ABSTRACT FORM

Project Title: 902402 CSEM

Expected Project Duration (in years): 3 years

PI	Project Manager	Lead Scientist	Lead Engineer
Aaron Micallef	Aaron Micallef		

Project Overview

The main goal is to modify and utilize a surface-towed controlled-source electromagnetic system for shallow water surveys in Monterey Bay and the Canadian Beaufort Sea, and work towards developing an AUV-based system for work at higher resolution and larger depths.

Problem:
Our understanding of the distribution and scale of various types of fluid flow systems, their mechanical and chemical characteristics, and how/where they seep out of the seafloor, is still limited. There is a paucity of process-based observations (e.g. due to their ephemeral nature), and precise understanding of how fluid flow/discharge creates seafloor geometries and sub-seafloor structures remains elusive. There is also a lack of understanding of the rates and temporal scales of these processes.
Controlled-source electromagnetic (CSEM) systems are effective at imaging fluids in the sub-seafloor and water column. The few CSEM systems available globally are tailored towards the exploration needs of the hydrocarbon industry. They tend to be slow, logistically and financially expensive to deploy, hindered by navigation and accuracy issues, and difficult to modify. As a result, the use of most CSEM systems is restricted by depth, whereas the spatial resolution of the data acquired is inadequate to investigate the association between fluid flow and geomorphic structures, and their evolution over time.
Most of these issues can potentially be addressed with an AUV-based CSEM system. A recent test offshore Japan has shown the feasibility of imaging sub-seafloor electrical resistivity using an AUV mounted with self-potential systems with limited impact on the operation of standard payloads, navigation and power consumption.

Research objectives:
CSEM is 3 year project that will develop a high resolution CSEM system for deployment in a wide range of water depths. To reach this goal, two sub-objectives are also proposed:

1. **To reconfigure and test a recently developed surface-towed CSEM system**

SWAN is a prototype for a surface-towed CSEM system (Figure 1), which is currently being developed by the University of Malta, GEOMAR and Texas A&M, to detect fluids within the upper 200 m of the seafloor in water depths of up to 100 m. The system will be inexpensive, small, modular, and allow fast data acquisition with low computational expense. I plan to bring the system to MBARI in early 2024 and adapt it for use on MBARI vessels. Two tests have been planned:

- Monterey Canyon: San Gregorio Fault is a >200 km long, active, right-lateral strike-slip fault intersecting the outer shelf and upper continental slope in Monterey Bay. The objective of the test will be to map the spatial distribution of active seeps along the fault in the outer shelf (reported in 1999) and the geometry of their flow pathways. This will allow us to obtain insights into margin hydrogeology, the mechanics of the fault, and the potential occurrence of chemosynthetic communities.
- Canadian Beaufort Sea: The Arctic Ocean is one of the prime sites for the deployment of CSEM technology in view of the complex hydrogeological systems hosted within its margins, and the rapid change they are undergoing due to increasing temperatures. Charlie Paull and his colleagues are planning an oceanographic expedition in the Canadian Beaufort Sea in the summer of 2025. One of the pending questions from their previous work in the area was the extent and depth of permafrost in the outer continental shelf (target seafloor depths of <120 m and sub-seafloor depths of <30 m) and its relation to documented seafloor change. This can potentially be assessed with the SWAN CSEM system.

2. **To assess if/how an AUV-based CSEM system can/should be built at MBARI to carry out repeat surveys of fluid flow systems at high spatial resolution and in a wide range of water depths**

Significance:

- Importance: Fluids play a central role in the geomorphic modification of our planet, and they are associated with specialized biota and untapped resources. The technology developed by the end of this program will allow the surveying of fluid flow systems and their geomorphic structures in unprecedented detail, with potential direct application to mapping of benthic communities (biogeophysics).
- Timeliness: There has been a recent surge of interest in the utilization and adaptation of CSEM technology to investigate and monitor sub-seafloor fluids, which has revealed a clear market gap, in both academia and industry.
- Uniqueness: There is only one publication documenting testing of an AUV-based CSEM system, and this did not focus on fluid flow systems or geomorphology.

Relevance to MBARI: The program makes novel use of AUV capabilities at MBARI while pushing the engineering and operational expertise in new directions. It also builds on existing research projects. Monterey Bay provides an excellent test bed for CSEM technologies. The program directly aligns with four strategic priorities: (i) Build scalable technologies to improve ocean health assessments, (ii) Map the deep seafloor at high resolution, (iii) Advance ocean-based artificial intelligence, and (iv) Study the impacts of climate change and other ocean threats.

Internal and external project links:

- Concurrent Seafloor Processes internal proposal (902312, Micallef)
- Concurrent Geo-Sense internal proposal (Micallef)
- Concurrent Continental Margins internal proposal (901023, Paull)
- Planned AUV and LASS mapping at Octopus Garden and Davidson Seamount (Caress)

Is this project one of multiple projects your team plans to submit?

Concurrently proposed internal projects:

- Seafloor Processes (Micallef): This is the core science project for the Seafloor Processes lab, which will focus on active seafloor processes at fine spatial and temporal scales.
- Geo-Sense (Micallef): Geo-Sense will assess the feasibility using Distributed Acoustic Sensing to monitor seafloor processes.

The technology being assessed and developed in this program will be directly relevant to monitoring fluid flow and escape, which contributes to both of the above programs.

Hierarchy of priorities:

1. Seafloor Processes
2. Geo-Sense
3. CSEM

Nature and Scope of the Proposed Project

This program starts as a modest platform/sensor integration and scoping study, which morphs into a larger R&D effort.

Year 1 activities:

- Adapt MBARI winch and SWAN system for deployment from MBARI vessel
- Execute test survey in Monterey Bay; process and invert CSEM data
- Run synthetic modelling to assess whether the SWAN system can map the targets in the Canadian Beaufort Sea
- Consider reconfiguration of system if required (e.g. increase dipole moment, reduce noise level of receivers, transform to deep-towed system and use an ocean-bottom transmitter)
- Carry out a scoping study (also with input from external partners) to assess if/how an AUV-based CSEM system can/should be built at MBARI (develop conceptual design (Figure 2), identify existing/new technology required, identify risks, assess demand, estimate resources, consider alternatives)

Year 2 will entail deployment of the SWAN system (or its reconfigured version) in the Canadian Beaufort Sea, as well as the detailed design of an AUV-based CSEM prototype system (or alternative) that can be used with other payloads (in particular multibeam echosounder and sub-bottom profiler).
Year 3 will cover the procurement of prototype components, assembly, and tank/field testing.

Anticipated Shared Resource Needs (year 1)

The team comprises:
Science

- Charlie Paull, Roberto Gwiazda – contribution to survey planning, CSEM data interpretation and synthetic modelling

Engineering

- Alana Sherman (200 hrs) - reconfiguration of SWAN system, scoping study
- Aaron Schnittger (320 hrs) – reconfiguration of SWAN system, scoping study
- Jon Erickson (160 hrs) – adaptation, testing and reconfiguration of SWAN system

- Paul McGill (80 hrs) – scoping study

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- Erik Trauschke (40 hrs) – scoping study
- Eric Fitzgerald (20 hrs) – winch adaptation and deployment; rigging and splicing
- Erich Rienecker (20 hrs) – winch adaptation and deployment

A vessel to test the SWAN system for 4 days. 24 hour operations would be ideal. R/V David Packard or Fulmar are potential options. If not, the R/V Rachel Carson can be used for day trips.

<u>Anticipated Expenses (year 1)</u>

Adaptation of SWAN system and deployment

- $10000 for freight and customs to bring SWAN system to USA from Europe
- $5000 of consumables
- $16800 for rental of Fulmar ($4200/day, if MBARI vessels are not available)

Reconfiguration of SWAN system (if required)

- $30000

Scoping study:

- $5000 for travel/accommodation costs to cover short visit by two external experts

<u>Intellectual Property (IP) Considerations</u>

Unlikely. There might be the need for a cooperative research and development agreement with other organizations if they are involved in the conceptual design.

<u>Data</u>

<1 TB of data, to be hosted on Titan.

<u>Anticipated Impact</u>

Consumers of project outputs include:

i. Scientists: A high resolution CSEM system, especially if combined with other payloads, provides a unique and versatile way to map seepage and flow, and associated seafloor/sub-seafloor changes over time, for a variety of fluids (freshwater, brines, methane, CO_2, hydrogen, helium) at a wide range of depths. Such capabilities are useful to multiple marine scientific disciplines.
ii. Industry: Improved monitoring of leakages from pipelines and geological storage.
iii. Society: Enhanced monitoring of offshore natural hazards and management of resources.

Connections with other organizations:

- University of Hawai'i at Manoa (Amir Haroon)
- Texas A&M University (Mark Everett)
- Scripps Institution of Oceanography (Steven Constable)
- Geological Survey of Canada (Mathieu Duchesne)

<u>Anticipated Outreach Needs</u>

Assistance communicating this work to the general public will be requested when the project has accomplishments to share (social media, infographics, press release).

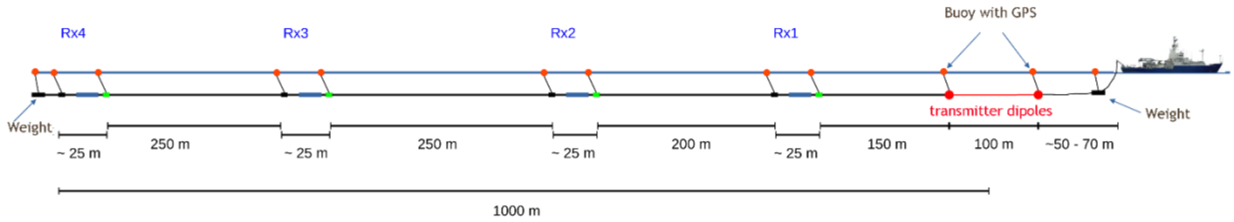

Figure 1: SWAN CSEM system.

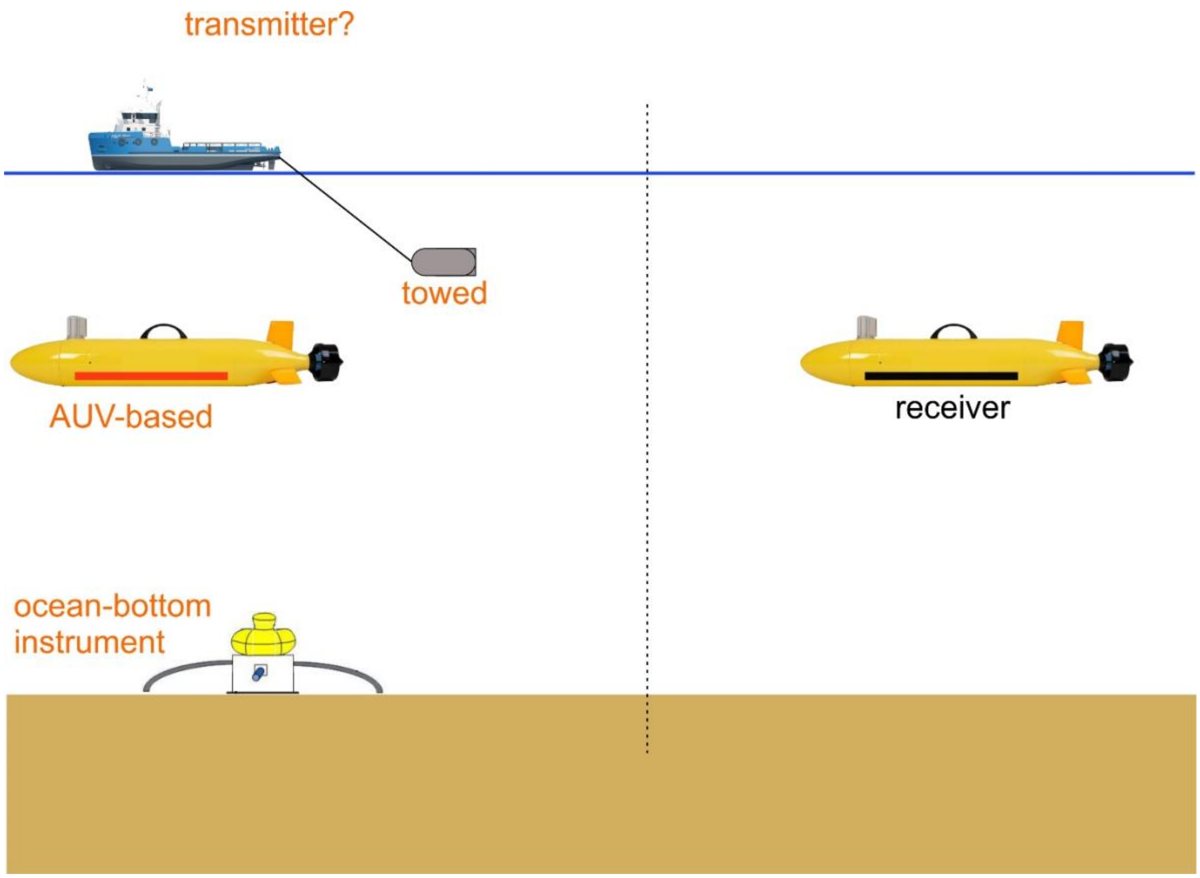

Figure 2: Conceptual designs of options available for an AUV-based CSEM system.