BRIDGES
BRINGING TOGETHER RESEARCH AND INDUSTRY FOR THE DEVELOPMENT OF GLIDER ENVIRONMENTAL SERVICES

THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION
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"Bringing together Research and Industry for the Development of Glider Environmental Services"

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DELIVERABLE 5.1

"Common interfaces and standards for sensors and their integration into the D and UD Explorer science bay"

ABSTRACT

This document describes the designs and formats for common interfaces and standards for sensors and how they will integrate into the D and UD Explorer science bay (D5.1).

The aim of the work package is to deliver four targeted sensor suites to enable maximum market penetration in three pioneer markets i.e. Living resources, Oil and Gas and Sea-bed mining. Some of the sensors required for these suites are at TRL 3-9 and the work package will advance the TRL for these sensors. In addition the sensor will be grouped to form sensor suites and these will be integrated with the D and UD Explorer.

This deliverable will manage, develop and apply a common set of procedures and standards for the sensors and the way they are integrated into suites and with the U and UD vehicles. Sensors will be integrated in to the flooded payload compartment and connected to the Payload Management Computer (PMC) through both serial and power connections.

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VERSION NUMBERING	
v0.x	draft before peer-review approval
v1.x	After the first review
v2.x	After the second review
vfinal	Deliverable ready to be submitted!

STATUS / DISSEMINATION LEVEL			
STATUS		DISSEMINATION LEVEL	
S0	Approved/Released/Ready to be submitted	**PU**	Public
S1	Reviewed	**CO**	Confidential, restricted under conditions set out in the Grant Agreement
S2	Pending for review		
S3	Draft for comments	**CI**	Classified, information as referred to in Commission Decision 2001/844/EC.
S4	Under preparation		

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1 Introduction

1.1 Purpose of document

This document is the final deliverable for Task 5.1 Common Interfaces & Standards of WP5.

1.2 Purpose of work package WP5 and Task 5.1

The aim of WP5 is to deliver four sensor suites covering the three target markets for the Deep(D) 2400m and UltraDeep (UD) 5000m vehicles. The purpose of Task 5.1 is to ensure the delivered sensors will be able to integrate with the vehicles successfully by identifying sensor configurations that meet the size, weight, electrical supply and communications constraints of the vehicles, recommending common standards and best practice for each sensor where there is a choice.

1.3 Related work packages

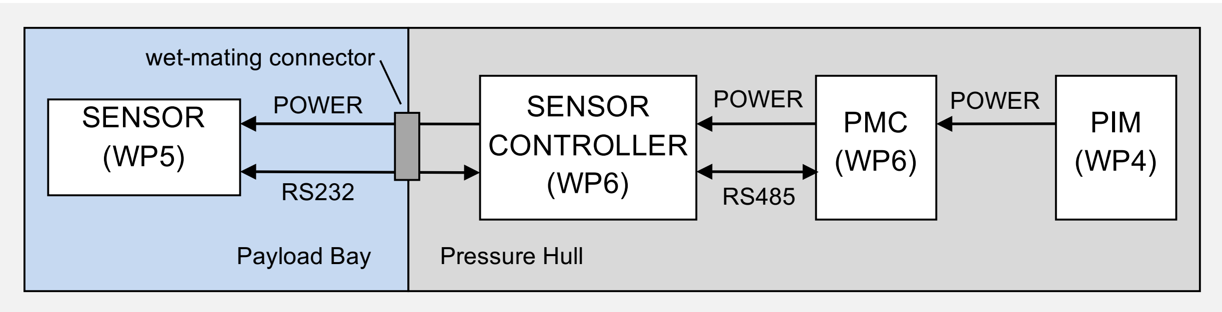
Task 5.1 is directly dependent on work in four other work packages in the project and we have liaised with all four of them (as detailed later) in completing this task.

Related work packages:

WP	Dependency
WP2	Sensor selection
WP3	Standards for vehicle-sensor communications
WP4	Sensor size/weight limitations and power
WP6	Sensor communications

1.4 Scope of Task 5.1

The sensors provided by WP5 are to be connected via cables to wet-mating connectors in the glider's flooded payload bay. The connectors are internally wired to Sensor Controllers to the Payload Management Computer (PMC) for communications and power. Power is obtained by the PCM from the Power Interface Module (PIM). The Sensor Controllers convert between the standard power and communications from the PIM and PMC into sensor-specific power and communications. The picture below shows a single Sensor/Sensor Controller pair.



The scope of this task is to specify the sensors and their power from, and communications with, the Sensor Controllers. The Sensors Controllers themselves and the PMC are the responsibility of WP6. The PMC and wet-mating connectors are the responsibility of WP4.

2 WP5 Sensors

2.1 Sensor List

The following list of WP5 sensors has been agreed by all WP5 partners and WP2. All sensors listed will feature in at least one of the four WP5 sensor groups.

WP5 Sensors:

Short Name	Manufacturer	Model	Type
SEABIRD_CTD	Sea-Bird Electronics	SBE 37-SIP MicroCAT	CTD
HYDRO_O2	Contros	HydroFlash O2	O2
CYCLOPS_CRUDE	Turner Designs	Cyclops-6K	Crude Oil
CYCLOPS_REFINED	Turner Designs	Cyclops-6K	Refined Oil
CYCLOPS_CHLOR	Turner Designs	Cyclops-6K	Chlorophyll
CYCLOPS_TURB	Turner Designs	Cyclops-6K	Turbidity
CYCLOPS_CDOM	Turner Designs	Cyclops-6K	CDOM
WATER_SAMP	Fluidion	(custom)	Water Sampler
OCTOPUS_UP6	CNRS-UPMC	Octopus UPV6	Imaging System
CMRE_SBP	CMRE	(custom)	Acoustic Sub-bottom Profiler
NOC_A	NERC (NOC)	Wet Chemical V3	Ammonia
NOC_N	NERC (NOC)	Wet Chemical V3	Nitrate
NOC_P	NERC (NOC)	Wet Chemical V3	Phosphate
NOC_S	NERC (NOC)	Wet Chemical V3	Silicate

Four other sensors (for pH (Fluidion), CO_2 & CH_4 (Pro Oceanus) and passive acoustics (Ocean Sonics)) have been considered for WP5 but are not currently expected to form part of the sensor groups and are not discussed further in this document. However, they may be tested and integrated at a later stage if their TRL can be improved.

2.2 Sensor Information Sheet

A comprehensive information sheet containing full details for all of the sensors is available at the following link :

http://www.bridges-h2020.eu/owncloud/index.php/s/XBilgJslPwg46Ns

This information sheet or the underlying manufacturers data sheets (where available) should be considered definitive if there is any conflict with values reproduced in this document. This document is evolving under the lead of one partner, who coordinates changes and additions.

2.3 Sensor Suites

The sensors are grouped into four Sensor Suites targeting four markets: General Purpose, Living Resources Monitoring, Oil & Gas and Sea-bed Mining Surveillance. They are defined as follows:

Sensor Suites:

Suite	Sensors
General Purpose	SEABIRD_CTD HYDRO_O2 CYCLOPS_CRUDE CYCLOPS_REFINED
Living Resources Monitoring	SEABIRD_CTD HYDRO_O2 NOC_P CYCLOPS_TURB OCTOPUS_UP6 CYCLOPS_CDOM WATER_SAMP
Oil & Gas	SEABIRD_CTD HYDRO_O2 CYCLOPS_CDOM CYCLOPS_CRUDE OCTOPUS_UP6 CYCLOPS_REFINED
Sea-bed Mining Surveillance	SEABIRD_CTD HYDRO_O2 OCTOPUS_UP6 CMRE_SBP

3 Size & Weight

3.1 Glider Payload Bay Size & Weight Limits

A weight of 5Kg (per sensor) has been approved for sensors in the D and UD vehicles' payload bays. The total size of the payload bay volume is 50 L.

The volume could fit a cone: Ø370xH650mm.

3.2 Sensor Sizes & Weights

The individual sizes and weights of the sensors are as follows. For sensors placed in the glider's flooded payload bay, the wet weights should be used in any calculations, but if any sensor is located within the glider's pressure housing (components of the CMRE_SBP will be), the dry weight should be used as no additional water is displaced. Note that some of the custom-built sensors (OCTOPUS_UP6, WATER_SAMP and CMRE_SBP) are at early stages of development and the numbers here are the best available.

Sensor Sizes & Weights:

Short Name	Dry Weight (kg)	Wet Weight (kg)	Size (mm)
SEABIRD_CTD	3.0	1.8	437x140x68
HYDRO_O2	0.2	0.14	211x23ø
CYCLOPS_xxx	0.62	0.5	168x45ø
WATER_SAMP	3.5	1.0	250x120ø
OCTOPUS_UP6	1.0-3.0	1.0	200x63ø[1]
CMRE_SBP	not yet known[2]	not yet known	not yet known
NOC_xxx	3.6	0.85	200x75ø

Provision must be made for the OCTOPUS_UP6 sensor to have sufficient field of view for the camera 150x150-180x180mm at 200mm).

The WATER_SAMP sampler will require space for up to 16 x 100ml blood bags for storage of samples. These will add nothing to the wet weight but will require additional space over that specified for the sampler itself and will start empty, filling during the mission.

The NOC_xxx sensors will require space for typically 5 x 1L blood bags for storage of chemicals and a larger bag (3L) for the collection of waste for each sensor. These will add nothing to the wet weight but will require additional space over that specified for the sensor itself. The waste bag will start empty and fill to a maximum capacity of 3L during the mission, about 30% from seawater samples and the rest from the other bags. The exact volume of

[1] Preliminary figures for camera housing only.
[2] The contract for the CMRE_SBP Profiler has only just been awarded (April 2016) and no size or weight data is yet available.

reagent and waste will depend on the number of samples the sensor is required to make during a mission.

4 Power

4.1 Glider Payload Bay Power Limits

The glider can provide up to 48V (switchable) at each of the wet-mating ports in the flooding payload bay. The power is provided by the WP4 PIM via the WP6 Sensor Controllers. Up to 2A peak current (per sensor) has been approved.

4.2 Sensor Power Requirements

The individual power requirements of the sensors are as follows. As noted above, some of the custom-built sensors are at early stages of development and the numbers here are the best available.

<u>Sensor Power Requirements:</u>

Short Name	Voltage (V)	Power (peak) (W)	Warm-up Time
SEABIRD_CTD	9-24	0.45 (not yet known)	2-2.7s
HYDRO_O2	4.5-36	0.95 (not yet known)	not yet known
CYCLOPS_xxx	3-15	0.27 (0.36)	5s
WATER_SAMP	12	2 (4)	not yet known
OCTOPUS_UP6	8-30	0.6 (<6 provisionally)	provisionally 0.5-2s
CMRE_SBP	48	25 (25)	not yet known
NOC_xxx	10-16	1.8 (3.6)	500ms

WP4 have confirmed that the CMRE sensor's high power requirements can be met by the glider.

Provided the current requirements can be met, the glider ports could be standardized on 12V for all of these sensors except the CMRE_SBP profiler which requires 48V.

5 Communications

5.1 Glider-Sensor Communication Standards

Task 5.1 recommends that the existing sensor-specific RS232 streaming or command protocols (where defined) are used for WP5-WP6 communications. We have reached this conclusion for the following reasons:

- ❖ WP3 has not yet recommended any standards to BRIDGES for glider-sensor communications across the sensor to sensor-controller boundary.
- ❖ While it is essential that metadata for every sensor included in the glider payload should be linked to the stored data from these sensors, and this will be dealt with by WP6.2. It cannot be addressed by WP5 as most sensors are commercial and some do not have digital interfaces so we cannot embed metadata or GUID in data streams from those sensors.
- ❖ From our review we have found that in the industry as a whole, there are not yet any suitable standards covering the communications between oceanographic sensors and the vehicles carrying them. Among the European FP7 projects, SenseOCEAN has adopted Modbus, a de-facto industry standard dating from 1979, and NeXOS has adopted PUCK, a more recent OGC standard, dating from 2012 Neither of these is an attractive proposition. Modbus over a serial line (as opposed to ethernet) is inefficient and hard to implement, relying on high-rate processor interrupts to identify frame boundaries. PUCK is only really intended to solve the problem (if it exists) of device discovery, and sensors supporting it still typically drop back on their native protocol for all other communications.
- ❖ Eight of the WP5 sensors (SEABIRD CTD, HYDRO_O2, CYCLOPS_xxx) are commercial off-the-shelf sensors with existing communication protocols (or analogue outputs). A further four (NOCS_xxx) have existing protocols, although as a BRIDGES partner, NERC could be persuaded to adopt a new protocol. That leaves three sensors being designed new for BRIDGES but there's little commonality of function between them (of an imaging system (OCTOPUS_UP6), a water sampler (WATER_SAMP) and a sub-bottom profiler (CMRE_SBP) and a protocol that could support meaningful communications with all of them would essentially consist of separate commands for each sensor with only the message format in common.
- ❖ All of the sensors in the WP5 list except the analogue CYCLOPS_xxx devices already support very simple (and architecturally similar) ASCII communications over RS232 either as command/response protocols (from the glider to the sensor) or autonomous streaming (from the sensor to the glider). The WP6 architecture provides for dedicated Sensor Controller electronics for each sensor type, each with their own microcontroller that could easily handle these interfaces even as switchable plug-ins in a single firmware image, just for the expense of a little more ROM.

Task 5.1 has therefore ensured that full specifications for the *existing* protocols have been provided to WP6 for the commercial sensors (SEABIRD_CTD, HYDRO_O2, CYCLOPS_xxx) and the NOC_xxx sensors, and this task continues to liaise with Fluidion (WATER_SAMP) and LOV (OCTOPUS_UP6) for the remaining ones with provisional specifications for both interfaces having also been communicated to WP6. The requirements of the CMRE_SBP are not yet known beyond that expectation that it will be self-logging with only optional data (e.g. depth or timestamps) coming from the glider over RS232 or TTL lines.

Metadata documentation for all WP5 sensors (where available) has also been provided to BODC.

With the exception of the analogue CYCLOPS_xxx sensors, all sensors can communicate over 2-wire (TX/RX) RS232 at RS232 signal strengths. Baud rates differ (see the device data sheets). The CYCLOPS_xxx sensors provide an analogue output which must be measured by the WP6 Sensor Controller electronics and they also require gain controls (see 5.4).

5.2 SEABIRD_CTD communications

The SEABIRD_CTD sensor auto-starts at power-up and after a 2.7s warm-up time streams (at up to every 6s, or on receipt of an RS232 pulse) a single ASCII comma-separated record containing conductivity, pressure, temperature and time automatically to the glider. The format of this record is summarized in the Sensor Information Sheet (2.2) and defined in the manufacturer's data sheet which is available here:

http://www.seabird.com/sbe37sip-microcat-ctd

5.3 HYDRO_O2 communications

The HYDRO_O2 sensor auto-starts at power-up and can be sampled by the glider at least every 10s as ASCII records in NMEA-0183 format containing dissolved oxygen concentration. The format of this record is defined in the manufacturer's data sheet which is available here:

http://www.contros.eu/hydroflash-O2-sensor.html

5.4 CYCLOPS_xxx communications

The CYCLOP_xxx sensors auto-start at power-up and after a 5s warm-time can be sampled by the glider at least every 30s by measuring an output analogue voltage (in the range 0-5V) which can be converted into a concentration for each sensor type. Two additional lines can be used (by pulling them high or low) to switch between three different gain settings, x1, x10 and x100. Full details are in the manufacturer's data sheet which is available here:

http://www.turnerdesigns.com/t2/doc/brochures/S-0134.pdf

5.5 WATER_SAMP communications

The water sampler can be instructed by the glider to take samples at up to every 5 minutes, to the limit of the number of bags (up to 16) available. The communications protocol is still under discussion but it will consist of ASCII commands sent by the glider to take a sample, to clean the device and to list available samples, all over RS232. Full details will be appended to the Sensor Information Sheet (2.2).

5.6 OCTOPUS_UP6 communications

The OCTOPUS_UP6 can be configured either to autostart on power-up or to start on demand. It can be configured either to stream results (data frames) back to the glider, or to return single results on request from the glider. The typical frame acquisition rate is 0.1Hz but 0.001-10Hz are possible. The results contain particle counts and frame metadata but not actually imagery (this can be downloaded from the camera directly when it is recovered from the glider). The camera can also request the glider to send it pressure and time (this is the only sensor that sends a command to the glider). We have confirmed that this information is available from the glider's navigation system to the WP6 sensor controllers. The communications protocol is still to be formally agreed but it will consist of ASCII commands (in both directions between sensor and glider) and streamed ASCII data (to the glider), all over RS232. Full details will be appended to the Sensor Information Sheet (2.2).

5.7 CMRE_SBP communications

As already noted, this sensor is at a very early stage of development. However its known that the sensor will be self-recording with data downloaded over TCP after retrieval of the sensor from the glider. During deployment, there is expected to be the option of the glider sending platform data (e.g. depth) and timestamps (via a TTL line) to the sensor but more details of this are not yet available.

5.8 NOCS_xxx communications

The NOCS_xxx sensors auto-start at power-up and can be sampled by the glider around every 5 minutes returning Ammonia, Nitrate, Phosphate and Silicate concentrations (depending on sensor type) via an ASCII command interface. These sensors expect regular of depth and direction from the glider (e.g. every 5 seconds). We have confirmed that this information is available at this rate from the glider's navigation system to the WP6 sensor controllers. The Interface Specification is available here: Full details are appended to the Sensor Information Sheet (2.2).

6 Cables

Cables to connect the sensors to the glider's wet mating ports will be provided with each sensor (not by the glider). The glider's bulkhead will be fitted with 9pin connectors by WP4 and their pin-outs will be specified by WP6. For all sensors except the CYCLOPS_xxx they provide V+, GND and RS232 TX & RX (at RS232 line levels only). For the CYCLOPS_xxx sensors they provide V+ and GND together with analogue output and gain control lines.

7 Anti-biofouling

The outline for Task 5.1 also called for recommendations on anti-biofouling best practice but this has been postponed until more is known about the arrangement of the sensors in the glider and (for the sensors still in design) their susceptibility to biofouling and their built-in anti-biofouling capabilities.

8 Conclusion

At the completion of Task 5.1, WP5 now has a confirmed list of sensors with full details of their physical constraints, power requirements and communications requirements. All sensors but one can be operated at 12V, the remaining one (CMRE_SBP) at 48V. For all existing sensors we have recommended using their existing communications protocols as they are all architecturally similar. All sensors except the CYCLOPS_xxx sensors have very simple ASCII command-driven communications protocols, or ASCII streaming over RS232. The CYCLOPS_xxx sensors output an analogue 0-5V signal instead. All details have been passed to WP6 to enable to the creation of Sensor Controller electronics and firmware with plug-ins for each sensor type (or class). It is proposed later this year to conduct bench-top trials connecting the real sensors to the real WP6 sensor controller electronics (albeit with possibly simplified firmware) to confirm that this approach works. Cables will need to be made by the sensor providers according to the pin-outs confirmed by WP4/6 nearer the time.