

# Sea Mammal Research Unit Instrumentation

## Product Brochure



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## Introduction

The SMRU (Sea Mammal Research Unit) Instrumentation Group have been at the forefront of development of marine mammal telemetry equipment for over 20 years and during this time have established an unrivalled international reputation for developing innovative products to advance both marine mammal and oceanographic science.

The closely knit group consists of biologists, hardware and software engineers, working in partnership with users to help address their key biological and oceanographic questions. Central to the group's success is the philosophy of collaborating with users to deliver telemetry equipment tailored to meet their particular needs.

## Tag Functionality

Solutions are based around a single core architecture upon which sensors, data delivery systems and power source are built. Figure 1 outlines the range of possibilities. All tags have a common set of core sensors (temperature, depth and acceleration) to which others may be added, either built intrinsically into the tag, or as a separate interface via an RF link. Data delivery may be via Argos, GSM, Bluetooth, or in some instances combinations of them. The power supply is generally either a lithium primary or solar rechargeable battery.

Fundamental to the tags is a flexible yet comprehensive software suite. This manages the continuous flow of data from the sensors, constructing an efficient representation of the animal's activity in the form of messages which are buffered for eventual transmission via GSM and/or Argos. All SMRU tags also store the raw sensor data in a TDR format for retrieval if the tag is recovered. The software is tailored to meet an individual's requirements and transforms the tag in to a powerful tool for marine mammal research. A discussion of the software operation modes is at the end of this brochure.

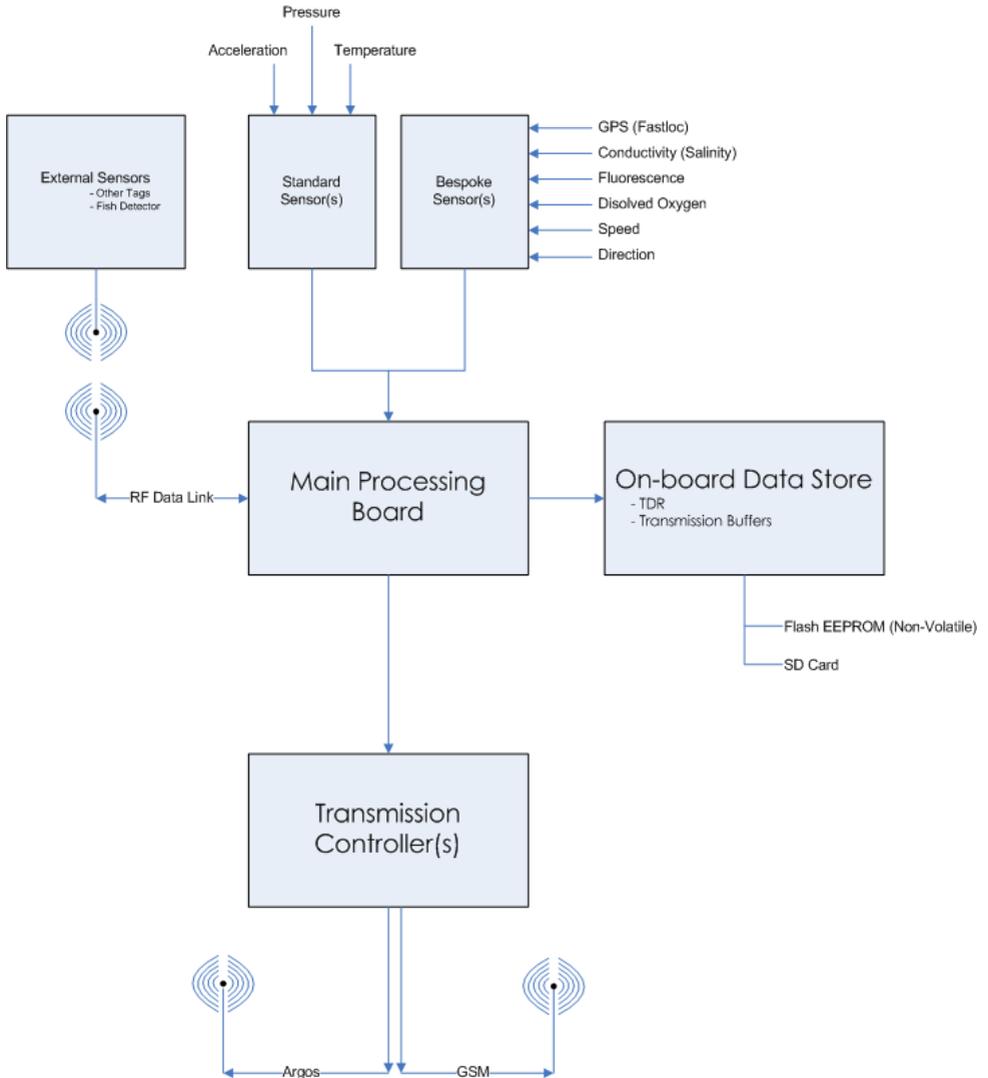


Figure 1. Schematic diagram of tag architecture and optional sensors and data channels



Examples of four areas of tailoring include;

- Increasing transmission rate early in the deployment where there is a risk of tag loss;
- flexibility in GPS sampling rate;
- using multiple PTT numbers in a single tag; for short deployments where data throughput is limited by surfacing behaviour rather than battery life;
- configuring the wet-dry sensor to allow the tags to work in saltwater, brackish or essentially 'pure' water; or perhaps all three in one deployment.

Tag data is relayed via SMRU where it is decoded and available to users as database extracts on a password protected web site. Your data are both safe and secure.

The freely available MamVis (Marine Mammal Visualisation) software allows dive, track and ocean sensor data to be explored within their geographical and oceanographic context. In addition data are provided in KML format that can be animated in Google Earth.

SMRU tags are continuously being adapted to improve the quality of the measurements taken; either through improved sensor design, novel packaging, or data handling and transmission.

The following sections detail some of the more common tag permutations together with some examples, followed by some typical applications which serve to demonstrate the tags' flexibility.



## CTD Tag - Standard

**Housing:** - Rated to 2000m

**Standard sensors:** - Pressure

- **Range:** 0-2000 m
- **Accuracy:** 2 dBar  $\pm$  0.01% / K
- **Resolution:** 0.05 dbar

- Temperature

- **Range:** -5 °C to 35 °C
- **Accuracy:**  $\pm$  0.005 °C
- Resolution:** 0.001 °C

- Salinity

- **Range:** 0 to 50 (PSU)
- **Accuracy:**  $\pm$  0.01
- **Resolution:** 0.002

- Wet/dry saltwater switch

- Real-time clock

**Location**

- Argos

**Longevity:**

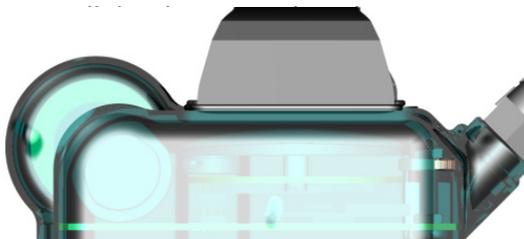
- Up to 1 year using D-cell with 50,000 Argos transmissions

**Dimensions (max):**- 100 x 70 x 60 mm

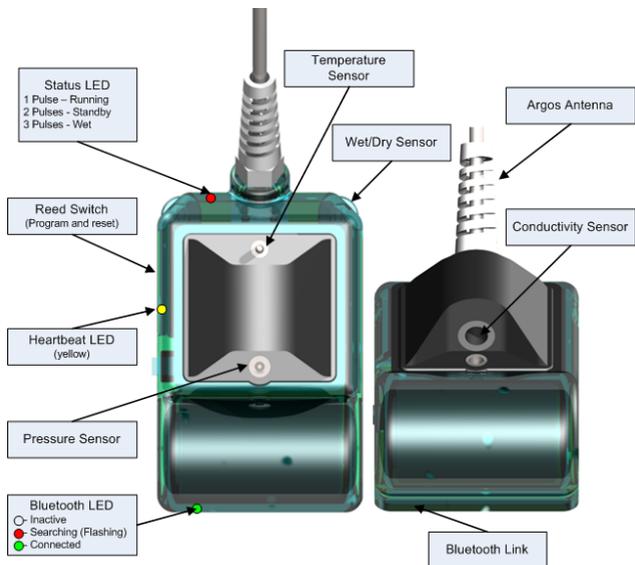
**Weight:**

- D-cell 580g (C-cell 430g)

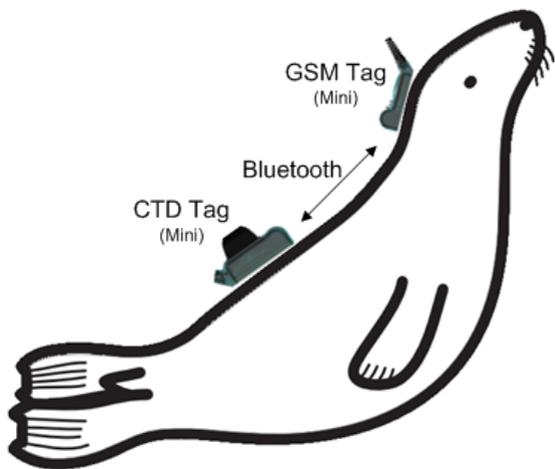
**Data Storage:**



C-Cell / D-Cell Tag Comparison



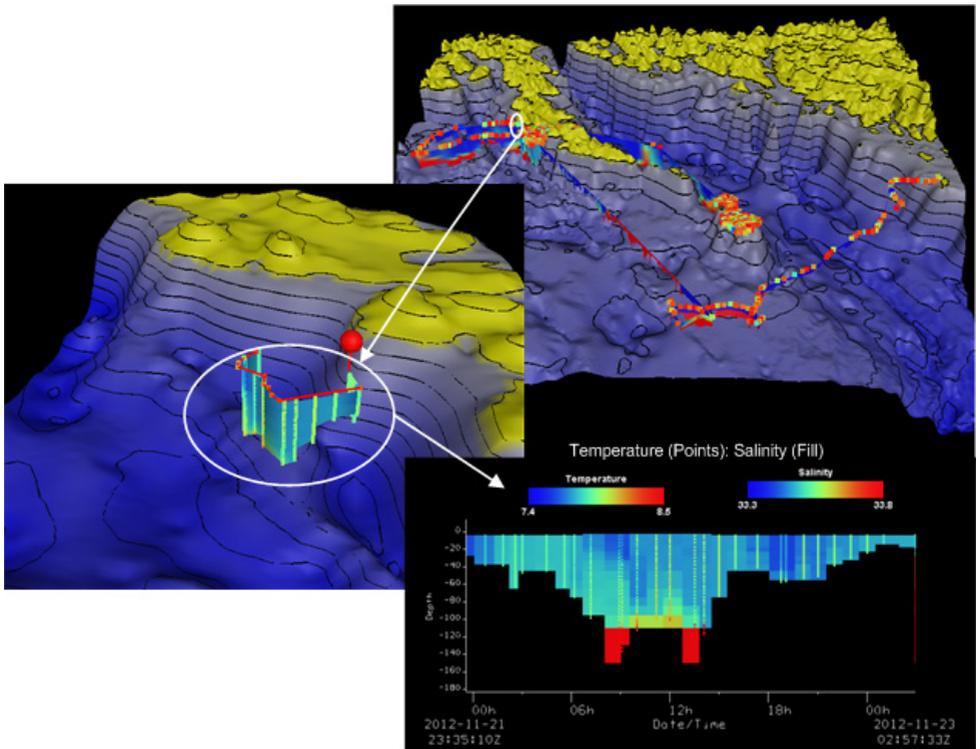
Example Deployment: Bluetooth-linked CTD/GSM Tag: *Akvaplan-Niva*



Short deployment:  
Oct 2012, Grey seal



- Accurate GPS via GSM tag along with high bandwidth data channel for CTD up-casts.
- CTD generating frequent up-casts.
- Data transferred to GSM tag via Bluetooth whilst in haul-out.
  - Up to 100 CTD up-casts per day
  - Up to 100 GPS Locations per day
  - Detailed dive records for every dive



*Grey Seal Deployment*

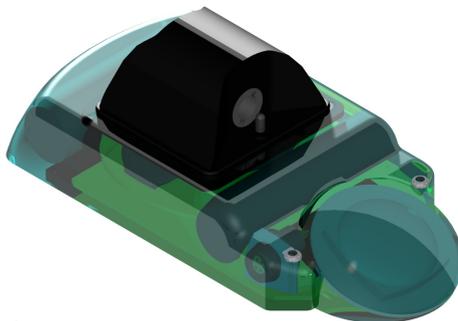


## CTD Tag – Other Formats

Examples of other formats include:

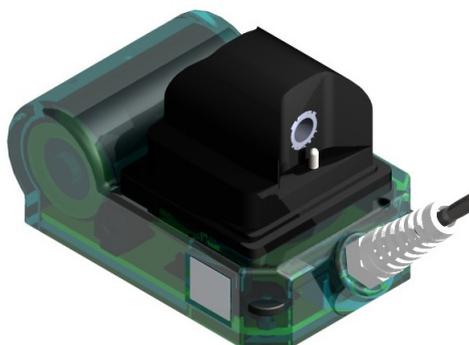
### CTD Archival Tag

- **Max Depth:** - 800 m
- **Sensors:**
  - CTD
  - Fastloc GPS
- **Rechargeable:** - 1 month
  - GPS: 5 Min Interval
  - CTD: 2 Sec Sample
- **Data Relay:** - Archival
- **Dimensions:** - 160x70x53 mm
- **Weight:** - 420 g



### CTD – Fluorometry Tag

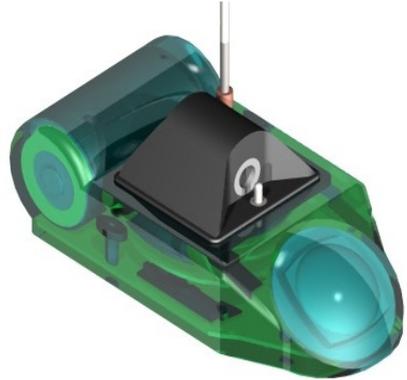
- **Max Depth:** - 2000 m
- **Sensors:**
  - CTD
  - Fluorimeter
  - Light
- **Data relay:** - Argos & Archival
- **Dimensions:** - 100x70x60 mm
- **Weight:** - 580 g





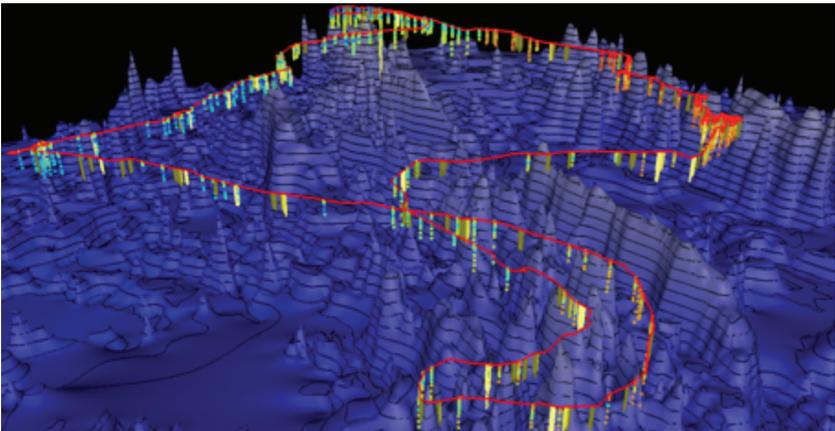
## CTD – GPS Tag

- **Max Depth:** - 2000 m
- **Sensors:**
  - CTD
  - Fastloc GPS
- **Data relay:** - Argos & Archival
- **Dimensions:** - 140x70x60 mm
- **Weight:** - 630 g



## Example deployment: CTD/GPS Tag

- Elephant seals, Bouvet: *Norsk Polar*
- 9 Month Deployment
- 9000 GPS Locations (Archived)
- 1800 GPS Locations (Transmitted)
- 1400 detailed dive profiles/day (4 point interpolated)
- >50 CTD up-casts per month (16 point interpolated)





## GSM Tag (Mini)

**Housing:** - Rated to 1000 m

**Standard Sensors:** - Pressure

- **Range:** 0-1000 m

- **Accuracy:** 2.5m (at 1000 m)

- **Resolution:** 5 cm

- Temperature

- **Range:** -5 °C to 35 °C

- **Accuracy:** ± 0.05 °C

- **Resolution:** 0.01 °C

- Wet/dry saltwater switch

- Real-time clock

**GSM Engine:** - Quad-band modem

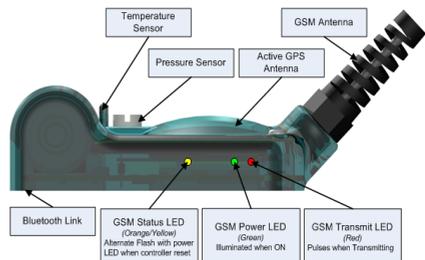
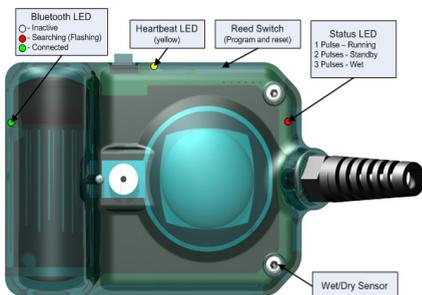
**GPS:** - Fastloc 3

**Longevity:** - Up to 1 year (10 min GPS interval, 10 hrs GSM)

**Dimensions (max):-** 100 x 70 x 35 (height) mm

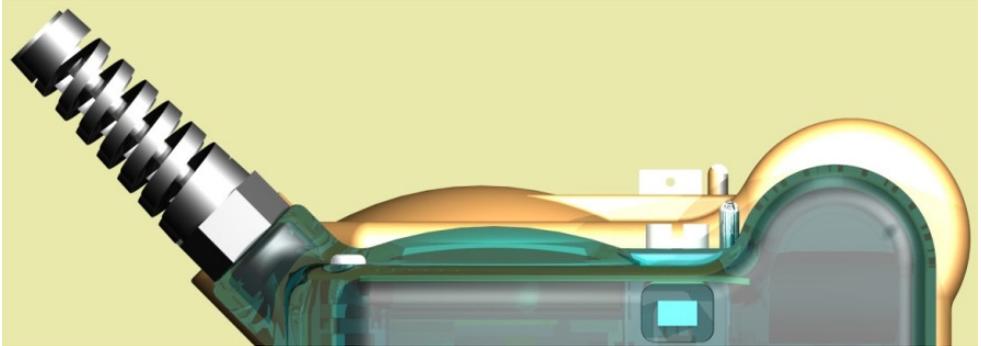
**Weight:** - 330g

**Data Storage:** - Full dive history archived on tag





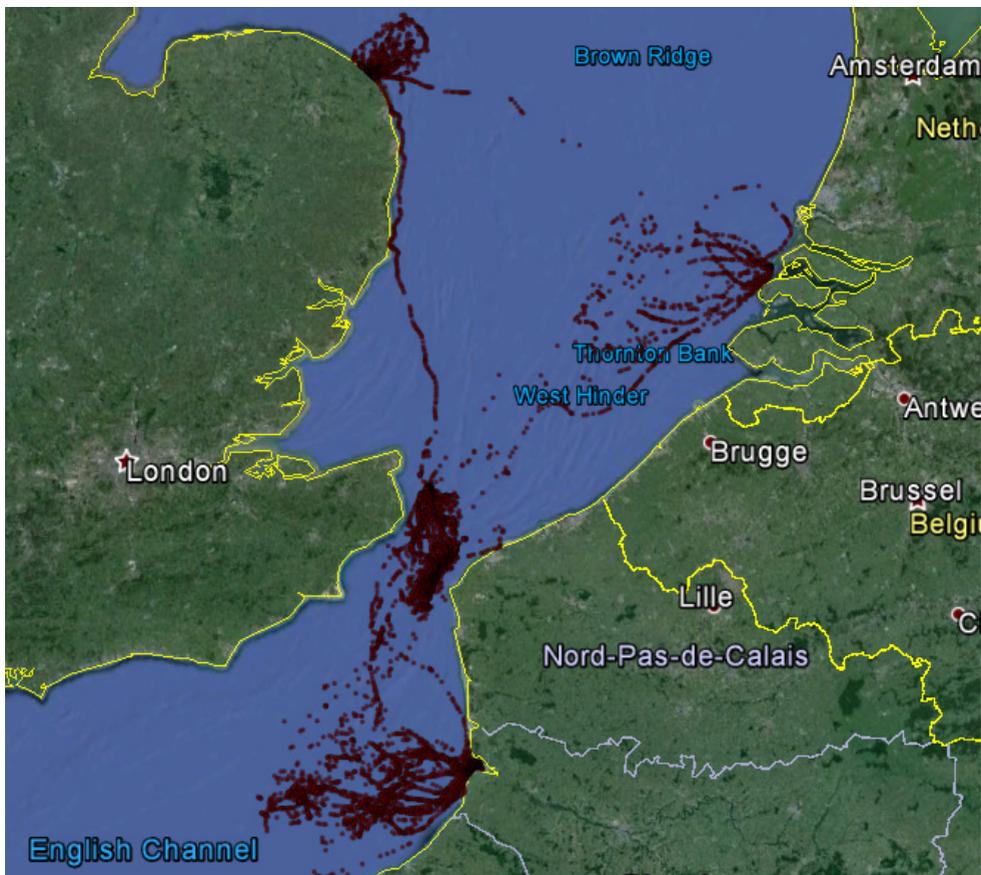
- Key Improvements:**
- Lower profile & 30% lighter than original GSM Tag
  - Longer operational lifetime (or more GPS locations)



*Comparison with Original GSM Tag*

**Example Deployment, Grey Seal: *Université de La Rochelle***

- 8 months deployment
- Data buffered when outside GSM coverage
- Summary of data transmission from single tag:
  - 9,200 GPS locations (i.e. 40 per day)
  - 49,500 detailed dive profiles (9 point interpolation / dive)
  - 17,200 temperature up-casts (12 point interpolation)
  - Data call cost: 96 GBP over whole deployment



*GSM Track*



## GPS Argos Tag - Standard

**Housing:** - Rated to 500 m (reinforced 2000 m with D-cell)

**Standard Sensors:** - Pressure

- **Range:** 0 - 2000 m
- **Accuracy:** 1.25m (@500m)
- **Resolution:** 5 cm

- Temperature

- **Range:** -5 °C to 35 °C
- **Accuracy:** ± 0.05 °C
- **Resolution:** 0.01 °C

- Wet/dry saltwater switch

- Real-time clock

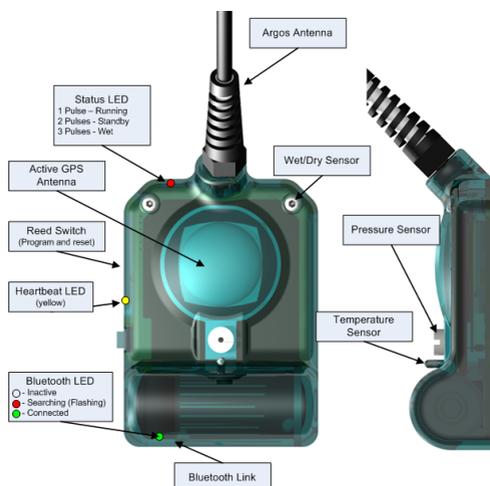
**GPS:** - Fastloc 3 (Fastloc 1 available)

**Longevity:** - Up to 1 year, standard settings, 'indefinite' with solar

**Dimensions (max):** - 100 x 70 x 35 (height) mm

**Weight:** - 320 g (solar variant)

**Data Storage:** - Full dive history archived on tag



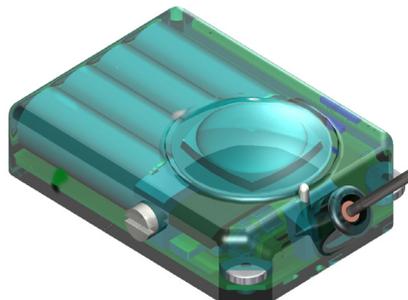


## GPS Argos Tag – Other Formats

### Low Profile Tag

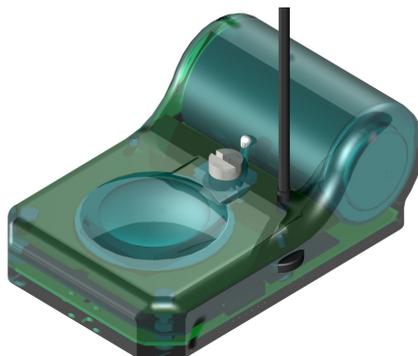
Examples of other formats include:

- **Max Depth:** - 1000 m
- **Sensors:** - Temp/Depth  
- Fastloc GPS
- **Data relay:** - Argos & Archival
- **Dimensions:** - 100x70x20 mm
- **Weight:** - 300 g



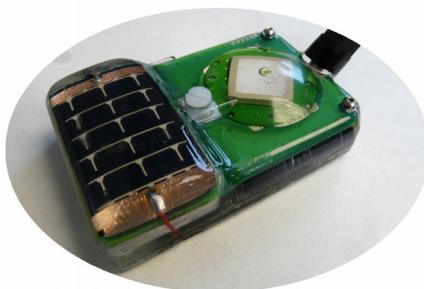
### Vertical Antenna Tag

- **Max Depth:** - 1000 m
- **Sensors:** - Temp/Depth  
- Fastloc GPS
- **Data relay:** - Argos & Archival
- **Dimensions:** - 100x70x20 mm
- **Weight:** - 350 g



### Solar

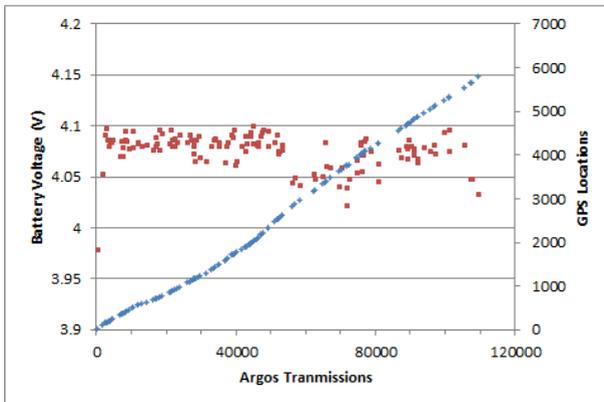
- **Max Depth:** - 500 m
- **Sensors:** - Temp/Depth  
- Fastloc GPS
- **Data relay:** - Argos & Archival
- **Dimensions:** - 110x70x25 mm
- **Weight:** - 350 g



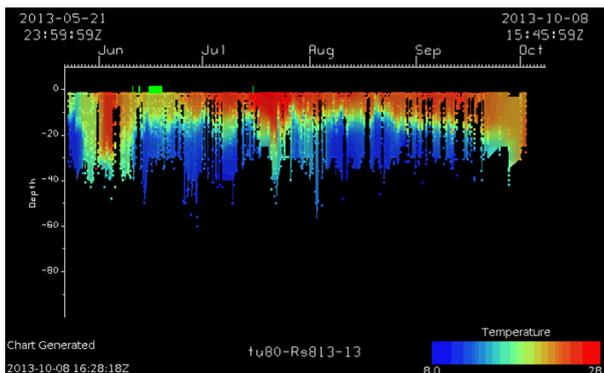


### Example Deployment: Solar GPS/Argos Tag *Coonamesett Farm Foundation*

- Deployed on loggerhead turtle May 2013. After 5 months deployment:
  - Maintained full battery charge throughout, see Figure 2
  - 110,000 Argos transmissions
  - 6,000 GPS locations
  - 2,000 depth profiles (5 point interpolation)
  - 116 temperature profiles (12 point interpolation)



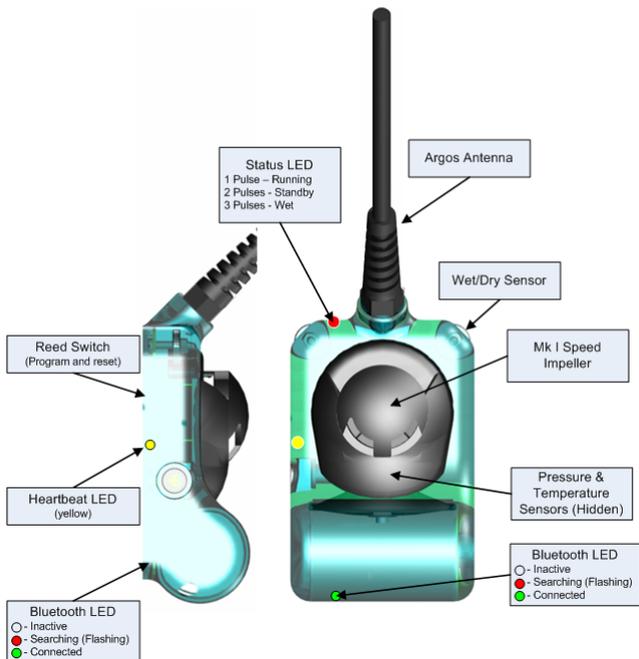
*Figure 2: Solar GPS/Argos tag deployment.  
The battery maintains full charge (>4V) over 5 months' deployment  
despite the large volume of data collected and transmitted via Argos*





## SRDL Argos Tag

- Housing:** - Rated to 500 m (reinforced option 2000 m)
- Standard Sensors:** - Pressure (resolution 5 m @ 2000 m, 0.5 m @ surface)
- Wet/dry saltwater switch
  - Real-time clock
  - Temperature (resolution 0.05 °C)
- Speed:** - Mkl Impeller (5 cm per revolution)
- Longevity:** - Up to 1 year, standard settings
- Dimensions (max):** - 100 x 70 x 35 (height) mm
- Weight:** - 400 g
- Data Storage:** - Full dive history archived on tag





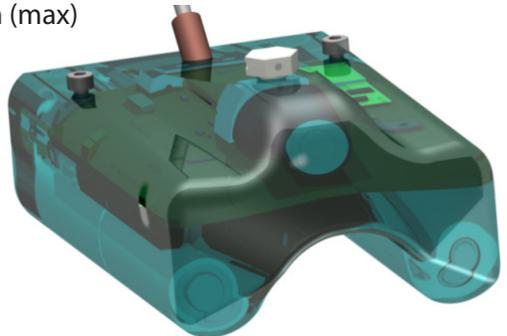
## Argos Tags – Other Formats

- Standard Sensors:**
- Pressure (resolution 1.25m @ 1000m)
  - Wet/dry saltwater switch
  - Real-time clock
  - Temperature (resolution 0.01 oC)
- Longevity:**
- Up to 1 year, standard settings, 'indefinite' with solar
- Dimensions (max):**
- Variety of packages available
- Weight:**
- Package dependent, typically 300g
- Data Storage:**
- Full dive history archived on tag

Examples of package options include:

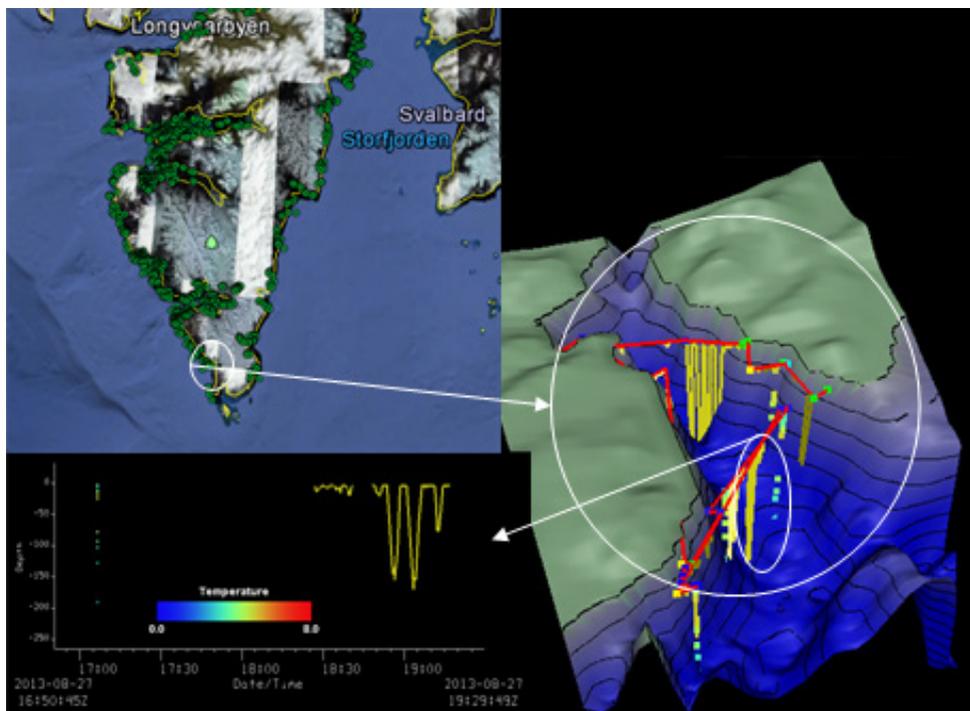
### Beluga Tag

- **Max Depth:** - 1000 m
- **Dimensions:** - 100x70x30 mm (max)
- **Weight:** - 330 g



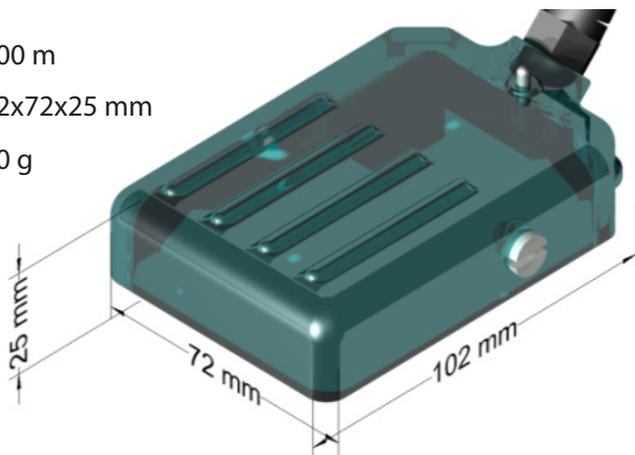
### Example Deployment: *Norsk Polar*

- > 30 locations/day
- 100 detailed dive profiles/day (5 point interpolated)
- 110 temperature up-casts per month (12 point interpolated)



### Low Profile Tag

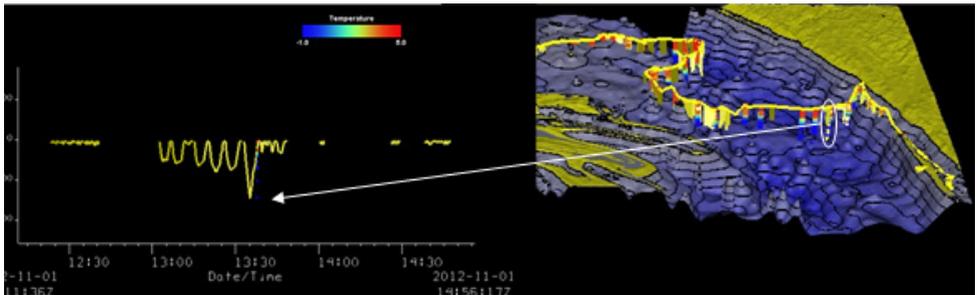
- Max depth: - 1000 m
- Dimensions: - 102x72x25 mm
- Weight: - 300 g





### Example Deployment: Ringed Seal *University of Manitoba*

- 8 months deployment
- 4,200 locations
- 18,800 dive profiles (5 point interpolated)
- 570 temperature profiles (12 point interpolated)



### Solar Argos Tag

- **Max Depth:** - 500 m
- **Dimensions:** - 100x70x30 mm (max)
- **Weight:** - 290 g
- **Longevity:** - Indefinite

### Example Deployment: Loggerhead Turtle *SMRU*

- 12 month deployment
- 240,000 transmissions, 2,200 locations (behaviour-limited)
- Maintained full battery charge throughout, Figure 3
- 740 detailed dive profiles (5 point interpolated)
- 116 detailed temperature up-casts (12 point interpolated)

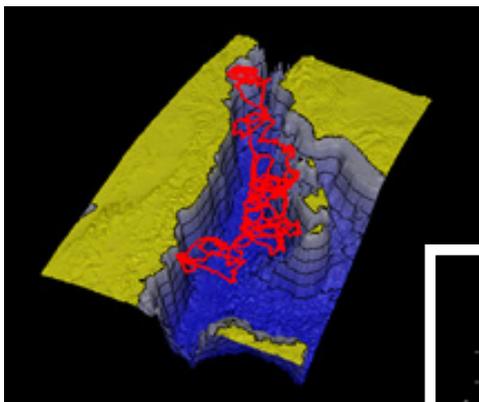
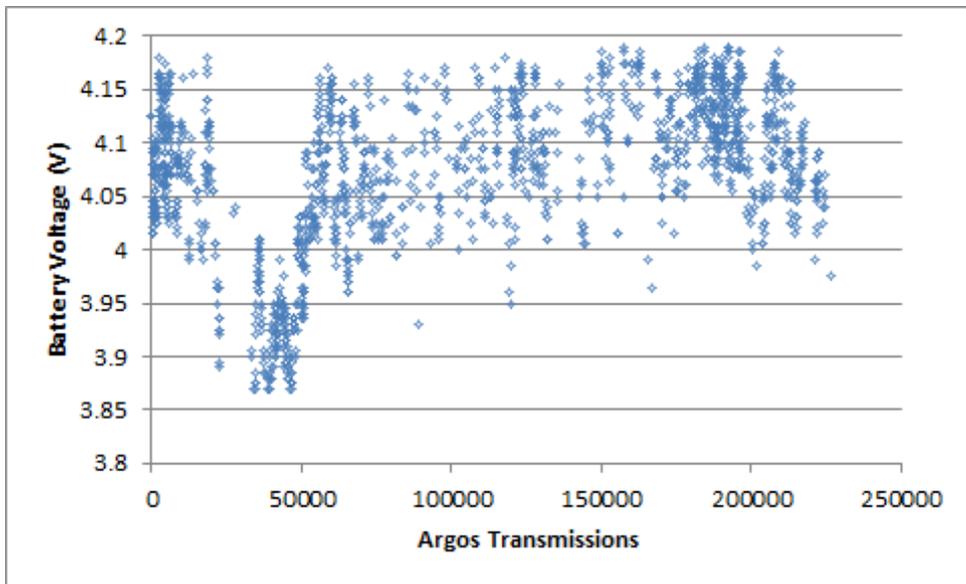
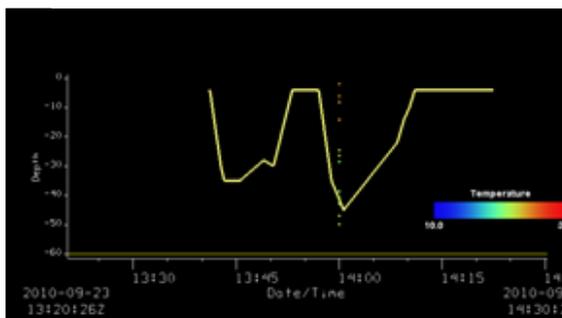


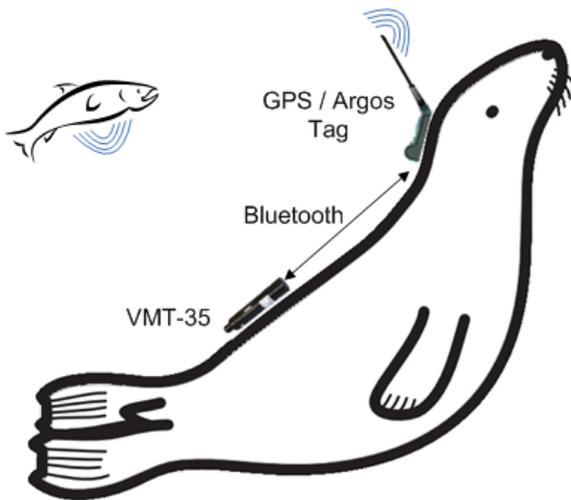
Figure 3: Data generated from 12 month deployment on loggerhead turtle showing battery at full charge (> 4V) despite 240,000 Argos transmissions. Figure also shows the Argos locations and examples of 5-point interpolated dive profiles





## 'Real-time' Fish Detection

- Assists in better understanding of predator / prey relationships
- Complements existing Ocean Tracking Network programme with additional sensor and data relay mechanism
- Tagged fish proximity detection using Vemco VMT Transceivers
- Data exchange in haul-out between VMT and SMRU tag
- Argos or GSM data relay providing near real-time fish detection data, detailed dive data and Argos location - tag recovery not required
- TDR equivalent data logged on tag for full dive history if tag recovered



### Example Deployment: Grey Seals 2013 *Dalhousie University*

- 3 month timeframe with 5 seals:
  - 400 Bluetooth uplinks per tag
  - 4,400 'ping' events
  - 1,200 grouped ping events with GPS location
  - 11,300 individual dive records (4-point interpolated) with GPS location

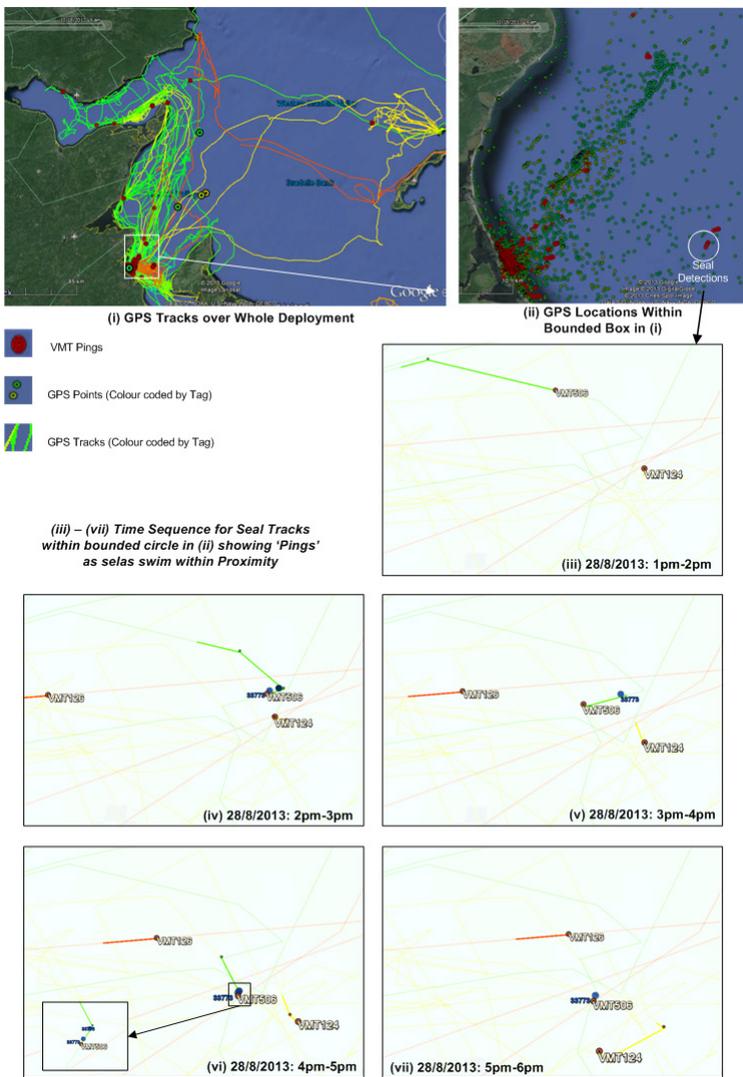


Figure 4: (i) GPS tracks from the whole deployment;  
(ii) GPS locations within rectangular box, showing individual GPS locations;  
(iii - vii) Hourly time sequence focussing on a small area where three seals,  
numbered 124, 126 & 506 swim within close proximity. The navy blue 'target' symbols indicate the locations  
where the VMT-tagged seal has detected the presence of another.

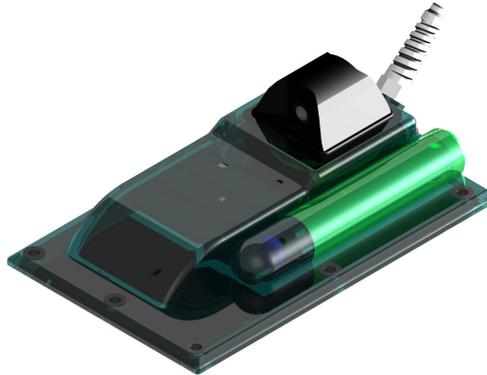


## Bespoke & Development

The following are a few examples of bespoke tags and development activities which aim to demonstrate the diverse range of interest and applications:

### CPR Adjunct tag *SAHFOS*

Since 1931 SAHFOS have been collecting data in the North Atlantic and North Sea on the ecology and biography of plankton. There has been a recent venture with SMRU to collect additional data, in the form of a tag adjunct to their continuous plankton recorder (CPR). This continuously samples salinity, temperature and fluorescence (chlorophyll-a). When the device reaches port, the tag adjunct relays the data to SMRU via GSM and passed on via FTP for the researchers to process in near real-time. The ultimate goal is to feed in to weather prediction models at the meteorological office.





## Accelerometry / Dead Reckoning Tag



*The MkII SRDL tag*

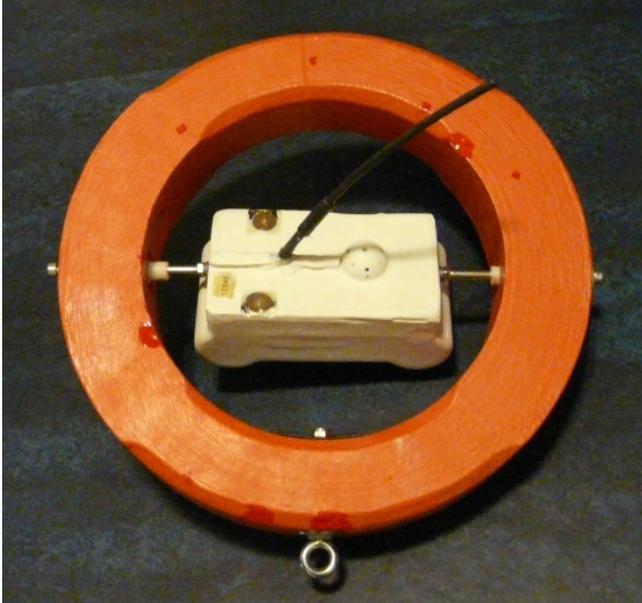
- Full range speed measurement (stall speed < 5 cm/s).
- Contoured for low speed measurement.
- 3-axis accelerometer, data logged to SD card.
- Full 3D magnetic compass.
- Ambient light sensor.
- Future software for on-board pre-transmission processing.



## **Surpact (Drifter) Tag** *CNRS L'Ocean*

Moored or ocean drifting tag taking continuous measurements and relaying back in real-time (via Argos) for climatic modelling and weather prediction. Various configurations have been developed which include the following sensors:

- Salinity 50mm below the surface.
- Temperature 50mm below the surface.
- Sea State / Wave frequency spectrum.
- Atmospheric pressure.
- Rain sensor.





## Software Architecture

### Data Structures

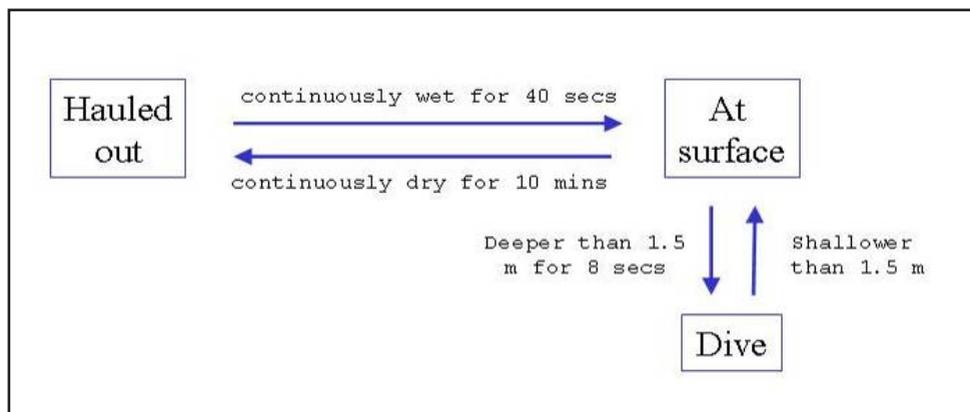
Below we describe the transmission formats of data structures. All parameters can be changed to suit individual applications.

### Data Sampling

Samples of depth and temperature are recorded every 4 seconds. Each tag contains its own specific calibration information, which allows it to immediately convert its sensor readings into real-world units (metres, °C, etc). Depth is automatically reset to zero whenever the wet-dry sensor detects the surface. Rapid sampling every 0.5 sec of the wet-dry sensor is instigated when approaching the surface to maximise transmission opportunities

### Behavioural States

The tag continually maintains a three-state model of the animal's activity, determined by surface sensor/depth sensor/ time interactions.





## Data Types

Three main type of data record are collected: dive, haulout and summary. This is in addition to other bespoke (e.g. salinity up-casts) data structure

### Dive Record

Dive records are constructed at the end of each dive. When a dive begins, all the samples are accumulated at until the end of the dive is detected, creating a full-resolution dive depth profile. The tag then calculates the internal points (usually four for Argos and nine for GSM tags) in the profile that give the best fit to the entire profile. A post-dive surface duration exceeding a predetermined time is termed a Cruise. An example dive record is:

Time of start of last dive (required)

Dive Number

for each dive:

- Maximum depth

- Dive duration (required)

- Post-dive surface duration (required)

- Mean speed

- Dive index (%)

- Inflection points:

  - Profile depth values

  - Profile temperature values

  - Profile speed values

  - Residual of profile fit

### Haulout Record

Haulout records are constructed at the end of each haulout. Haulout (and cruise) records simply contain the start- and end-times of unbroken periods spent in the "Hauled Out" (or "At Surface") states. These records require only a few bits to transmit but can account for long periods of the total data record. An example:

Haulout Start (date-time)

Haulout End (end-time)



Haulout number (sequence, cycling 1 through 32)

### Summary Record

Summary records are constructed every few hours (usually two or six), this contains summary statistics such as the proportion of time spent in each of the three behaviour states; the number of dives; mean, maximum and standard deviation of maximum dive depth; mean, maximum and standard-deviation of dive duration. An example:

Summary period start (date-time)

% time in state Dive

% time in state Haulout

% time in state At Surface

Maximum depth

### Temperature Cast Records

If a dive is one of the deepest dives in a given period (for example six hours), the tag collects temperature data at 1 second intervals on the ascent. Filtering and compression is performed by the conventional broken-stick method used for XBT casts, producing temperature-depth pairs.

## Data Relay- GSM

The tag periodically attempts to register with a local GSM mobile phone service provider. GSM coverage may extend up to 20 km or more from the nearest GSM base station and many parts of the world's coastline and near-shore waters are covered. If the tag registers successfully a GPRS session is established and data are transferred via FTP to a server at SMRU. These data are then decoded and made available for the user through a secure web server. Diagnostic SMS text messages are also sent.

Normally we incorporate a Vodafone SIM, which is configured for international roaming. If the attempt to register is unsuccessful, perhaps because the seal is far out to sea, data will accumulate in the internal memory until the next successful GSM registration. Up to six months' worth of data can be stored on board. Using GSM to relay data ashore is far more energy efficient, allows



higher bandwidth, and is much cheaper than the Argos system. However, if a seal travels far out to sea, the user must be patient and wait for the seal's return to get a data update!

## Data Relay - Argos

Many factors affect the ability of the tag to make a successful Argos transmission (e.g. the animal's surfacing behaviour, proximity to other competing Argos devices, and satellite availability at different times of day). A buffering strategy is used to avoid the biases that this could introduce if data records were simply transmitted as they occurred. The tag maintains a circular buffer for each type of record. As each event record or summary record is created it is added to the next position in the appropriate buffer, displacing the oldest record. A separate pointer is maintained to the latest member of the buffer to have been transmitted, and this moves along one at a time as each new page is constructed. Provided that the buffer is large enough to smooth out fluctuations in the rate occurrence of the events, this simple mechanism ensures that each record has an equal chance of being received.

## Energy Budgeting

In general the energy required for low level sampling is very small – the bulk of the available energy within the battery being used for GPS acquisition and/or Argos transmission. The lifetime of the tag must be carefully managed to ensure the full complement of data is extracted and transmitted from the tag before the battery expires – it would be wasteful to generate large volumes of GPS locations, or CTD up-casts if this produces too much data to send. SMRU have developed a number of tools have been developed to help with the selection of various parameters such as sample and transmission rates, underpinned by a wealth of field data. This allows our software team to choose parameters which are best suited to the deployment.

For Argos tags, for example, target points are often set at several dates, specifying the number of transmissions that are to be made by that time. The tag adjusts the number of transmissions made each day to keep itself on track



to meet the next limit. If the behaviour of the animal means that the allowance is not used then restrictions are eased temporarily.

For animals that haul out for extended periods it is often desirable to reduce the transmission rate during haul-outs, otherwise the number of Argos locations obtained at sea may be adversely affected. In haul-out, the tag increases the interval between transmissions to double the normal 40-45 seconds. After 3 hours a duty cycle of 5 hours quiet / 2 hours on is instigated. Note that it is only transmissions that are inhibited, the tag never switches itself off entirely and always maintains its 4 second basic sampling heart-beat. Satellite coverage varies considerably with time of day in some areas, especially at low latitude. It is therefore possible to prevent the tag from transmitting during those hours of the day when it is known that coverage is likely to be poor.



## Notes



## Notes



## Notes



## Notes



## Contact and Further Details

This brochure highlights some of the diverse range of marine telemetry equipment on offer at SMRU.

We would be more than happy to discuss your requirements in more detail, to see how our range of tagging and software solutions could be implemented or tailored to meet your particular application.

Further details, including ordering and terms and conditions may be found on our website:

[www.smru.st-andrews.ac.uk/Instrumentation](http://www.smru.st-andrews.ac.uk/Instrumentation)

For all enquiries, please contact Simon Halliwell at SMRU:

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We look forward to hearing from you