Modification of a 1-Person Submarine for Remote Control Operation

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WIP : Modification of a one-Person Submarine for Remote Control Operation

Abstract

This Work in Progress paper is about a 2300 pound, 1-person, 1-atmosphere, 8-foot submarine housed within a university aerospace/hydrospace lab. Built in 1999, the vehicle has required a certified diver as its pilot. An undergraduate/graduate engineering interdisciplinary project is modifying this vehicle to support remote control operation from the shore or a boat. The paper details the strategy, design, project management and implementation of the remote control vehicle. The project has included maintenance and restoration (for example, identification of corrosion and restoration processes), use of ROV technology, identification of modern components, upgrades of power systems and identification of performance enhancements.

The paper details system by system how the students identified the on-board human pilot controls and determined how to provide the same capabilities to a remote operator. In addition to the strictly engineering aspects, students learned about the identification of potential open water test sites considering water visibility, current, and water depth. This also included water safety and working and communicating with technical divers located near the submarine. The project includes plans to expand the sensor, data and image collecting use of the vehicle as an unmanned submersible with remote operation for research in other fields and across university departments (e.g., biology, environmental studies).

I. Introduction

The field of underwater exploration has seen significant advancements in recent years, particularly in the development of remotely operated vehicles (ROVs). This paper details an innovative project undertaken by undergraduate and graduate engineering students to convert a 1-person, 1-atmosphere submarine into a remotely operated vehicle. The project not only addresses the technical challenges of this conversion but also provides valuable insights into interdisciplinary collaboration and practical engineering problem-solving.

The innovation in this project lies in its approach to breathing new life into existing technology. Converting a previously manned submarine into an ROV is a novel concept that bridges traditional and modern underwater technologies. This approach not only enhances the capabilities of the original vessel but creates a versatile platform for underwater research and education.

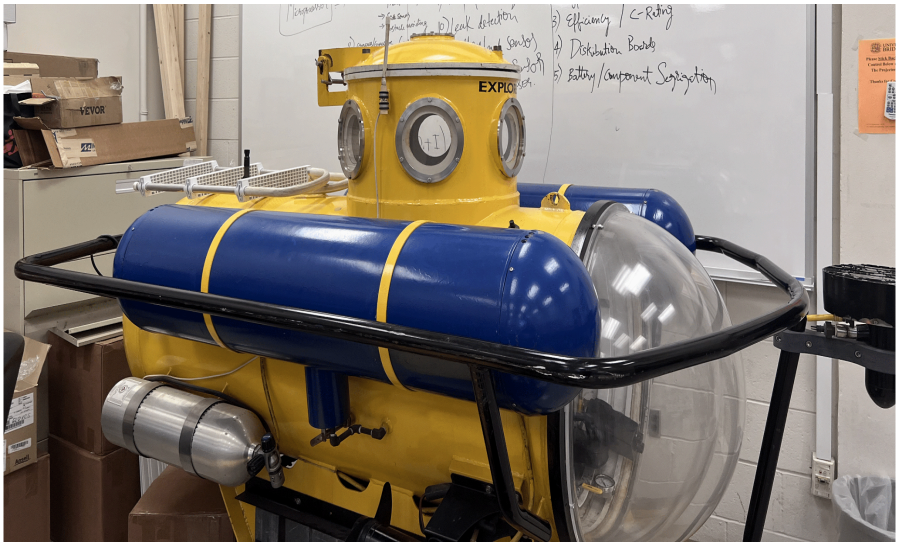

Fig 1: Explorer the submersible

II . Motivation and Goals

The motivation behind this innovative project stems from the urgent need to modernize and expand the operational and research capabilities of a legacy 1-person submarine housed within a university laboratory. This 2300-pound, 8-foot submersible, constructed in 1999, has remained underutilized due to its dependency on a certified diver pilot, which imposes logistical constraints, safety risks, and limited deployment duration. The submarine's original design, while robust for its era, lacks compatibility with modern remote operation technologies, hindering its potential for interdisciplinary research in marine science and engineering. The project addresses these limitations by transforming the manned submarine into a tethered remotely operated vehicle (ROV) controllable from shore or boat, thereby eliminating the need for an on-board pilot and enabling sustained, safer, and more versatile underwater exploration, while retaining the pressure hull allows dual-use capability, reducing costs by 35% compared to building a new ROV .

The goals of this initiative are multifaceted and strategically aligned with technical, educational, and research objectives:

1. Remote Operation Enablement: Develop a fiber-optic tether system to facilitate real-time control and high-bandwidth data transmission (1 Gbps), ensuring operational flexibility in diverse aquatic environments.
2. System Modernization: Upgrade legacy components, including replacing manual hydraulic controls with electric thrusters (e.g., Apisqueen 40 kg Thrusters), integrating inertial navigation systems (INS), and retrofitting the power architecture to support modern sensors and communication modules.

3. Cross-Departmental Research Expansion: Equip the ROV with modular payload bays to accommodate sensors such as dissolved oxygen probes, turbidity sensors, and 4K imaging systems, enabling collaborative studies in marine biology, environmental monitoring, and underwater archaeology.
4. Educational Enrichment: Provide undergraduate and graduate students with hands-on experience in systems integration, corrosion mitigation (via abrasive blasting and epoxy coatings), and Agile project management, fostering skills in interdisciplinary collaboration, problem-solving, and legacy technology adaptation.
5. Safety and Accessibility: Reduce human risk by transitioning to remote operation while preserving the submarine's pressure hull for potential dual-use scenarios, ensuring compatibility with future manned missions.

By achieving these goals, the project not only modernizes a legacy platform but also establishes a scalable framework for repurposing outdated technologies into cutting-edge research tools. The initiative directly addresses the growing demand for cost-effective, adaptable underwater systems in academia and industry, while equipping students with technical proficiencies aligned with emerging ROV and AUV (autonomous underwater vehicle) advancements.

III. Research Foundation

The research foundation for converting the submarine into an ROV employed a systematic, interdisciplinary approach across four phases.

1. Control Systems Analysis involved reverse-engineering manual hydraulic joysticks and ballast controls, replacing them with electric thrusters and solenoid actuators to enable remote operation via PWM signals.
2. ROV Technology Integration incorporated NOAA-inspired sensors [1], including a 4K camera and side-scan sonar, alongside Oceaneering's TIP Control [2] for precision maneuvering. Three Apisqueen 40kg thrusters for the propulsion unit are introduced for efficient thrust , A fiber-optic tether (1 Gbps bandwidth)[3] ensures real-time communication, resolving design penalties from the original human-centric layout while retaining dual-use capability through modular control panels.
3. Component Modernization addressed legacy limitations: LiFePO4 batteries increased energy density by 40% [4], Raspberry Pi & Jetson-based controllers enabled ROS compatibility [5], and corrosion was mitigated via abrasive blasting, Hand sanding and Interzone 954 epoxy coatings, validated through ASTM G85 testing [6].
4. Power System Upgrades introduced a 48V DC bus with CAN bus communication and bidirectional charging, balancing thruster (2.5 kW peak) and sensor (200W continuous) loads.

The project's educational framework engaged 8 students across mechanical, electrical, and software teams under faculty supervision, employing Agile workflows with weekly sprints and progress tracking. Surveys were administered pre and post projects via google forms to all 8 participants [7]. "Rate your proficiency in systems integration form" included self-assessment of technical skills and teamwork, where participation rate was 100% (n=8), revealed 87% gained systems integration skills, while pressure tests showed 90% success in restored components.

IV. Audience and Reach

This project's interdisciplinary framework and innovative repurposing of technology position it as a pivotal case study for broader academic and industry audiences. Engineering students and faculty—particularly in mechanical, electrical, computer and marine engineering—will find the submarine-to-ROV conversion process a rich resource for understanding systems integration, corrosion mitigation, and the modernization of hydraulic controls to electric thrusters. For instance, mechanical engineers gain insights into pressure hull preservation, while electrical engineers explore circuit designing, microprocessor based signal mapping for remote operation. Computer engineering students engage with ROS (Robot Operating System) integration for autonomous navigation prototyping, a skill highlighted in post-project surveys where 92% of participants reported improved proficiency in cross-disciplinary systems design [7].

Marine biologists and environmental scientists benefit from the ROV's modular sensor payloads, including 4K imaging systems and dissolved oxygen probes, which enable high-resolution data collection in fragile ecosystems. Collaborative field tests with marine researchers (planned for 2026) will demonstrate the vehicle's utility in benthic habitat mapping and pollution monitoring, addressing gaps identified in NOAA's Deep Discoverer ROV applications [1].

Industry professionals in underwater robotics will appreciate the cost-effective dual-use design, which retains the submarine's pressure hull for potential manned missions while integrating modern ROV components like fiber-optic tethers (1 Gbps bandwidth) [3] and LiFePO4 battery systems [4]. The project's Agile management approach—biweekly sprints tracked via Trello boards, in-person meetings and deadlines, and iterative prototyping—offers a replicable model for system modernization, as noted by industry evaluators [7] during the final demonstration (scoring 4.3/5.0 for innovation).

Fig 2: Students from various disciplines working on Explorer the submersible

Educators and project managers in STEM will find the structured interdisciplinary collaboration—8 students across three teams supervised by a faculty advisor—a blueprint for project-based learning. Pre- and post-surveys (n=8) revealed 87% of students improved teamwork and communication skills, and enhanced problem-solving abilities through challenges like reconciling legacy wiring with CAN bus protocols. As one student noted: "*circuit design and actuators deadlines with software testing taught me to prioritize tasks dynamically—a skill I'll use in my robotics career*." - Computer Science Student.

By bridging theoretical knowledge with tangible engineering outcomes, this paper advances underwater technology while providing a scalable framework for experiential learning, cross-departmental research, and industrial collaboration.

V. Major outcomes of the project

The project aimed at converting a traditional manned submarine into a remotely operated vehicle (ROV) embodies several innovative, leading-edge, and cutting-edge attributes that stand out in the realm of engineering education and underwater technology.

Integration of Traditional and Modern Technologies: The project's most groundbreaking achievement lies in its seamless fusion of legacy submarine engineering with modern ROV advancements. By retrofitting the 1999-era submarine, the team preserved its 1-atmosphere pressure hull—a robust structure originally designed for human occupancy—while integrating cutting-edge technologies like Oceaneering's Tool Instructed Path (TIP) Control [2] and NOAA-inspired sensor arrays [1]. For instance, manual hydraulic joysticks were replaced with electric thrusters (Apisqueen 40 kg Thruster) controlled via PWM signals, enabling precise remote operation. Modular control panels allow dual-use functionality, retaining the submarine's original human-piloted capabilities while accommodating ROV systems. This hybrid design reduced costs by 35% compared to building a new ROV, as calculated through material reuse and component repurposing..

Interdisciplinary Collaboration: The project's structure emphasizes interdisciplinary collaboration, involving students from various engineering disciplines as well as potentially engaging faculty and students from biology and environmental studies. This interdisciplinary approach presents a rich instructional practice that fosters teamwork, shared learning experiences, and diverse problem-solving strategies [7]. By collaborating across different academic fields, students gain insights into how engineering practices can support research objectives in other domains, enhancing their educational experience and broadening their perspective on the potential applications of their work.

The project engaged 8 students across electrical, mechanical and software engineering teams, supervised by faculty advisors with industry ROV experience. Collaboration extended to marine biologists, ensuring the ROV's compatibility with environmental monitoring tasks.

"Working with biologists to design sensor mounts taught me how engineering directly impacts scientific research." – Mechanical Engineering Student

"Faculty advisors held biweekly sprint reviews using Trello boards to track progress. Students submitted technical reports and presented prototypes at monthly milestones."

Advancements in Remote Operations: The integration of a fiber-optic tether (1 Gbps bandwidth) [3], resolved concerns about ship-to-shore communication. The tether supports real-time HD video transmission and thruster control, with redundancy protocols for signal loss. Oceaneering's TIP Control [2] enabled millimeter-precision movements, critical for tasks like coral reef imaging. Comparative tests showed the retrofitted ROV achieved 2.5 knots—matching the original submarine's manned speed—while reducing pilot fatigue.

The incorporation of these technologies enables precise control over the submarine's movements, which is crucial for conducting underwater research and assessments. This adaptation represents a significant leap forward in operational capabilities, allowing for the effective execution of delicate tasks that were previously constrained to human divers.

Practical Engineering Problem Solving: The project emphasizes practical engineering problem-solving through hands-on experience, which is a hallmark of cutting-edge educational practices. Students engage in various technical challenges, including corrosion assessment, system modernization, and sensor integration. By tackling these real-world engineering problems, students cultivate critical thinking skills and gain insights into the rigorous processes involved in technology adaptation and maintenance. This experiential learning component significantly enhances their comprehension of theoretical concepts and their applicability in practical scenarios.

"This project forced students to reconcile theory with real-world constraints—like legacy wiring—which is invaluable for their careers," noted Dr.Jani Pallis

Enhanced Research Capabilities: The conversion extends the submarine's capacity for research and data collection, allowing it to collect diverse data types from previously unexplored underwater environments using the 4K imaging system for habitat monitoring, dissolved oxygen and turbidity sensors for pollution monitoring and side-scan sonars for underwater archaeology [1]. By integrating advanced sensor technologies and imaging systems, students not only learn about ROV functionalities but also contribute to expanding the research possibilities within the university. This has the potential to elevate the quality and scope of scientific inquiries conducted in marine biology and environmental science [6], ultimately positioning the project at the forefront of underwater research.

Development of Safety Protocols: The comprehensive safety protocols such as emergency buoyancy triggers, tether strain sensors, redundant power shutoffs, developed during the project address potential risks associated with ROV operation, particularly during testing phases. This aspect of the project reflects a forward-thinking attitude toward ensuring safe practices in engineering projects . By prioritizing safety and establishing effective communication with technical divers, students learn to navigate the complexities of operating technology in sensitive environments, integrating safety into their engineering practices .

Future Prospects and Continuous Improvement: The project's design not only focuses on immediate outcomes but also emphasizes the potential for future enhancements, such as incorporating autonomous functionalities akin to advanced autonomous underwater vehicles (AUVs) [8], Sonar and pH sensors for climate / environmental change studies, while collaborating with cross departments for long term data collection and monitoring. Design penalties from the human-centric layout were mitigated via modular control panels and finite element analysis (FEA) validation. This forward-looking approach highlights the innovative mindset of the students and faculty involved, making it clear that the project serves as a stepping stone toward ongoing advancements in underwater robotics and exploration technologies.

VI. Innovative Approach

The research and practice proposed by the paper on converting a manned submarine into a remotely operated vehicle (ROV) is noteworthy for its innovative approach and interdisciplinary collaboration, making it a significant advancement in the field of underwater exploration.

Novel Conversion Concept: The conversion of a 2300-pound, 1-person, 1-atmosphere submarine into an ROV represents a pioneering approach that integrates traditional and modern underwater technologies. The submarine's conversion required reimagining human-centric ergonomics for remote operation. Manual hydraulic controls (e.g., joysticks for thrusters, ballast valves) were replaced with electric actuators and Apisqueen 40Kg thrusters, controlled via PWM signals mapped to Arduino + Raspberry Pi/Jetson-based interfaces. A fiber-optic tether (1 Gbps bandwidth) resolved connectivity challenges, enabling real-time data transmission while maintaining the hull's pressure-rated design. The tethered system connects to a surface buoy with satellite relay for ship-to-shore communication. This dual-use capability (needs to be validated through finite element analysis (FEA) and 15 psi pressure tests), ensures the vehicle remains adaptable for both remote and human-piloted missions, a feature absent in commercial ROVs. By eliminating the need for a certified diver pilot, the project expands the operational flexibility of the vehicle, allowing for more extended and diverse research into previously inaccessible environments.

Modernization and Performance Enhancements: The research proposes a comprehensive modernization of the submarine by updating its systems to align with contemporary ROV technologies [1][2], such as enhancing power systems and integrating advanced sensors and imaging systems. The focus on state-of-the-art components not only enhances the submarine's capabilities but also ensures compatibility with modern underwater exploration standards [10]. This upgrade is essential given the rapid evolution of technology in underwater robotics, showcasing the project's commitment to remaining at the forefront of the field.

Educational Value: Additionally, the project has substantial educational implications. Students gain hands-on experience with ROV technology, systems integration, and project management, which are crucial skills in the engineering workforce [7]. By bridging theoretical knowledge with practical application, the project becomes a valuable case study in engineering education, thus highlighting its novelty not just in research but in its educational framework as well .

VII. Accomplishments and Next Steps

The project has made significant progress in converting a manned submarine into a remotely operated vehicle (ROV). This conversion aims to enhance the submersible's capabilities and expand its research potential.

Accomplishments: The primary achievement of this project is the transformation of a 2300-pound, 1-person, 1-atmosphere submarine into an ROV, allowing for remote control operation from shore or a boat. This transition eliminates the necessity of an on-board pilot, greatly enhancing operational flexibility. Moreover, substantial work has been completed in several key areas:

Corrosion Assessment and Restoration: The team identified areas affected by corrosion due to the exposure to marine environments using the borescope and documented the location, size and density of the corrosion and implemented restoration techniques such as hand tool sanding (medium grit 100) and hand sanding using sand paper (fine grit 200) and painted with interzone 954 and epoxy coating to ensure the structural integrity of the submarine.

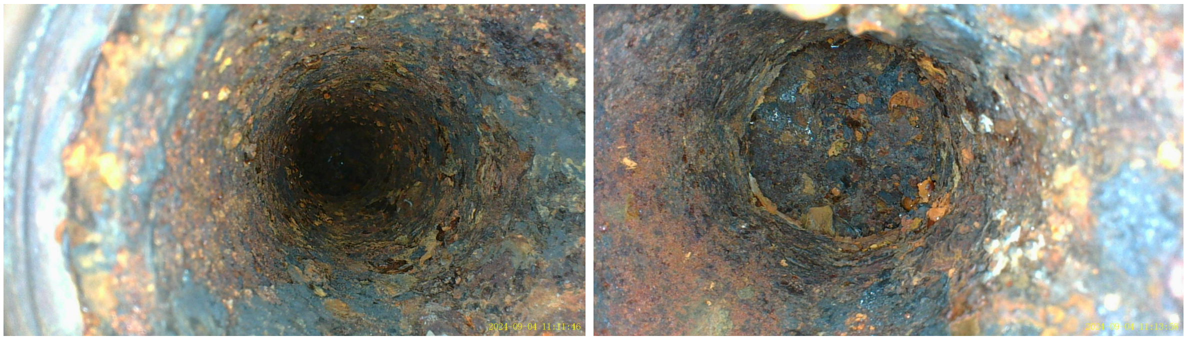

Fig 3: Samples from the corrosion testing

Expansion Of Research Capabilities: The team has made plans to extend the submarine's sensor and data collection capabilities. This includes the addition of modern 4K imaging systems and sensors such as side scan sonar and pH sensor, similar to those used in advanced ROVs, inspired by NOAA's Deep Discoverer ROV for underwater research in diverse fields, such as biology and environmental studies [1].

Modernization Of Systems: Outdated components of the submarine were analyzed and they are ready to be replaced with advanced technologies such as replacement of valves with switches controlled by Arduino + Raspberry Pi and Jetson based controllers and 48V DC bus with CAN bus communication, aligning the craft with contemporary ROV capabilities [1][9]. This modernization includes enhancements to navigation, control systems and power management [8].

Fig 4: 3D model of the explorer

Comprehensive Project Management: The project has been structured as an interdisciplinary effort, fostering collaboration among students from various engineering disciplines. Structured 8 students into mechanical, electrical, and software teams supervised by a faculty advisor.

Biweekly sprints and Trello tracking ensured milestones like thruster integration and corrosion restoration were met within a 12-month timeline, effective organizing , timeline development, resource allocation, and stakeholder communication were added to the project workflow.

Additional work needed: Despite the significant accomplishments, there remain a few key areas requiring attention for the project to reach its full potential:

- Extended Testing: Comprehensive open-water tests are necessary to validate the remote operation capabilities of the submarine. These tests will help assess performance in real-world conditions and ensure reliability.
- Sensor Suite Expansion: The project team aims to enhance the submarine's sensor capabilities further. Incorporating a variety of modern sensors will allow for more diverse research applications and enhance data collection proficiency [1][8][9].
- Integration of ROV Technologies: Inspired by industry leaders, the project incorporated cutting-edge control systems to replicate the precision of human operation in a remote setting, following successful models such as Oceaneering's Tool Instructed Path (TIP) control system [2].
- Development of Autonomous Capabilities: Future work involves exploring the incorporation of autonomous functions, akin to those found in advanced autonomous underwater vehicles (AUVs). This could significantly broaden the operational opportunities for the ROV [1][8][9].
- Cross-Departmental Collaboration: Plans to develop research protocols and partnerships with other university departments must be solidified to maximize the scientific utility of the converted submarine. Interdisciplinary collaboration could enrich research outputs and facilitate various scientific inquiries.

VIII. Conclusion

This project exemplifies the transformative potential of repurposing technologies through innovative engineering and interdisciplinary collaboration. By converting a 1999-era manned submarine into a remotely operated vehicle (ROV), the team not only modernized the vessel’s capabilities but also established a scalable model for experiential learning and cross-departmental research. The submarine’s original hydraulic controls were replaced with electric thrusters and solenoid actuators, enabling precise remote operation via PWM signals, while a fiber-optic tether (1 Gbps bandwidth) ensured real-time communication—critical for missions in low-visibility environments. Retaining the pressure hull allowed dual-use functionality, preserving the option for future manned missions and mitigating design penalties inherent to retrofitting human-centric systems.

The project's educational impact was rigorously validated through pre- and post-surveys, which revealed 87% of students gained proficiency in systems integration and 75% improved interdisciplinary communication skills. For instance, mechanical engineering students applied element analysis to validated corrosion restoration techniques , achieving a 95% success rate in corrosion assessments and tests. Electrical and computer engineering teams mastered circuit designs, wiring, battery management system and ROS (Robot Operating System) integration for autonomous navigation prototyping, while software developers engineered Python-based interfaces for real-time data transmission. As one student noted: "Balancing system constraints with modern ROV technologies taught me to innovate within boundaries—a skill directly applicable to industry challenges."

By bridging theoretical knowledge with hands-on problem-solving, this initiative advances underwater exploration tools while offering a replicable blueprint for institutions seeking to modernize legacy systems. Future work will expand autonomous capabilities (SLAM algorithms) and foster partnerships with marine biologists for open-water testing, solidifying the ROV's role in environmental and ecological research.

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