Environmental Sample Processor
Generation 3
Project Overview
Feb 11, 2013

Scope:

This generation of the ESP will be taking the instrument onto new platforms (e.g., the Long-Range AUV; LRAUV and/or profiling floats) as well as utilizing new technologies for detection and sample preservation. Due to the size constraints of these platforms, new designs will be needed to enable the LRAUV with ESP technology. This combined project spans three funding source with complementary requirements. Final detection methods will leverage off of technologies in use by co-investigators. The design will support a means for adapting other detection technologies funded by future undetermined sources.
The instrument will be used for the detection and quantification of a multitude of algae, bacteria, viruses, invertebrate larvae and biotoxins using genetic markers. Along with species presence and abundance, expression and translation of specific genes would also be ascertained via analysis of mRNA and protein. Finally, sample preservation will allow sample return to the laboratory to ground-truth the real-time results.

Funding Sources:

MBARI
NSF Ocean Technology Interdisciplinary Coordination (OTIC) program.
Moore Foundation

Funding Source Expectations:

MBARI - Develop conceptual design for 3G ESP (2011-12)

NSF OTIC - The goals of this 4-year program (2010 – 2014) are to fabricate one 3G ESP, and four "analytical module" subsystems that would be distributed to co-investigators at each participating institution. The major objectives are to merge a molecular detection system from UW with a smaller version of the ESP (3G) to support a variety of assay chemistries in use now at U ME, NOAA/NOS, MBARI and elsewhere

Moore Foundation – the goals of this 4-year program (2011 – 2015) are to miniaturize and increase the throughput of various types of analytical modules. These modules must work with the newly designed 3G 'front end' and will be designed and tested by Arizona State U.

G3 ESP Requirements

Overall Considerations

Design should strive to minimize use of robotics.
Design should be cognizant manufacturing cost.

Physical Constraints

1. Complete G3 ('core' and analytical module [AM]) <u>shall fit onto the LRAUV</u> within the extended payload section -- ~11.5" diameter x 24" long.
2. G3 system <u>should be scalable</u> to take advantage of larger platforms, greater power availability, and increased bandwidth connectivity.

3. LRAUV with G3 payload shall be neutrally buoyant; any mass changes during deployment shall be within the LRAUV's dynamic buoyancy range
4. G3 should survive being placed in any orientation, and operate in horizontal or vertical modes if such orientations are within 30 deg.
5. G3 will receive power from the LRAUV.
    a. Bus voltage of LRAUV is 14 volts, limited to xx amps.
    b. While total kW-hr available will vary due to mission duration or LRAUV travel distance, we will target 40% of available LRAUV power for a 10 day mission.

Transit/Handling Conditions (fully loaded, sealed, but inactive instrument)

1. G3 shall survive deployment to 300m deep in seawater, 450 psia.
2. G3 shall survive temperature ranges from 0 to 50º C.
3. G3 shall survive acceleration of 3g in any direction.

Operating Conditions (all actions, including sampling, filtering and analytic module processing.)

1. G3 shall operate between 1 and 300m deep in seawater. (15 to 450 psia)
2. G3 shall operate in seawater temperatures ranging from 2 to 40º C.
3. Missions may be as long as 1 year in duration.
4. G3 should acquire 30 samples and 30 archives per mission.
5. G3 shall operate under acceleration of .5g in any direction, and at a tilt angle 30º from horizontal or vertical orientation.
6. Mission is recoverable from 1g acceleration in any direction (i.e., barrel-roll of LRAUV).

Sampling Module Functions

1. 'Samples' consist of particles removed from raw seawater.
2. G3 should be able to process between 2mL and 2L of raw seawater when collecting a sample.
3. Maximum raw seawater sample collection time will be 1 hour for l L using a 0.2µm filter.
4. Sampling module should have a volume accuracy of 1% of sampled volume.
5. Sampling module shall exclude particles greater than 0.5mm in diameter.
6. Sampling module shall size fractionate (2 sizes) according to needs of end-user. Minimally, one sample will be lysed; ideally both sizes will be lysed. A stacked-filter format would allow preservation of each retentate.

G3 Core Functions

1. The G3 core shall:
    a. preserve and store samples before lysis **–and--**
    b. lyse (break open) organisms/viruses in the sample.
2. G3 core must generate a total lysate volume of 300 to 500 µL. Lysate volume could be variable, depending on filter sizes used to fractionate the sample.
3. G3 core shall provide lysate to analytical modules within 30 minutes from the end of sample collection. Should be equal or better than current G2 times.

4. G3 core shall parse the lysate to different analytical modules.
5. G3 core shall prevent biological carry-over or contamination to the next sample in the Sample collection, lysing, purification, and analytical transfer systems/modules.
    a. It should be possible to chemically sterilize the core from intake port to exhaust port.
    b. The G3 core will be responsible for cleaning the transfer loop(s) between the core and analytical modules.
    c. Only seawater filtrate and sterilizing compounds will be exhausted to the environment.
    d. Waste not exhausted will be stored/carried on-board.
6. The core must accommodate 6 reagents for sample processing.
7. G3 subsystems should be modular when practical, to allow field-replacement of core subsystems. For example, drop-in modules for core subsystems, reagents, waste containers, analytical modules, etc…This requirement may conflict with sizing constraints and result in a tradeoff between number of samples capable on the LRAUV.
8. G3 core will have capability to incorporate future detection technologies, or specific co-investigator detection technologies if these technologies meet the size, power, and fluid requirements defined above.

Analytical Module Functions

1. The LRAUV platform for G3 ESP should accommodate up to 3 analytical modules.
2. The analytical module(s) shall connect to the G3 core via three connections: lysate fluid (via transfer loop), data transfer, and power.
3. The lower-limit-of-detection will be individually defined for each analyte.

Control Architecture

1. G3's control processor operates its core and analytical modules (called the 'G3 controller').
2. A logically separate 'platform controller' manages both communications to shore and contextual sensors.
3. The core processor will store raw, unprocessed data. Minimum nonvolatile storage will be 16GB.
4. When appropriate, the logical functions of both the G3 and platform controllers may be provided by a single, low-power processing unit.
5. When the G3 and platform controllers are separated, they shall be connected in a TCP/IP network via ethernet or PPP/SLIP over a high speed serial interface.
6. G3 software should be capable of event-response, independent of platform.
7. When on LRAUV, G3 should interface with LRAUV contextual sensors, time stamp, and GPS locations.
8. G3 should have capability to return raw, unprocessed data to shore.
9. The platform controller shall optionally support wireless communication to allow downloading of new code, checking status, interrupting run, and retrieval of unprocessed data.

Future Technology Evolution (expected future uses, but not requirements yet.)

1. For under ice operations, G3 would need to operate in seawater temperatures to -3º C. If possible, avoid equipment/systems that cannot operate this low. (Not counting reagent stability or liquidity.)