the epoxy to weaken to the opposing spring force within 6 seconds of being actuated. At which point the bond fails and the device is released.

RESULTS

Refining the RRD Shape

The RRD shape and design has incorporated refinements from user feedback of tests performed on prototype units. The hook, used to torsionally secure the rear of the design, was embellished and refined in this redesign. The recoverable RRD includes more epoxy material supporting the release mechanism which mates and keys into a front lip of the baseplate. Lastly, a secondary spring near the rear of the device ensures that, upon release, the baseplate will be cleared. Figures 7 and 8 illustrate the design changes to the device.

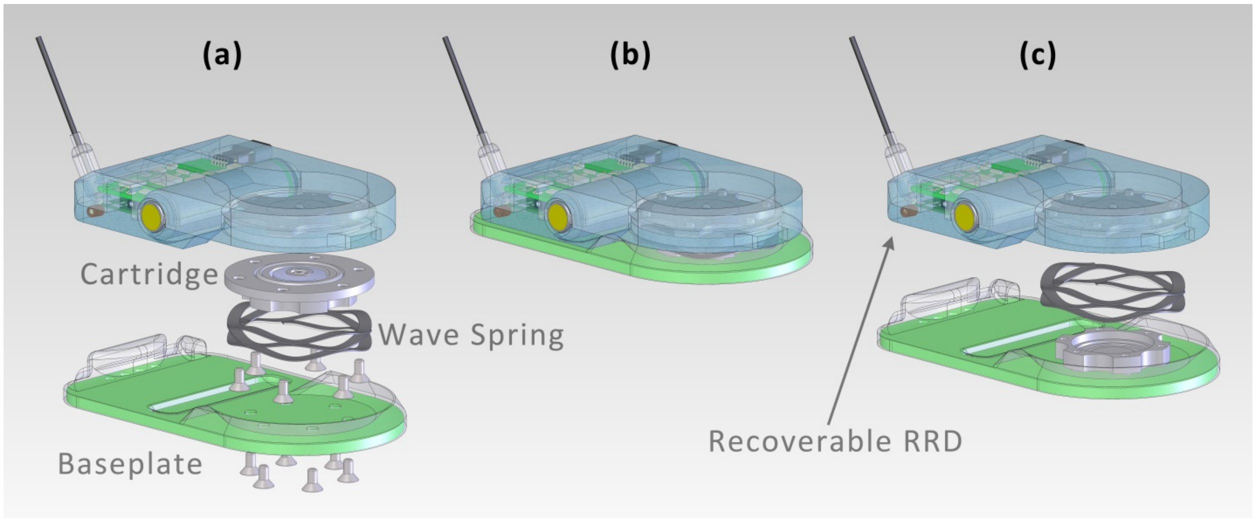

Figure 7: A computer model of the RRD's major components is shown being (a) assembled, (b) deployed, and (c) retrieved.

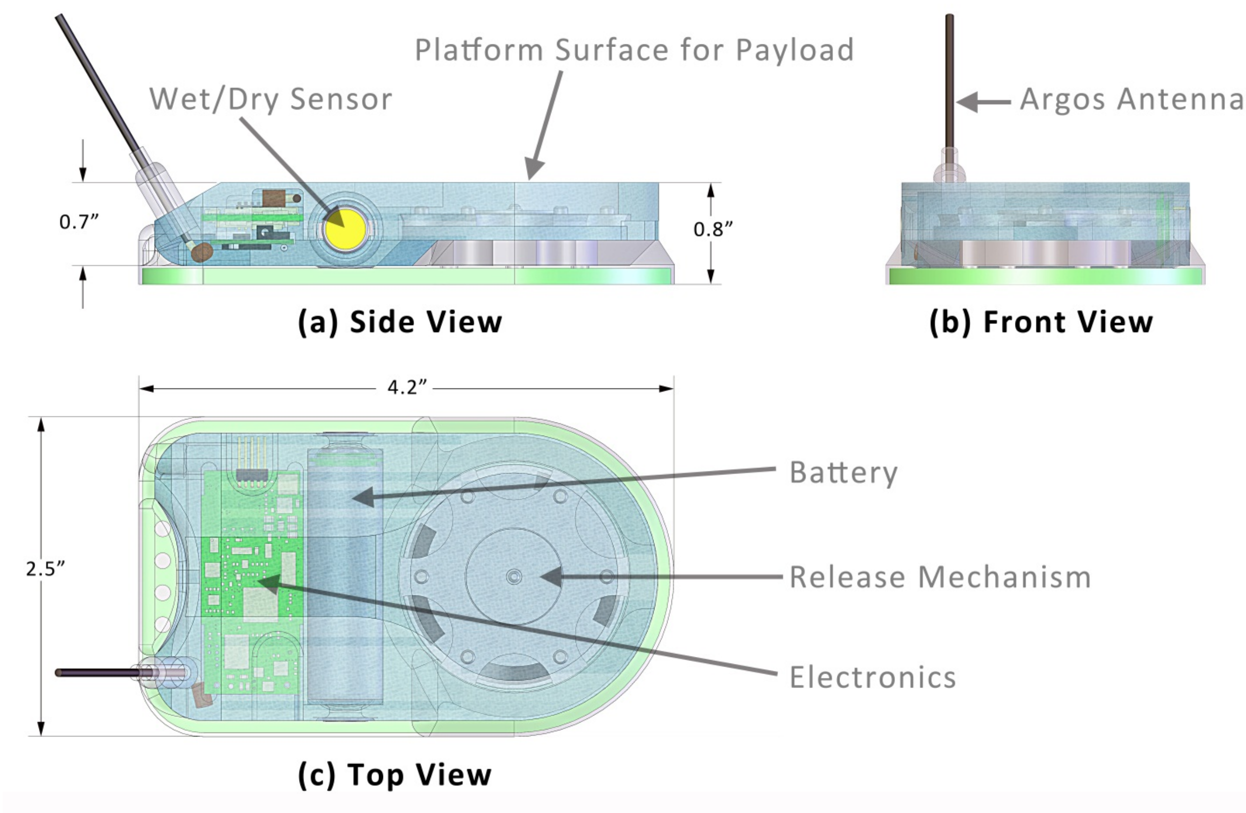

Figure 8: A computer model of the potted RRD and its sub-systems are annotated and shown in (a/b) sections and (c) plan. The device dimensions are currently L: 4.2" x W: 2.5" x H: 0.8".

Planned Field Tests
Field tests without animals are planned for December 2011, followed by test deployments on animals in January 2012. Ten RRD units are scheduled for delivery to Russ Andrews and the Alaska SeaLife Center in December 2011. These units will be tested for robustness and functionality to verify the prototypes can withstand the abuse typically encountered when attached to marine mammals. This will include, but is not limited to conducting laboratory simulations of the environmental conditions expected in the field. Pending a successful outcome of these tests, Russ Andrews will take an additional 10 units in January 2012 for deployment on free-ranging Australian Sea Lions. The RRD and system components are scheduled to be tested at this time with follow-up deployment, if necessary, in March 2012.

Identification of Technical and/or Programmatic Issues
Several technical issues associated with manufacture of the system's components have been identified over the past 12 months. The electronic design includes a precision-cut crystal for demodulation of received Argos messages. This crystal is custom made for this project and the manufacturer requires long lead times. Since the system leverages Bluetooth technology for communication with a handheld UI, additional software has to be written for applications using this hardware. Gluing the puck to the base (of the release mechanism) using ElectRelease has resulted in variable bond-strengths, because the epoxy tends to delaminate from the surface. Production techniques for better bonding of these surfaces are under development.

IMPACT/APPLICATIONS

RELATED PROJECTS

None.