Analysis of Argos 3 Viability for Buoy Platforms

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Abstract

Since the introduction of Argos 3 technology, comparable satellite communication technologies have emerged as a solution for buoy platforms. Here, we report the implications of data throughput, power consumption, and impact on the scientific community in transitioning to an Argos 3 PMT system. Using an in-house developed microcontroller and buoy platform, systems were configured as SVP drifters (sea surface temperature, battery voltage, and strain gauge) in a controlled environment. Each system was powered by a 2.5 amp-hour AA cell battery pack until depletion to compare Argos 2 PTT (A2), Argos 3 PMT (A3) and Iridium Short Burst Data (SBD) technologies. Statistics were collected regarding system longevity, data throughput and latency. It has been determined that sacrifices are incurred transitioning to A3. Power consumption of an A3 system is reduced while increasing data throughput in comparison to an A2 system. However, A3 will have reduced power savings with the deployment of additional A3 satellites. Under the current design, A3 cannot achieve near real-time data delivery. The A3 system requires modifications to meet the functional requirements of the end user. It is recommended that changes be made to the A3 system prior to widespread implementation into buoy platforms.

Introduction

A SVP Ocean observing platform was developed in-house at Scripps Institution of Oceanography (SIO). Argos and Iridium technologies were explored in both field experiments as well as through controlled testing. In light of favorable performance regarding both satellite technologies, an investigation was pursued to determine viability for buoy applications. Previous investigations of Argos 3 and Iridium SBD technologies have been conducted by respective DBCP Pilot Projects. Due to fragmentation between buoy manufactures and lack of overlap of manufactures participating in respective pilot projects, an investigation was conducted with an emphasis on system longevity regarding the Kenwood YTR-3000 PMT and the Iridium 9602 SBD modems under controlled conditions.

Method

Using an in-house developed buoy platform, Argos 2, Argos 3 and Iridium SBD systems were configured identically with exception to modem hardware. Test systems were sealed in hulls, placed onto the roof, and allowed to transmit until their end of life.

All three systems types were run on an in-house developed microcontroller and configured as a SVP drifter for sensor payload and sampling scheme. Argos 2 and 3 systems were configured to sample the sensor payload every 15 minutes. Iridium SBD systems were configured to sample every hour.

Both Argos 2 and 3 systems used the Kenwood YTR-3000 PMT modem running firmware version 2.02. Argos 2 and 3 configurations are outlined in Table 1. All Argos 3 settings are PMT defaults with exception to GMSK Transmitter, and H WUP. The Argos 3 transmission and dataset buffer management was handled by the PMT. Argos 3 systems were uploaded with satellite orbital parameters and current location prior to the experiment to eliminate the initial backup mode period. Backup mode causes the PMT to transmit a null startup house-keeping message at a continuous 60 second repetition rate and the downlink receiver activated for 1 second every 3 minutes until PMT location and orbital parameters have been downloaded from an Argos 3 satellite[1]. Backup mode has been observed to last 1-2 days. Argos 2 systems were equipped with commercial Argos 2 capable antennae by Hirschmann. Due to the lack of commercial Argos 3 capable antennae, new Argos 3 antennae from Clearwater Instrumentation were used.

Table 1: Kenwood YTR-3000 PMT configuration

	Argos 2	**Argos 3**
YTR-3000 Mode	PTT	PMT
Transmission mode	A	C
BPSK Transmitter	1 watt	1 watt
GMSK Transmitter	Disabled	Disabled
H WUP	Disabled	Disabled
Receiver	Disabled	Enabled
Interactive-Ack	N/A	Enabled
Pseudo-Ack	N/A	Enabled
Nb tries for Pseudo-Ack	N/A	5
Repetition Rate	90 seconds	30 seconds
GPS option	N/A	Disabled
Checksum	No	Enabled (FCS)

For Argos 3 based configurations, PMT location and orbital parameters are automatically downloaded and used to calculate satellite pass predictions, enabling power savings when no satellite is overhead. Argos 3 systems were configured to utilize Pseudo-Ack as well as Interactive-Ack Modes. Pseudo-Ack enables the PMT to transmit to legacy Argos 2 satellites, transmitting the same dataset until a user defined number of times have been reached (Table 1). Once reached, the PMT will advance to the next

[1] YTR 3000 User Manual v. 1.14, section 7

dataset stored in the buffer. With Interactive-Ack enabled, under Argos 3 satellites, full handshaking occurs. Hand shaking enables a reduction of the transmitter repetition rate, increasing data throughput while reducing checksum errors. If Interactive-Ack is disabled, Pseudo-Ack protocol will be used under an Argos 3 satellite.

The Iridium SBD systems were equipped with an Iridium 9602 SBD modem, U-Blox Neo-6Q GPS module, and dual-element active GPS and certified Iridium antennae by Hirschmann. Sensor observations and SBD transmissions occurred on an hourly schedule. A modification was made to the standard firmware to run the GPS module for a minimum of 30 seconds. This was done to mitigate the effects of a constant unobstructed line of sight to the sky which enables GPS performance unrealistic of an ocean environment.

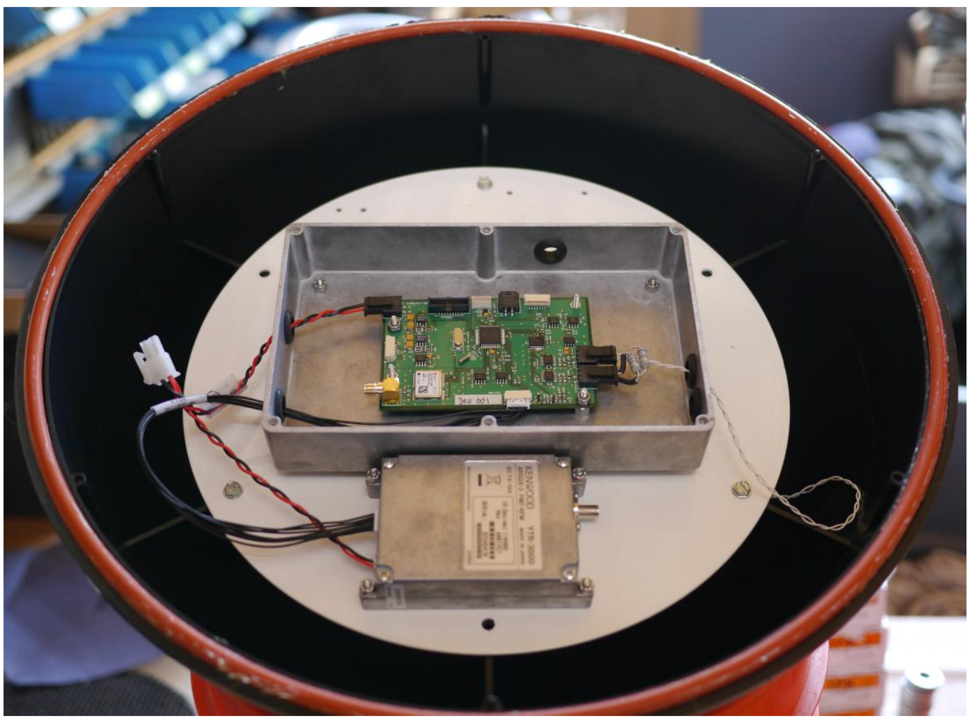

Figure 1: SIO Argos 2/3 SVP electronics package

All three system types were housed in a sealed 15” diameter hull (Figure 1), and placed on the roof at SIO. Each system was placed atop a 5 gallon bucket filled with water for cooling purposes. Each system was powered with a 2.5 amp-hour battery pack consisting of 8 Panasonic AA-cell batteries connected in series. All battery packs were sourced through industry[2] and were inspected for consistency.

[2] Digikey Part Number: P646-F024-ND

Results

Battery Endurance

Table 2: Average Lifetime

Technology	Average Lifetime
Argos 2	16 days
Argos 3	20 days
Iridium SBD	24 days

The results of the endurance tests (Table 2) suggest that system longevity increases with a transition away from Argos 2 PTT technology. Argos 3 and Iridium SBD technologies show a 25% and 50% increase in longevity respectively.

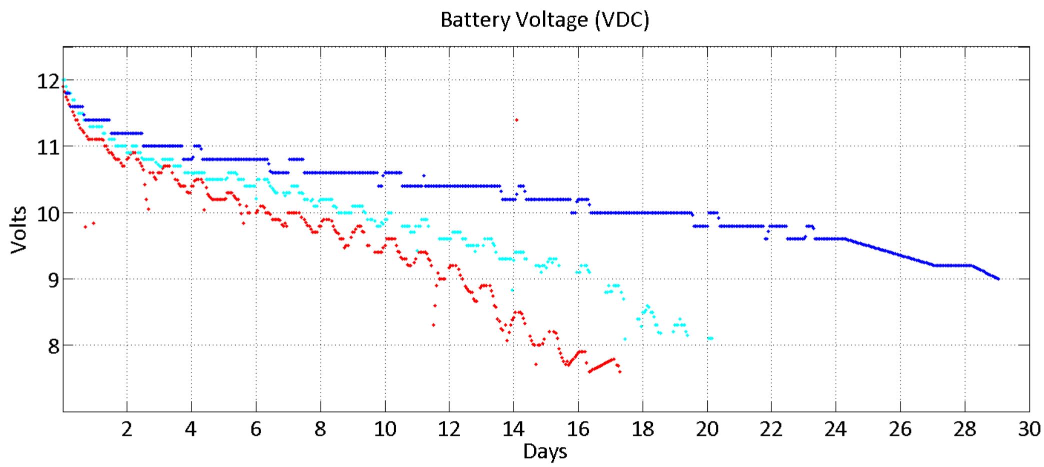

Figure 2: Battery voltage vs. Time. Note the cutoff for A2 (red) = 7.6 volts, A3 (cyan) = 8.0 volts, and SBD (blue) = 9.0 volts

Both Argos 2 and 3 systems exhibited similar cut-off voltages (Figure 2), while Iridium SBD systems require a higher minimum voltage in order to generate the required current for an SBD transmission. For both satellite modems, AA-cell cutoff voltage is higher than typical D-cell performance due to limited current delivery capabilities of the smaller cell.

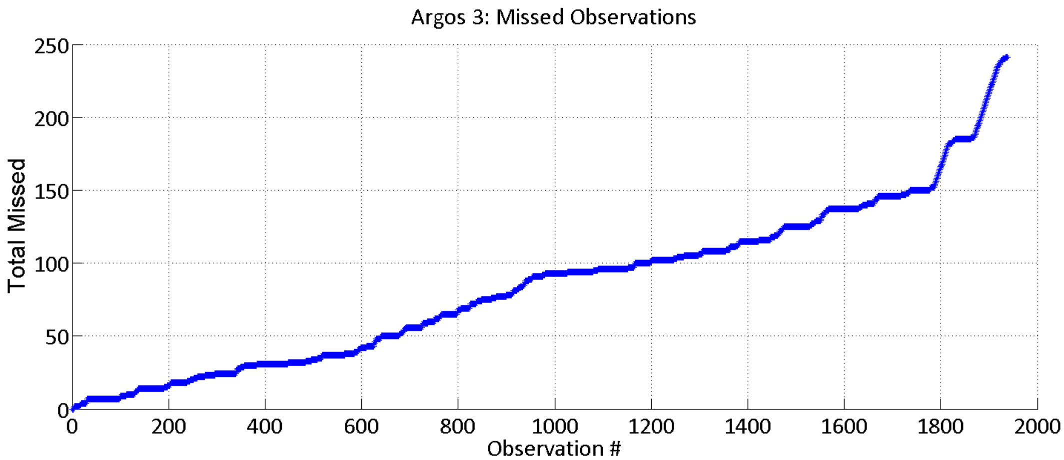

Figure 3: Rapid increase in Argos 3 missed transmissions near end of life

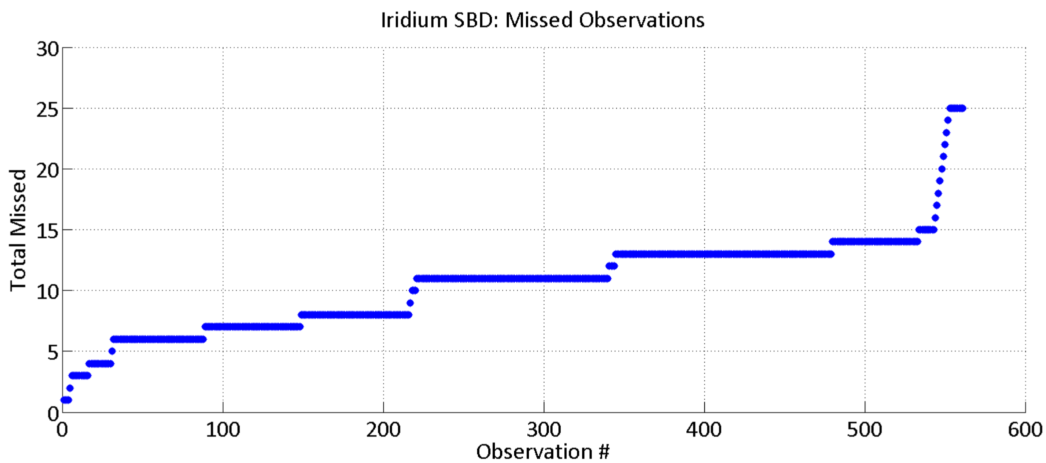

Figure 4: Rapid increase in Iridium SBD missed transmissions near end of life

All three systems transmitted sparsely beyond the lifetimes reported in Table 2. Throughput was significantly reduced due to decreased current delivery near the battery's end of life (Figure 3 and Figure 4). Statistics reported in Table 2 and hereinafter are computed excluding the near end of life observations. Receptions of repeated Argos 2 and 3 observations were omitted from statistical analysis. Throughput was evaluated as observations received given a sampling window. For example, for Argos 2 and 3, observations at 0, 15, 30, and 45 minutes are 100% throughput for that hour, while a single observation at 30 minutes is 25% throughput for that hour.

Throughput

Table 3: Observed Throughput

Technology	Throughput	Observation Interval
Argos 2	29.6%	15 min.
Argos 3	90.9%	15 min
Iridium SBD	97.5%	60 min

Argos 2 SVP systems have poor throughput (Table 3) due to a lack of historical observations transmitted.

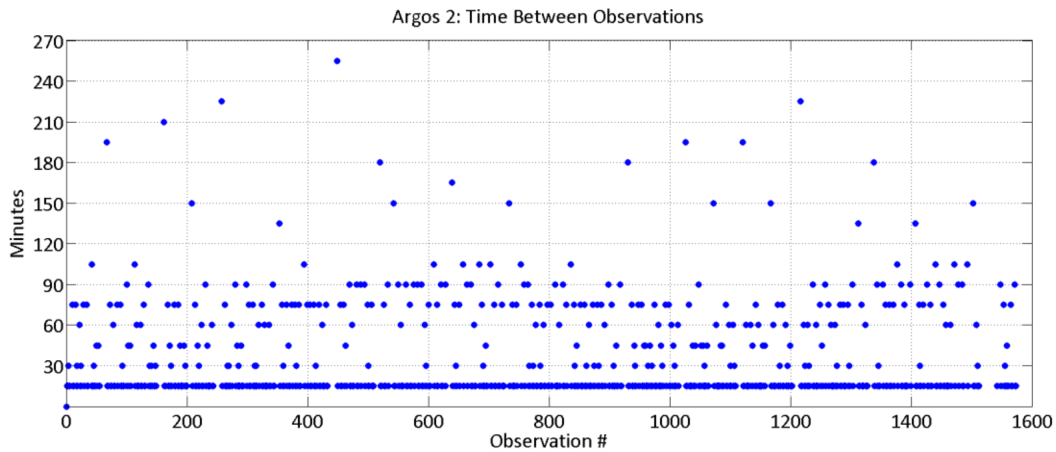

Figure 5: Typical time elapsed between Argos 2 observations

While an Argos satellite is over head, data throughput is favorable. Average observation resolution was 47.9 minutes (Figure 5).

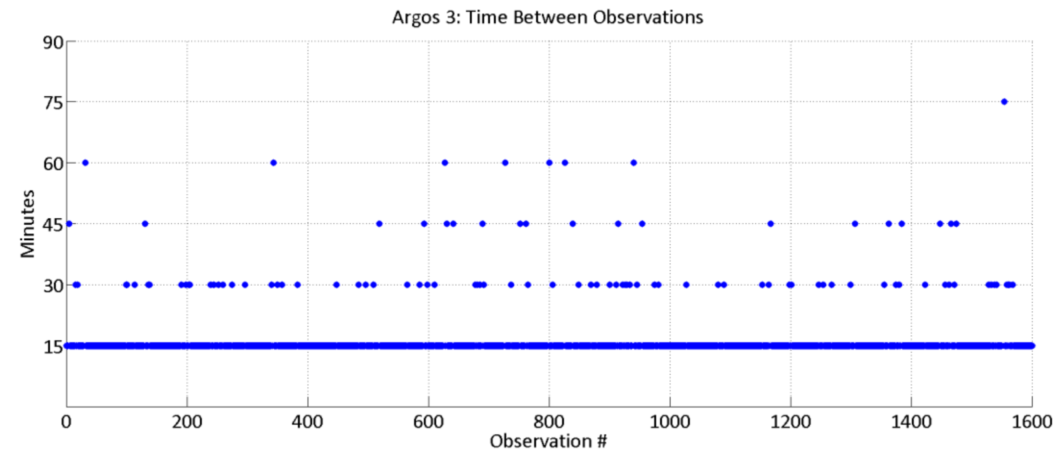

Figure 6: Typical time elapsed between Argos 3 observations

Argos 3 throughput is much improved over Argos 2 (Table 3). For received transmissions, 93% and 86.2% had good checksum utilizing Interactive-Ack and Pseudo-Ack respectively.

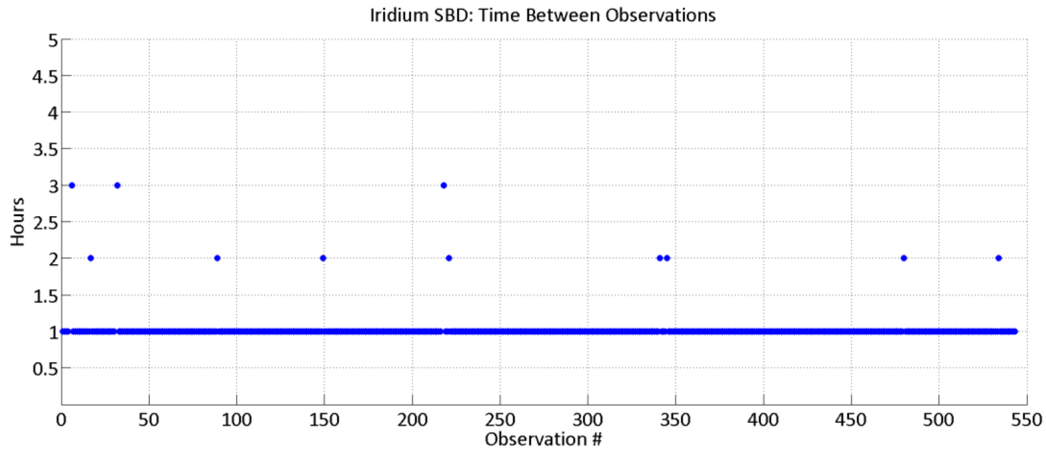

Figure 7: Typical time elapsed between Iridium SBD observations

The Iridium SBD system showed a throughput of 97.5%. Due to the unobstructed view to the sky, results will differ when deployed in open waters depending on transmission management handled by the host system.

Latency

Table 4: Observed Average Latency

Technology	Average Latency
Argos 2	N/A
Argos 3	6.2 hours
Iridium SBD	1.89 minutes

Argos 2 latency (Table 4) is only affected by the Argos constellation passes, and ground station processing. Provided a satellite is overhead, off the coast of California, latency has been observed as low as 15 minutes after transmission. Argos satellite coverage is a function of geographical region, and latency is subject to variation.

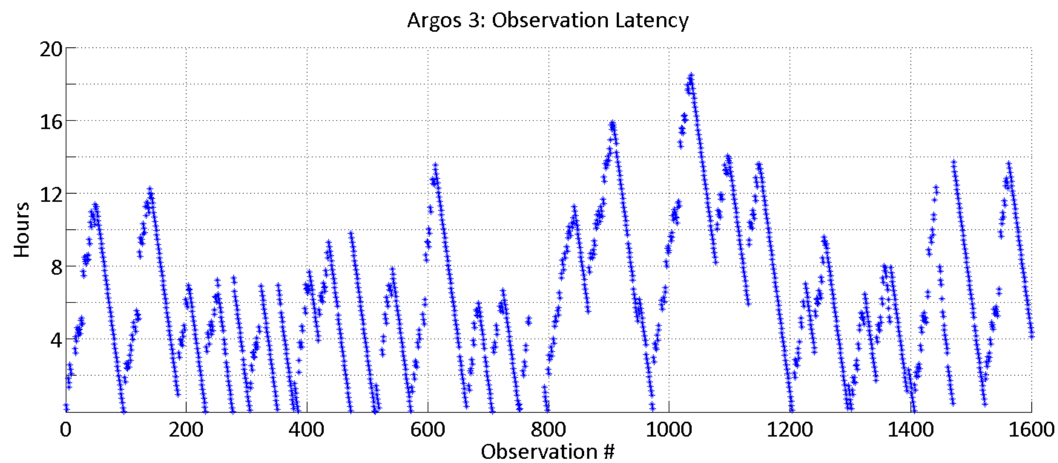

Figure 8: Argos 3 observation timeliness

Argos 3 peak latency was 18.3 hours after collection, with an average latency of 6.2 hours. Latency was the greatest leading up to an Argos 3 satellite pass, and lowest after the pass (Figure 8). Transmitter repetition rates as low as 5 seconds were observed while in Interactive-Ack mode under an Argos 3 satellite. An average of 15 observations and a maximum of 58 observations were received per Argos 3 pass. Average duration spent transmitting per Argos 3 pass was 6.6 minutes.

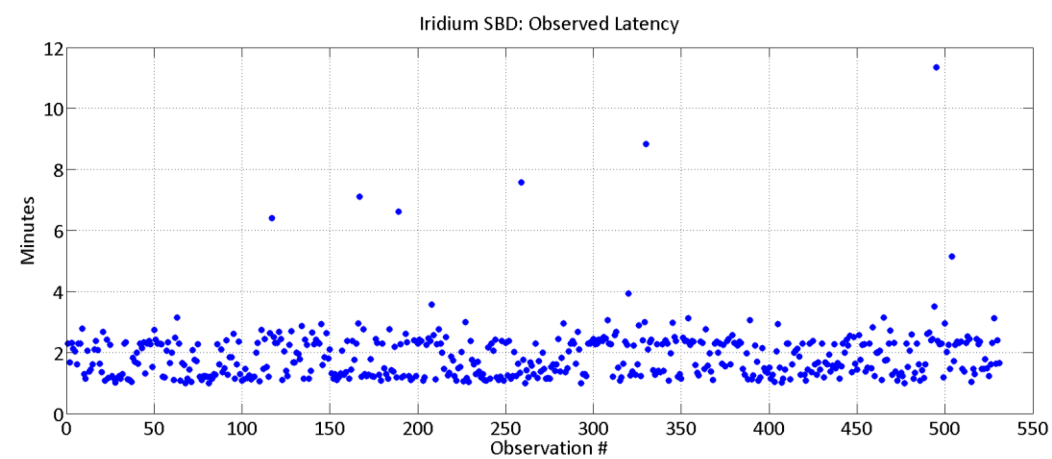

Figure 9: Iridium SBD latency measured from GPS timestamp to SBD file timestamp on SBD server at SIO

Iridium SBD latency was calculated using the observed GPS timestamp and the SBD file timestamp on the SBD server at SIO. Latency was observed on the order of minutes (Figure 9). Iridium SBD transmission delays are due to the host acquiring Iridium satellite lock, failed transmissions, and Iridium gateway processing.

Discussion

Advantages of Argos 3

There are advantages to the Argos 3 system utilizing Interactive-Ack mode in comparison to Argos 2. Argos 3 with Interactive-Ack has shown to be capable of improving throughput while decreasing power consumption compared to Argos 2. FCS checksum, managed by the PMT, enables noise free data to be available upon reception. By comparison, Argos 2 requires significant filtering prior to data analysis.

Advantages of Iridium SBD

Iridium SBD technology has proven superior performance in consideration of data latency, throughput, and power consumption. Iridium SBD checksum management results in noise-free data. Advancements in GPS module technology have shown to improve satellite lock capabilities and position accuracy. Iridium SBD's 2-way capabilities enable in-situ parameter changes and polling of diagnostic information. Certified Iridium and GPS antennae options are readily available through commercial resellers.

Potential issues for Argos 3

During evaluation testing, Argos 3 systems were subject to reliability issues specifically related to Interactive-Ack. One of the test systems exhibited issue achieving Argos 3 satellite downlink. As a result, data was transmitted over Pseudo-Ack protocol only. Significant latency increases and poor throughput were observed in comparison to well performing Argos 3 systems (Figure 10).

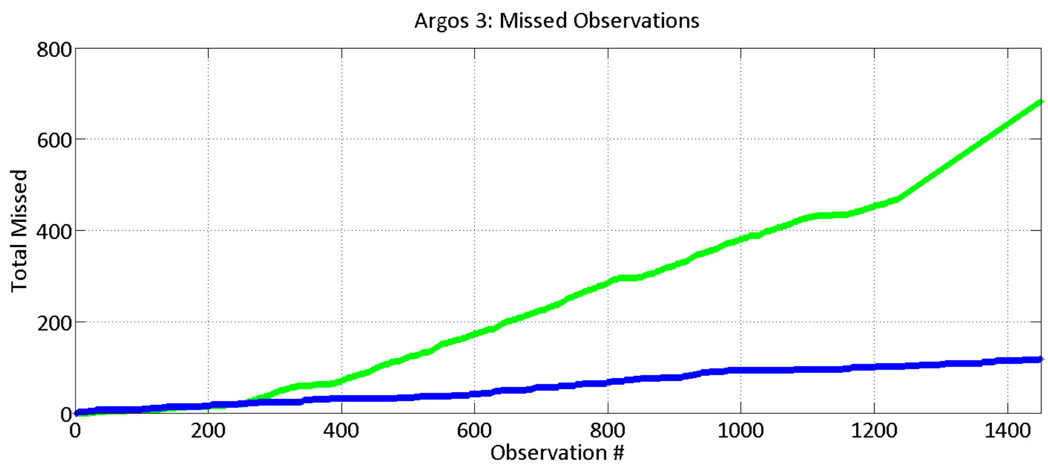

Figure 10: Damaged Argos 3 antenna (green), and expected Argos 3 behavior (blue)

An inability to lock the Argos 3 downlink signal will affect PMT location calculation, satellite orbital parameters in addition to Interactive-Ack. Failure to establish an Argos 3 downlink will eventually result in invalidation of location calculation and orbital parameters leading to significant throughput degradation. Due to the controlled nature and duration of the test, neither location calculation nor orbital parameters affected throughput. The sharp increase in missed observations (Figure 10) is a result of the PMT managed buffer running out of memory as a result of the system running in Pseudo-Ack mode only. CLS recommends PMT location to be updated every 3 days for a drifting buoy, while orbital parameters are valid for 6 months[3].

Under Interactive-Ack, the PMT receiver is turned on for the duration of the dataset transfer. During testing, the PMT receiver was powered for an average of 6.6 minutes per Argos 3 satellite pass for Interactive-Ack data transfer. Power savings may be achieved by disabling Interactive-Ack, and relying on Pseudo-Ack. Pseudo-Ack only enables user configuration of the PMT receiver downlink. For Pseudo-Ack only, the receiver downlink listening window affects PMT location and orbital parameter downloads used for satellite pass prediction. CLS recommends that the receiver downlink listening window to be set at the default of 60 seconds for Pseudo-Ack only configured drifters.

Further field testing is required for evaluation of the manual configuration of the receiver downlink listening window. Favorable results can be expected under controlled testing. As the Argos 3 constellation increases, the configured listening window will result in increased power consumption during the additional satellite passes. The receiver downlink window parameter can be modified in-situ through Argos 3 capabilities as required by the application.

Buffer management by the host system may be required depending on observation intervals and functional requirements for data timeliness. Field tests have been previously conducted by Pacific Gyre utilizing a host system managed Last In First Out (LIFO) buffer. In utilizing a LIFO buffer, Pacific Gyre has reduced data latency to that of the Argos 2 system while increasing throughput with historical observations.

Potential issues for Iridium SBD with GPS

Concerns remain regarding Iridium SBD systems. Due to required host system management of position and SBD message delivery, power consumption consequences are a risk in a variable ocean environment. Caution should be taken in regards to timeliness of satellite lock for both GPS and Iridium constellations.

Road map

Further field work is required to determine large scale field performance of Argos 3 systems. The lack of commercial Argos 3 capable antennae may delay developments while increasing risk of antennae failure or detuning. Limitations to near real-time capabilities hinder Argos 3 applications. Active LIFO buffer management by the host system is recommended in situations where Argos 3 is integrated for near real-time observations.

[3] YTR 3000 User Manual v1.14, section 4.1.1.3