Verification Procedure & Results **Document No.: 3167-20107 rev A**

Test Case ID:	Test Case Name:	Test Plan Document No.:	Test Plan Rev.:	Test Date:
007, Ver-CG-74	**VE-CG-3100 Post-recovery Evaluation, Southern Pacific Bight**	**3167-20000**	**2-00**	

Test Director (Print Name) Ed Dever	Signature in lieu of electronic signature	**Design Engineer**	Approval Signature John S. Dingess in lieu of electronic signature	Date 10-11-2012
Test Conductor (Print Name) David Neiman	Signature [signature]	**System Engineer**	Approval Signature Ed Dever (in lieu of electronic signature)	Date 10/15/2012
Witnessed by (Print name)	Signature	**QA/QC Engineer**	Approval Signature Michael A. Zernick	Date 10/21/12

Test Class ☑ Performance ☑ Behavioral ☐ Reliability ☐ Endurance / Longevity ☐ Survivability ☐ Safety

Test Description

The glider power and data usage will be evaluated against OOI requirements for deployment endurance. Allowances for data and power usage by the modem, extrapolated to a 1-year deployment, will be made in calculating endurance.

Requirements Addressed

L4-CG-GD-RQ-135, L4-CG-GD-RQ-138, L4-CG-GD-RQ-82, L4-CG-GD-RQ-76, L4-CG-GD-RQ-157, L4-CG-GD-RQ-86, L4-CG-GD-RQ-91, L4-CG-GD-RQ-147, L4-CG-GD-RQ-87, L4-CG-GD-RQ-137

Test Setup	Test Artifacts
Glider flight documentation	This document Power consumption records for deployment Power analysis from TWR (Appendix A) Data storage needs for the glider (Appendix B)

Test Procedure				Test Results		
Step No.	**Instructions**	**Expected Results** (Accept Criteria)	**Requirement ID**	**Test Data**	**Pass/Fail**	**Notes/Waiver No.**
7.1	Evaluate power consumed during prototypical open-ocean glider operation	Open-ocean gliders will have a deployment interval of twelve months.	L4-CG-GD-RQ-135	Per Appendix A, the glider has a projected endurance under the speed and sampling conditions required by OOI science goals of 389 days, with a power reserve of 15A-hr for modem operations.	Pass	If we account for the 36A-hr reserve used to calculate the 60-day emergency recovery time, the endurance predicted is 375 days, which still exceeds the 12-month requirement.

Test Procedure				Test Results		
Step No.	**Instructions**	**Expected Results** (Accept Criteria)	**Requirement ID**	**Test Data**	**Pass/Fail**	**Notes/Waiver No.**
7.2	Evaluate total deployment time (as determined by available power) to determine glider range during deployment	Over the deployment interval, open-ocean gliders will have a minimum horizontal range through the water of 6300 kilometers.	L4-CG-GD-RQ-138	The 12-month endurance calculation was based on operation of the glider at ~20cm/s, for which test conditions were created and used. The 6300km range is achievable using the test conditions.	Pass	This requirement is based on constant 20cm/s forward speed over the full year.
7.3	Evaluate the ability of the on-board power to maintain full functionality over the entire deployment interval.	Open-ocean gliders will have sufficient power to operate the controller with full functionality for the required deployment interval.	L4-CG-GD-RQ-82	Inherent in the endurance calculations is full functionality of the controller.	Pass	Ensure that glider can operate normally during the full deployment interval.
7.4	Evaluate the ability of the glider to meet a 60-day low power emergency operation.	The open-ocean glider will have sufficient battery reserves to allow the open-ocean glider controller, GPS location system, and telemetry system to remain functional for 60 days following the end of the planned deployment interval.	L4-CG-GD-RQ-76	See step 7.1	Pass	A low-power emergency mode was developed for the coastal glider that allowed 60-day limited operation (at surface, 1/day communications) using 36A-hr. This is 3.5% of the open-ocean glider power capacity.
7.5	Evaluate the power required to operate the modem. This will require some assumptions about modem usage (transmit/receive, etc.). Use the SM75 results for transmission efficiency.	Open ocean gliders mounting acoustic modems will have sufficient energy to transfer a total of 15 megabytes via the acoustic link during the deployment interval.	L4-CG-GD-RQ-157	From the test results, TWR engineer David Pingal estimated1Amp-hour per megabyte of data transfer. This was used as part of the power analysis (Appendix A).	Pass	

Test Procedure				Test Results		
Step No.	**Instructions**	**Expected Results** (Accept Criteria)	**Requirement ID**	**Test Data**	**Pass/Fail**	**Notes/Waiver No.**
7.6	During this deployment, several navigation parameters will be used. Routine use of the open-ocean glider calls for station-keeping in the face of a 20cm/s current. For this requirement, conditions that would allow the glider to maintain a constant average speed of 20cm/s will be evaluated for power usage.	The horizontal component of the velocity of the open ocean glider relative to the water will be a minimum of 20 cm/s when averaged over the vertical extent of each complete dive cycle.	L4-CG-GD-RQ-86	The navigation conditions used to develop the power-consumption data used in Appendix A were optimized for ~20cm/s flight. Operational areas for the open-ocean gliders allow the same navigational conditions to be used in production deployments.	Pass	
7.7	Evaluate the data storage needed for the full deployment interval, excluding .dbd files.	The data storage subsystem will have data storage capacity to store all of the open-ocean glider engineering and sensor data collected during a deployment interval	L4-CG-GD-RQ-91	See Appendix B,The science data card has the capacity for 534 days of glider sensor data.	Engineering: Science: Pass	The glider .mbd list will be set to capture the non-NaN columns of the .dbd file, as the .dbd file is sensitive to deletion as the engineering disk fills.
7.8	Compare data storage required for the deployment, scaled to 1 year, to the 2GB per Persistor card. The acoustic modem power requirement (L4-CG-GD-RQ-157) states that 15MB total is expected for transfer, so add 15MB to the data storage used on the card that stores modem data.	The open ocean glider data storage subsystem will have data storage capacity to store all of the data obtained from remote instruments via the acoustic modem in addition to that stated in the Glider Common Requirements.	L4-CG-GD-RQ-147	The 15MB requirement for storage of modem data equals ~6 days of glider sensor data, which is well within the excess capacity of the glider science memory card.	Pass	

Test Procedure				Test Results		
Step No.	**Instructions**	**Expected Results** (Accept Criteria)	**Requirement ID**	**Test Data**	**Pass/Fail**	**Notes/Waiver No.**
7.9	Evaluate re-deployment ability following refurbishment.	Open-ocean gliders will be recoverable and reusable following refurbishment and refueling.	L4-CG-GD-RQ-87	No differences were noted between the open-ocean and coastal gliders to invalidate the way this requirement was passed for the coastal glider.	Pass	
7.10	Compare forward speed calculated to verify L4-CG-GD-RQ-86 to 20cm/s requirement.	Gliders will have sufficient range to stay in a fixed geographical location for the deployment interval when confronted with a steady ocean current of 20 cm/s.	L4-CG-GD-RQ-137	The navigation conditions used to develop the power-consumption data used in Appendix A were optimized for ~20cm/s flight. Operational areas for the open-ocean gliders allow the same navigational conditions to be used in production deployments.	Pass	
Deferred requirement from TC003						
3.4	Compare glider actual power usage to that predicted by the mission planning spreadsheet	Agreement between spreadsheet and actual power usage will be considered adequate by the Endurance System Engineer	L4-CG-GD-RQ-90	The mission-planning spreadsheet has been updated by TWR engineers in response to telemetered data. Current agreement of spreadsheet prediction and glider data is considered adequate by the Endurance System Engineer	Pass	

Appendix A: Deployment endurance calculation

Follows is the analysis of the power use by the open-ocean glider during the test deployment starting 9/21/2012. This analysis was discussed and accepted at the Open-ocean glider team call10/18/2012. Note that the analysis is of power-usage data collected once appropriate conditions for long-endurance operation were created, and that the issue with the FLBB staying on at depths greater than 200m is being addressed by TWR. The changes as a result of correcting this issue will result in wiring to the science bay that is closer in alignment to the OOI Coastal Glider than the original wiring in the test article Open –ocean glider SN276.

Hi David,
Here is the latest update.
Thanks,
Clayton

From: Clayton Jones
Sent: Monday, October 15, 2012 2:38 PM
To: Clayton Jones; 'Ed Dever'
Cc: Bill Wieler; David Pingal; John Dingess; 'David Neiman'
Subject: RE: Open Ocean Energy Usage
Hi Ed,
An update on energy usage:
Over the weekend the glider has been flying to the new mooring position.
With sampling on every downcast (four per day) and collected and transmitted in the .tbd files at a 60 second resolution, the energy consumption is 2.97 Ah/day.
If we subtract out the FLBB energy usage for 800 m of collection per cast and use the 1015 available Ah allowing for acomms as per below...
2.97 Ah/day - (4 downcasts * .09 Ah (reduce FLBB by 800 m)) = 2.61 Ah/day
1015 Ah / 2.61 Ah/day = 389 days
Still nicely on target.
Thanks,
Clayton
From: Clayton Jones
Sent: Wednesday, October 10, 2012 6:10 PM
To: 'Ed Dever'
Cc: Bill Wieler; David Pingal; John Dingess
Subject: Open Ocean Energy Usage
Hi Ed,
The open ocean Slocum is presently using 2.39 Ah/day doing double yos with an average speed of .23 m/sec resulting in an average 11.9 hours between surface events. The sensors are presently on every other yo.
Collecting science on every down cast results in an additional .592 Ah/day over flight alone or put another way the glider is using .296 Ah/cast (with FLBB on for the full 1000m).
Therefore:
Glider flight alone is 2.39 Ah/day - .592 Ah/day (science) = 1.80 Ah/day
This matches what we are reporting with the glider Silbo, presently flying from the Canary Islands to Brazil.
A few comments:
There is a software bug with low power mode where the FLBB is on for the entire 1000m profile instead of being turned off after 200m. We will address this in a subsequent code release. This fix will result in .09 Ah/cast savings.
Summary:
1030 Ah (de-rated battery) - 15 Ah (acoustic communication) = 1015 Ah available
.296 Ah/cast (present science on with FLBB on 1000m) - .09 (reduce FLBB by 800m) = .206 Ah/cast science
So if we take a base of 1.80 Ah/day for flight and add...
Sampling downcast every yo:
1.80 Ah/day flight only + .824 Ah/day (science .206 Ah/cast * 4 casts per day) = 2.624 Ah/day
1015 Ah / 2.624 Ah/day = 387 days
Sampling downcast every other yo:

1.80 Ah/day flight only + .412 Ah/day (science .206 Ah/cast * 2 casts per day) = 2.212 Ah/day
1015 Ah / 2.212 Ah/day = 459 days
So, in short... we believe that we can meet the specification. Apologize for how long it took us to dial this in.

A few other comments:
The science sensors are being sampled at their full speed rate and are being collected in the .ebd file format at this rate. To reduce the Iridium message size we have reduced the resolution to a sample every 300 seconds in the .tbd files. We have some fields non-essential sensors (such as the static FLBB ref fields) being collected and other sensors that we have been reporting in the .sbd for diagnosis that we can clean up. This will allow us to increase the resolution and we will provide the energy impact soon as we move to a 60 second interval overnight. We may also be able to tweak the energy down further by setting the low power mode to greater than 30 seconds. This will be tested on Silbo soon.
Thanks,
Clayton
Name: ab_ooi.mi
Glider:

- Dive-to depth: 990m (overshoots to hit 1000m)
- No. Yos/segment: 2
- Altimeter: off
- Low Power Cycle Time: 30 sec.
- Pitch Control: Fixed Battery Position
- Total Drive Volume: 250 ccs
- Dive Volume: -62.5 ccs
- Climb Volume: 187.5 ccs

Science Sensors:

- FLBBCD, OXY4, CTD
- Sample every other dive, downcast only
- Tbdlist.dat recording at 300 second intervals:
  - SCI_WATER_COND

SCI_WATER_TEMP
SCI_WATER_PRESSURE

sci_oxy4_oxygen
sci_oxy4_saturation
sci_oxy4_temp
sci_flbbcd_chlor_units
sci_flbbcd_chlor_sig
sci_flbbcd_chlor_ref
sci_flbbcd_bb_units
sci_flbbcd_bb_sig
sci_flbbcd_bb_ref
sci_flbbcd_cdom_units
sci_flbbcd_cdom_sig
sci_flbbcd_cdom_ref

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Appendix B: Data storage analysis

Part 1: Engineering data storage needs

Engineering data storage needs has been estimated by TWR engineer David Pingal as follows:

Capacity	
Flash card capacity (bytes)	2.00E+009
Missions / code (bytes)	1000000
Mission duration (days)	365
Mission duration (sec)	3.15E+007
Sensor size (bytes)	4.25
Capacity – flight controller	
Missions / code (bytes)	1000000
Usable capacity (bytes)	2.00E+009
Max data rate (bytes/sec)	63.3878742
Max data rate (sensors/sec)	14.9147939
Generation – flight controller	
Sample period full duty (sec)	4
Sample period low power (sec)	30
Duty cycle low power (%)	50.00%
Sample period average (sec)	17
Max sensors / sample	253.551497

In TWR use, the term ‘sensor’ can mean a physical sensor (*e.g*. the glider depth from the engineering pressure sensor), a control (*e.g*. the ballast pump setting), or a calculated value for use when the glider is being used as a simulator. In total, the engineering computer stores a total of 1878 sensor values in data files denoted “.dbd”. These files can become quite large, are not intended for telemetry, and in the case of shortage of file space on the 2GB flash-memory storage card on the engineering computer are deleted (oldest first). However, the entries that are relevant to the command and operation of the glider can be stored in a file denoted “.mbd”, which can store the engineering data in non-decimated form. A third data file type (.sbd) can be used to store and telemeter decimated data that is needed in near-real time for glider monitoring and operation.

The final entry in the table gives the number of engineering sensors that could be stored at each monitoring cycle of the engineering computer, assuming the glider is operated 50% of the time in standard mode with a 4-second cycle time and 50% in a reduced-power mode with a 30-second sampling time. This combination of cycle times was accepted by OOI as part of reaching the mission endurance goals for the open-ocean glider. An analysis of the 1878 available variables by OOI Instrument Technician Chris Wingard found that 256 variables are active (actually record data during glider operation). Further analysis found 14 of those that were not needed for the open-ocean glider, leaving 242 that need stored. Assuming that each of these 242 variables records a new value at each sample period (itself a conservative estimate), we conclude that the flash memory space available is sufficient to retain the complete set of engineering data for the glider for a 1-year deployment.

Part 2: Science data storage needs

Science data storage needs can be estimated conservatively by assuming the science data volume on the glider 10/18/2012 was all collected during the deployment begun 9/17/2012. The total science data volume was requested by John Dingess via the following command issued when the glider was at the surface:

```
!get sci_m_disk_usage

 --------------------------------

= 97.312500 Mbytes
```

Between 9/17 and 10/18 is a total of 31 days, from which 1 day is subtracted to account for the glider sensor adjustments and other factors. This leaves a daily data rate of 97.32MB/31 days, or 3.13MB/day. Since the flash-memory card on the glider's science computer has a capacity of 2000MB, the science data capacity for the glider is 2000/3.13 or 637 days, well in excess of the 365 days needed for a full deployment.