Overview of SMRU series 9000 SRDL satellite tags

Basic tag construction and function

Housing:	normal solid epoxy body rated to 500m, reinforced 2000m
Standard sensors:	pressure (resolution 5m @ 2000m, 0.5m @ surface), wet/dry saltwater switch, real-time clock, temperature (resolution 0.1 C)
Optional sensor:	speed index

WildCat RF unit (0.5W), full 32-byte transmissions with built-in checksum

Battery: Shelf life 24 years
Once deployed, tag lifetime is determined mainly by number of transmissions attempted: e.g. 85,000 are possible spread over 1 year, 80,000 over 2 years.

{link} Switching on and off

The SRDL software is highly configurable. All of the numbers that appear in italics in the following text are example values that can be modified.

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, degrees Centigrade etc). Depth is automatically reset to zero whenever the wet-dry sensor detects the surface.
Rapid sampling (*0.5* sec) of the wet-dry sensor is instigated when approaching the surface (*6* metres).

Behavioral categories

The tag continually monitors the sensor data it is collecting and maintains a three-state model of the animal's activity, determined from surface sensor/depth sensor/ time interactions.

Diving: below a set depth (*6* m) for some set time (*10* secs). Ends when animal is…

Hauled Out : dry for set time with historesis, set usually to about *10* minutes continuously dry before this state is entered. Normally ends when wet for more than *40* seconds.

At Surface: neither diving nor hauled out. State entered when the animal remains at the surface, not below depth set as dive threshold but periodically causing the surface sensor to be wet.

Interpretation of sampled data – events and summaries

As the tag monitors transitions from one state to another, data records of two complementary types are constructed and made available for transmission:

Event-based records correspond closely to the 3 fundamental states: **Haulout** and **Cruise** records simply contain the start- and end-times of unbroken periods spent in the "Hauled Out" and "At Surface" states respectively. These records require only a few bits to transmit but can account for long periods of the total data record. Each individual dive detected within the Diving state also triggers an event-based **Dive** record. These are considerably more complex and there are many more options available to control how they are transmitted.

A **Summary** record is constructed for every *6* hour time period. This contains summary statistics such as the proportion of time spent in each of the three states; the number of dives; mean, maximum and standard deviation of maximum dive depth; mean, maximum and standard-deviation of dive duration. These values give a fuller picture of behaviour than could be derived from the subset of received events because they are based on the entire recorded activity of the animal. There is also no possibility of biasing towards periods of relatively favourable satellite reception conditions (but see Buffering below for other strategies that avoid this).

The length of the summary period is normally set to 3, 4, 6, 12, or 24 hours, depending on species and particular research interest (detection of diel patterns, for example). Summary records are relatively compact to transmit, and it is normally possible to achieve an almost unbroken coverage. This provides a good "feel" for the overall behaviour of the animal, against which more detailed data about individual dives can be set.

The tag can additionally be programmed to collect **Temperature Casts**. If a dive is one of the *2* deepest dives in each *2* hour period, the tag monitors the depth during the central phase and then 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 *12* temperature-depth pairs.

Buffering

Many factors affect the ability of the tag to make a successful transmission (e.g. the animal's surfacing behaviour, proximity to other competing Argos devices, 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.

Pages of data

Each Argos transmission contains 256 bits of data (248 bits with new PTT id's). For each deployment we set up a number of data templates, which we call pages.

For example, a specification might be:

- page 1: 1 summary record and 2 haulout records,
- page 2: a set of 3 dives in detailed form,
- page 3: a set of 6 dives in more concise form,
- page 4: a temperature-depth profile (XBT-style upcast).

The number of bits allowed for each data item within the records (e.g. the maximum depth of a dive) is adjusted so that the records fit as closely as possible into the 256 bits available.

Specifying the sequence in which these pages are transmitted then provides further control over the relative frequency of transmission of different data types. The sequence could be simply 1,2,3,4,1,2,3,4…. , but if there is particular interest in detailed dives and little in temperature profiles this could change to 1,2,2,2,3,3,4,… The page template is refilled from the buffers each time it is used, so the sequence 2,2,2 above would send details of different dives in each of 3 consecutive transmissions.

The buffering strategy means that records are effectively selected at random for transmission, so we can calculate the proportion of each record type that we expect to receive under a proposed deployment specification. This requires estimates of the rate at which events occur (e.g. number of dives per day) and of the proportion of transmissions that are lost between the tag and the satellite in the deployment region. We use a spreadsheet to tweak the specification to provide the optimal balance between different data types:

	A	B	C	D	E	F	G	H
1	**PAGE CONTENTS**	**Page 0:**	**Page 1:**	**Page 2:**	**Page 3:**	**Total per cycle:**		
2	**number of times each page sent per cycle**	6	1	2	3	**12**		
3								
4	*basic dives*	2				12		
5	*detailed dives*				1	3		
6	*summary*			1		2		
7	*cruise*	1				6		
8	*haulout*			1		2		
9	*dive periods*					0		
10	*ctd*		1			1		
11								
12								
13	**proportion received error free**	**number of transmissions per day**	**deployment duration (days)**					
14	0.1	266.6666667	300					
15								
16	**type**	**group size**	**number of events per day**	**number of transmissions per group**	**prob(group received without error)**	**proportion eligible**	**expected number of items received**	**number of events over deployment**
17								
18	*basic dives*	3	200.00	4.00	**34.39**	1	20634.00	60000
19	*detailed dives*	3	200.00	1.00	**10.00**	1.00	6000.00	60000
20	*summary*	3	4.00	33.33	**97.02**	1	1164.20	1200
21	*cruise*	1	10.00	13.33	**75.46**	1	2263.76	3000
22	*haulout*	1	2.00	22.22	**90.38**	1	542.28	600
23	*dive periods*	1	4.00	0.00	**0.00**	1	0.00	1200
24	*ctd*	1	12.00	1.85	**17.73**	1	638.13	3600
25								

Record types in detail

This section lists the most important fields that are available within each record type:

Dive

When a dive begins, all the samples are accumulated at until the end of the dive is detected, creating a full-resolution dive profile. The tag then calculates the *4* internal points in the profile that give the best fit to the entire profile. Dives are transmitted in groups of consecutive dives. The timestamp refers to the most recent one – previous dives are positioned in time using the dive duration and surface duration fields. All other fields are optional. The post-dive surface duration cannot exceed *9* minutes, since this triggers a **Cruise.**

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 and Cruise

Start time
Duration
Haulout/Cruise number

The “number” field counts to *32* and then wraps back to zero. When events with consecutive numbers are received, we can infer that there were definitely no missing events between them.

Summary

End time
Cruising time (%)
Haulout time (%)
Diving time (%)
Average , maximum, SD of dive maximum depth
Average , maximum, SD of dive duration
Average speed during dives
Number of dives

for “deep” dives
Average , maximum, SD of dive maximum depth
Average , maximum, SD of dive duration
Average speed during dives
Number of dives

Encoding individual data items

The number of bits to be used to transmit each data item must be specified. It is normally necessary to make a reduction from the resolution recorded internally by the tag (e.g. 10cm for depth, 0.01 C for temperature).
For many quantities it is appropriate to represent a value with a precision that is proportional to its scale (e.g. depth +/- 1m at 20m, but +/- 5m at 200m). In these cases a lookup table of cut points may be specified such as the example of a 3 bit encoding below:

Transmitted value	**True value**
0	< 5
1	5 – 10
2	10 – 20
3	20 – 40
4	40 –60

5	60 – 80
6	80 – 100
7	> 100

Power budgeting

The power required for sampling and calculations is very small compared to transmissions. The lifetime of the tag is therefore controlled by restricting the number of transmissions that are attempted. Target points may be set at several dates, specifying the maximum number of transmissions that can be made by that time. The tag will restrict 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, restrictions are lifted temporarily.

For animals that haul out for extended periods it is often desirable to reduce the transmission rate during haulouts, otherwise the number of Argos locations obtained at sea may be adversely affected. In haulout, 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 regime.

Satellite coverage varies considerably with time of day in some areas. 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

Increased data rate: multi-PTT option

For short deployments where maximising data throughput is a priority, the inter-transmission limit imposed by Argos can become limiting. In this case it is possible to transmit more frequently by cycling through up to 4 different PTT codes in a single tag.