ABSTRACT FORM

Project Title: 902401 Geo-Sense

Expected Project Duration (in years): 1 year

PI	Project Manager	Lead Scientist	Lead Engineer
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Project Overview

The main goal is assess the effectiveness of Distributed Acoustic Sensing (DAS) in monitoring sedimentary flows, and work towards developing a self-sustaining, portable DAS system.

Problem: Sedimentary flows are important geomorphic agents in continental margins. They can transport large volumes of sediment (up to hundreds of km^3) at high velocities (up to 20 m/s) and for long distances (up to 1000 km). In the past decades, we have developed valuable insights on the location, structure and extent of sedimentary flows. However, key questions remain unanswered, particularly with regards to the initiation (timing, trigger) of these flows, their behavior and impacts. Reasons for these knowledge gaps include the logistical, power and data-transfer constraints on long-term monitoring in deep and remote seafloor locations, resulting in low frequency and resolution of measurements at point-locations.

Distributed Acoustic Sensing (DAS) – a technique that measures the phase change in Rayleigh scattered laser light from fiber-optic cables to calculate ground strain at fine spatial resolution (<5 cm) and long lengths (>100 km) – has recently been shown to be a powerful technology to detect seafloor hazards (e.g., earthquakes, ocean currents). DAS has transformative potential in geomorphology because it can characterize fine-scale processes (in terms of location, timing, transformation, erosion and velocities) over multi-kilometer distances, enable long-term time-lapse monitoring, and be deployed in logistically challenging areas. DAS technology has not been deployed to investigate seafloor geomorphic processes thus far. Reasons include: (i) limited availability of submarine cables and access to dark fibers and interrogators, (ii) risk of interference with communication channels when capacity is available, (iii) submarine cables tend to be located away from seafloor processes of interest. As a result, the sensitivity of cable configurations, interrogator units and analytical approach to monitor sedimentary flows remains an unknown.

Research questions: This is a scoping study that will address the following questions:

1. Are the MARS cable and DAS effective at monitoring sedimentary flows in Monterey Canyon?
2. Is a self-sustaining, portable sensing system to monitor active seafloor processes feasible?

Significance:

- Importance: (1) This program opens up the potential of using existing submarine cable networks to monitor sedimentary flows, which are a threat to seafloor infrastructure and play a role in the transport and burial of organic carbon, nutrients and contaminants. (2) It may also provide the flexibility to monitor a wide range of seafloor processes (not just sedimentary flows) that is unprecedented in terms of detail, duration and spatial coverage.

- Timeliness: (1) A DAS interrogator has been installed on MARS since July 2022 and is expected to be operational for at least 5 years. This will overlap with an experiment planned by Charlie Paull in November 2024 – March 2025, which will monitor sedimentary flows in Monterey Canyon using Ocean Bottom Seismometers and moored sensors, providing a unique opportunity to calibrate the DAS data and use MARS to monitor sedimentary flows in the future. (2) There is an increasing demand for new technologies to monitor seafloor processes at fine spatial and temporal scales. (3) The components for distributed sensing have started to become affordable enough to make a stand-alone system economically feasible.
- Uniqueness: (1) This will be the first time that DAS technology has been used to monitor seafloor processes. (2) I am aware of only one attempt to develop a self-sustaining, portable DAS system (Shell, 2013, for pipeline surveillance, leak detection, and in-well monitoring).

Relevance to MBARI: MBARI is uniquely positioned to implement the proposed program: (i) The MARS cable, which MBARI operates and maintains, is already connected to a DAS interrogator (owned by University of California, Berkeley), with data collection planned from July 2022 for at least 5 years. It is located in proximity to Monterey Canyon, where multiple sedimentary flows occur every year. The geometry of the MARS cable provides the azimuthal coverage necessary for triangulation of events. (ii) Program makes good use of engineering expertise in adapting instrumentation for deployment in deep-water settings. (iii) It builds on existing links with Berkeley and Stanford, and with OptaSense. The latter is the manufacturer of the DAS system installed on MARS, and was involved in the development of the portable DAS system for Shell. The program directly aligns with two strategic priorities: (i) Build scalable technologies to improve ocean health assessments, and (ii) Advance ocean-based artificial intelligence.

Internal and external project links:

- Concurrent Seafloor Processes internal proposal (902312, Micallef)
- Concurrent CSEM internal proposal (Micallef)
- Concurrent Continental Margins internal proposal (901023, Paull)

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.
- CSEM (Micallef): CSEM will test, adapt and develop new controlled-source electromagnetic instruments to monitor fluid flow and seepage.

The technology being assessed in this program will be directly relevant to monitor sedimentary flows, and later on fluid flow and seepage, both of which are key themes of the two programs listed above. Data from the Seafloor Processes program will inform the activities to address question 1.

Hierarchy of priorities:

1. Seafloor Processes
2. Geo-Sense

3. CSEM

Nature and Scope of the Proposed Project

Question 1: 1. Are the MARS cable and DAS effective at monitoring sedimentary flows in Monterey Canyon?

Activities:

- Procure and process data acquired by MARS DAS from July 2022 onwards.
- Compare noisy events with in-house and publicly available data on seismic, biological and oceanographic events, including field measurements from Monterey Canyon between November 2024 and March 2025, to isolate sedimentary flows.

Question 2: 2. Is a self-sustaining, portable sensing system to monitor active seafloor processes feasible?

Activities:

- MBARI engineers and DMO personnel, as well as scientific and industry leaders, will be consulted via online and in-person meetings (including a workshop) to:
  - Develop a conceptual design of the prototype (cable, interrogator, power, data storage, event-trigger), deployment/recovery mechanism, and data processing/analyses
  - Identify existing and new technology required to assemble the prototype
  - Identify risks and appropriate mitigation measures
  - Assess demand and opportunities for use of the system
  - Estimate the resources needed to develop the prototype (e.g., equipment, personnel requirements), its deployment/recovery mechanism, and utilization
  - Establish whether the prototype should be developed from 2025 onwards and compile a potential 4 – 5 year work plan.

Preliminary consultation has already taken place with members of the SZ4D initiative, colleagues at Berkeley and Stanford, OptaSense and Sintela.

These activities are part of a scoping exercise that may lead to a larger effort starting in 2025, which would entail development of the sensing system (e.g., procurement of components, prototyping, testing, calibration, etc.).

Anticipated Shared Resource Needs

The team comprises:

Science

- Charlie Paull, Roberto Gwiazda – MARS DAS data analyses and calibration with field data
- John Ryan (16 hrs) – access to and interpretation of MARS hydrophone data

Engineering

- Alana Sherman (100 hrs) - project management
- Denis Klimov (120 hrs) – evaluation of DAS interrogator candidates and event-trigger mechanisms; preliminary system architecture and algorithms
- Paul McGill (80 hrs) - battery power calculations and instrument power reduction strategies, as well as interfacing to MARS
- Rich Henthorn (80 hrs) - contributions to event-triggered response

- Yanwu Zhang (20 hrs) - MARS DAS data analysis and contributions to event-triggered response

DMO

- Knute Brekke (40 hrs) - assistance with ship and ROV logistics, as well as the MARS and current DAS system.

Anticipated Expenses

Workshop at MBARI:

- Room and cleaning fee ($150)
- Catering ($350)
- Travel expenses for external visitors ($9500)

Intellectual Property (IP) Considerations

There might be the need to sign a non-disclosure agreement with an industry partner for MBARI engineers to access information on interrogator and cable components.

Data

150 TB of DAS data over 1 year. These will be stored on Titan.

Anticipated Impact

Consumers of project outputs include:

i. Scientists: Program has a strong potential to promote the widespread application of monitoring approaches for a wide range of seafloor processes at high temporal constraints and across major geographic gaps. This will lead to a step change in our understanding of the initiation and evolution of active seafloor processes, while reducing the number (and associated cost) of crewed vessel trips required.

i. Industry: Transformation of industry's ability to better situate seafloor infrastructure (e.g. cables, pipelines, blue-energy platforms) and monitor (at some point, in real-time) geohazard impacts on these assets, geological storage, and environmental change.

ii. Society: Improvement of early warning systems for offshore natural hazards.

Connections with other organizations:

- University of California, Berkeley (Julien Marty, Brian Pardini)
- Stanford University (George Hilley, Biondo Biondi)
- OptaSense (Andres Chavarria, Steve Cole, Victor Yartsev)
- Sintela (David Hill)

Anticipated Outreach Needs

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

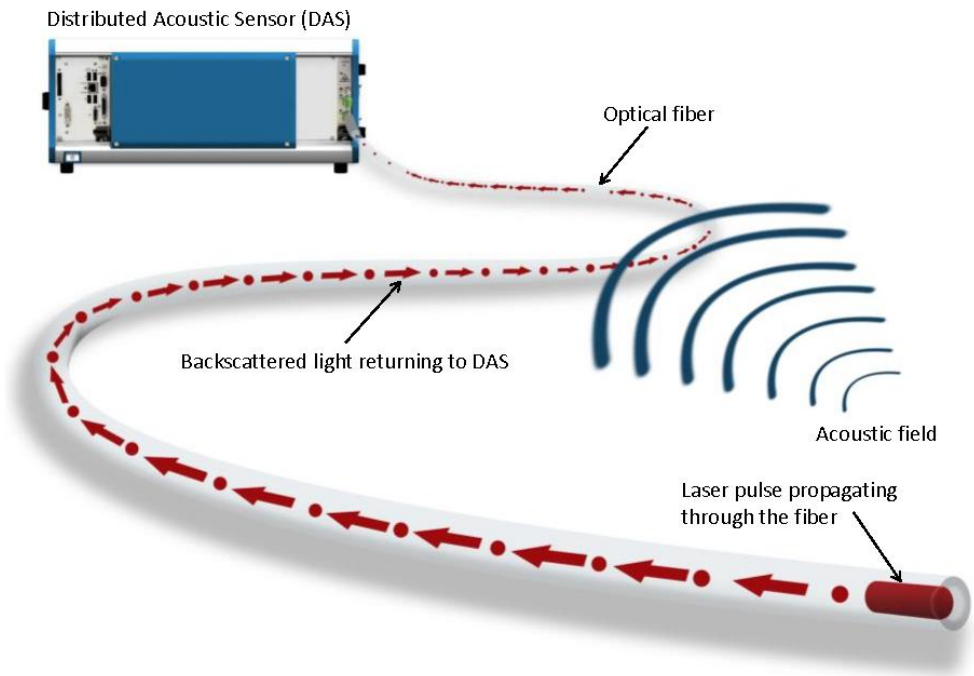

Figure 1: Schematic illustration of DAS infrastructure.
Source: Johannessen, K.A., Drakeley, B.K., Farhadiroushan, M., 2012. Distributed Acoustic Sensing - A New Way of Listening to Your Well/Reservoir.

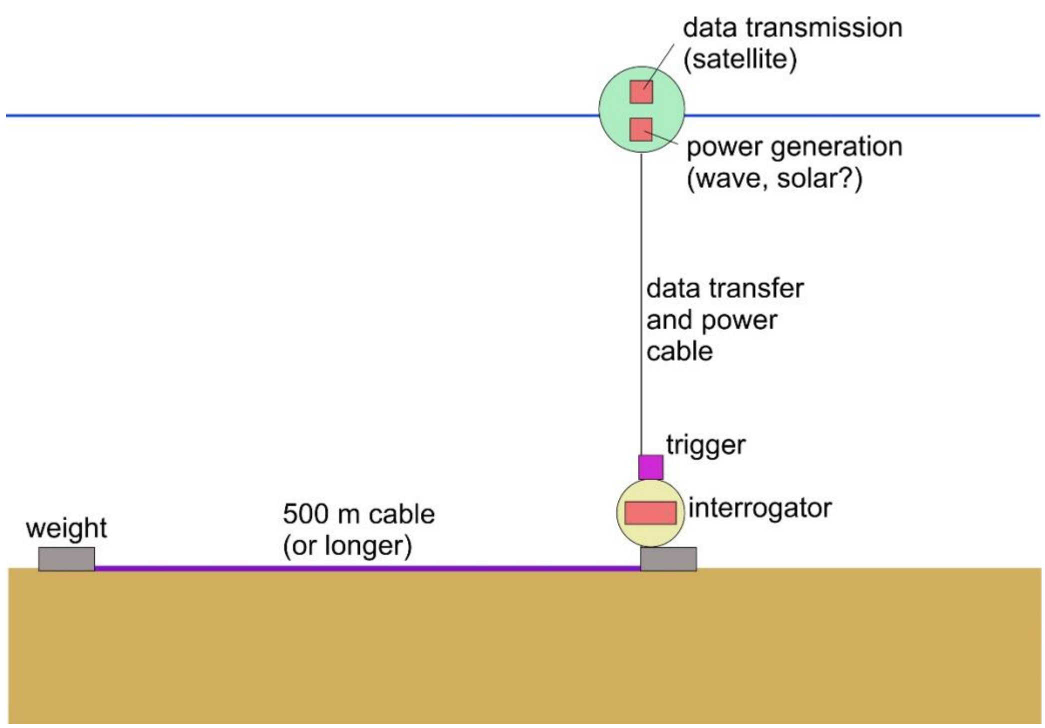

Figure 2: Conceptual design of Geo-Sense that would provide the highest level of autonomy.