# ECE 4335 Senior Design Team 5

# ADDIE Analysis Report

# Underwater Pipeline Survey ROV System

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**Purpose:**

The project's purpose is to develop an underwater vehicle to help maintain, develop and improve underwater pipelines or utilities equipped with Hall-effect sensors to scan and inspect the underwater elements.

**Problem:**

Refineries, chemical process plants, oil companies, and some utility companies depend on underwater infrastructure to operate their business. One of the biggest challenges within the industry is detecting faults in the underwater infrastructure. This includes poor visibility and dangerous conditions for divers. This technology will allow companies to better maintain the infrastructure to avoid breakages, leaks and ultimately damage and the costs associated. In short, subsea pipelines often transport oil, gas, and other essential resources which are subject to corrosion, structural fatigue and damage. Failures in these critical systems can cause environmental disasters, financial losses, and service disruptions. The project addresses the need for efficiently and accurately detecting defects in pipelines thus mitigating the potential downtime caused by failures.

By developing a fish-like ROV we aim to provide a more agile and autonomous solution to pipeline inspection. The technology enables continuous and real-time monitoring of pipelines therefore reducing maintenance costs and mitigating the risk of catastrophic failures. By utilizing hall-effect sensors we avoid the issues associated with camera-based ROV monitoring products already present. Furthermore, a fish-like design means that fins will be used for propulsion rather than a propeller meaning areas with heavy vegetation would be more easily navigable. This design also reduces the environmental impact of operating a swarm of pipeline monitoring ROVs.

Natural gas pipelines need to be inspected every three to twelve months based on the Federal Right of Way Maintenance Requirements for Pipelines. Pipelines that transport hazardous fluids require inspection every three weeks, but no less than twenty-six times per year. Although this may not seem too frequent for the average person, there are more than twenty thousand miles worth of pipeline underwater in the world. Large portions of that belong to massive companies which means costs add up. It can cost from ten thousand to one-hundred thousand dollars per ROV which is much more cost effective than some of its counterparts. Furthermore, preemptively dealing with underwater infrastructure issues will save companies large sums of money, prevent potential catastrophes, and in the long-term help keep the environment healthier.

**Need:**

The need for this product stems from the growing demand for reliable, efficient, and non-invasive methods to inspect and maintain pipelines and other infrastructure. Current methods such as human divers or tethered ROVs are often time consuming and limited in their operation. This fish-like ROV equipped with hall-effect sensors addresses these challenges by providing an autonomous and agile solution to detect and report back defects even in low-visibility environments. Since the product mimics a fish, it can be deployed in swarms to cover large areas of a pipeline.

**Objective**:

The objective of this project is to deliver a fully functional autonomous fish-like underwater ROV capable of detecting potential underwater pipe leakages. The ROV’s capabilities will allow it to autonomously swim through varying underwater environments while leveraging its fish-like design to navigate underwater obstacles, mitigating entanglements from underwater plant life found with common propeller ROVs. Given the ROV’s autonomous design, its system will provide it with the ability to patrol large areas without human intervention yet offering a manual override control when needed. While technical background is suggested, the ROV will feature a user-friendly design and interface, ensuring seamless deployment and retrieval. Via the ROVs hall sensors, the ROV will detect leaks in underwater pipes by sensing disruptions in the magnetic fields. The ROV will collect data on pipeline conditions, GPS leakage location, and transmit real-time feedback to operators on shore, ensuring immediate awareness of issues.

A machine on a table

Description automatically generated

Figure 1. Current UH Prototype

**User Analysis:**

The primary user of this fish-like ROV will likely be companies involved in subsea pipeline maintenance or production such as oil and gas companies or offshore energy providers. These users require a reliable and efficient solution for inspecting and maintaining their infrastructure. The users will require a moderate level of technical experience to operate the ROV. Most users of this ROV will have a background in engineering or technical operations. No specialized programming skills will be required to operate the ROV. The system will have an intuitive interface and software that automates functions such as navigation and data collection.

**Further Consideration**

This project has several important implications beyond its primary function of pipeline inspection, for instance environmental protection. By using a fish-like ROV with fin-based propulsion, the design minimizes disturbance to marine life and underwater ecosystems compared to traditional propeller-driven ROVs. This reduces both noise and physical disruption, making the system eco-friendlier.

Public safety is another key consideration. By providing real-time data on pipeline conditions, the ROV helps prevent catastrophic failures that could result in oil spills or other environmental hazards. Early detection of pipeline defects ensures that companies can address issues before they become larger problems, safeguarding both the environment and human communities reliant on the resources transported by these pipelines.

Cost-effectiveness is also central to the design. Autonomous operation reduces the need for expensive manual inspections, while the ROV’s scalability allows for large areas to be surveyed efficiently. This makes the system a viable solution for companies of varying sizes, particularly those managing extensive pipeline networks.

Finally, the project aligns with regulatory requirements, ensuring that companies can meet mandatory inspection intervals without disrupting operations. The technology’s autonomous nature allows for frequent, cost-effective inspections, helping companies avoid penalties and minimize risks associated with non-compliance.

**Background Information and Research:**

A fish-shaped flexible design offers several advantages over traditional remotely operated vehicles (ROVs) for oil and gas pipe maintenance. The biomimetic form and flexible movement allow the fish to navigate through complex and confined spaces more effectively, such as narrow bends and intricate networks found in subsea pipelines. Additionally, the natura movements of the fish-shaped design minimize disturbances to the surrounding environments. In addition to pipeline inspection, the fish design can be modified for closeup exploration of underwater life. Current robotic prototypes are unnatural and disrupt the natural life around them, which makes it difficult to study animals’ behaviors, swimming patterns, and interactions within their habitats. In addition to these unresolved issues in both the oil and gas industry and ocean conservation, ROVs are usually tethered. Tethered ROVs can get tangled in seaweed, coral, aquatic life, and boats. This creates a hazard for both the underwater ecosystem and the technology.

The proposed design will be a lifelike fish shaped ROV which is untethered and can work autonomously as well as remote controlled. There is one prototype which is the MIT based design called SoFi. SoFi can navigate underwater, collect data, and create robotic swarms; but it has difficulty overcoming ocean currents, has limited depth, short battery life, short remote-control range, poor acoustic modem design, and low visibility. While it will be very difficult to improve upon all of these, we will focus most of our efforts on improving navigation in low visibility environments and redirecting the project towards pipeline inspection instead of ocean conservation. We intend to make these changes by installing hall effect sensors in the hull or on the fins which will help guide the fish using electromagnetism instead of cameras. This will allow the ROV to navigate as long as there is a metal pipe for it to follow. Ideally the fish will be able to record GPS locations of faults and relay back to the base so that it can be further inspected or repaired.



Figure 2. MIT SoFi Prototype

A model of a robot

Description automatically generated

Figure 3. Hall Sensor Placement Proposal

**Resources:**

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