



Design and Fabrication of a Low-Cost Underwater Exploration ROV for Inspection

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I. INTRODUCTION

Underwater inspection is useful for observing submerged surfaces, equipment, tanks, and other locations that may be difficult or inconvenient to inspect directly. A remotely operated vehicle allows the operator to remain outside the water while the vehicle carries a camera into the inspection environment. Inspection-class ROVs have been studied as practical tools for visual observation and other underwater tasks, while reviews of ROV design emphasize the importance of matching propulsion, control, sensing, and vehicle configuration to the intended mission [1].

The present work addresses a deliberately smaller problem: the design and fabrication of a simple, low-cost, manually operated, tethered ROV for basic underwater exploration and visual inspection. The ROV is not intended to reproduce the sensing, navigation, or maneuverability of industrial ROVs. Instead, it concentrates on a small set of functions that can be implemented with readily available components: horizontal propulsion, wired operator control, and live front-camera monitoring.

The final ROV uses two identical horizontal brushed DC underwater thrusters. The control system consists of an Arduino Uno, an L293D H-bridge motor-driver stage, and two joystick modules, with each joystick assigned to one thruster. A 12 V, 3000 mAh IKO1230 battery supplies the system through a rocker switch. The vehicle is connected to the operator by a 15-ft (approximately 4.57 m) tether carrying power, control, and camera/video

Abstract—This paper presents the design and fabrication of a low-cost, manually operated, tethered remotely operated vehicle (ROV) for basic underwater exploration and visual inspection. The ROV is intentionally limited to a simple propulsion and control architecture rather than advanced autonomous functions. It uses two identical horizontal brushed DC underwater thrusters, an Arduino Uno controller, an L293D H-bridge motor-driver stage, two joystick modules, a 12 V 3000 mAh battery, a transparent ABS JB2 junction enclosure, and a front-mounted waterproof automotive/rear-view type camera. Each joystick independently controls one thruster, providing confirmed forward and reverse operation. A 15-ft wired tether carries power, control, and camera/video connections to the surface, where a USB capture card and laptop provide live visual monitoring. The enclosure is specified by its manufacturer as IP65/IP67; this rating is treated only as an enclosure specification and not as certification of the complete fabricated ROV. The recorded ROV cost is approximately ₹12,330. The paper discusses the mechanical arrangement, propulsion concept, electrical architecture, buoyancy principles, camera-based inspection workflow, motor-driver limitation, fabrication, and confirmed ROV observations. No unmeasured vehicle speed, thrust, operating depth, runtime, leakage duration, or camera-performance values are presented. The resulting platform is intended as a simple and accessible basis for water-tank inspection, underwater exploration, educational robotics, and small-scale observation, with more advanced sensing and control reserved for future work.



connections. A front-mounted waterproof automotive/rear-view type camera provides the visual feed through a USB capture card to a laptop. The main contribution of this work is therefore the integration and fabrication of a practical low-cost ROV architecture rather than a new propulsion or control theory. The paper documents the actual ROV, identifies engineering constraints that arise from the selected components, and separates confirmed observations from theoretical considerations and future improvements.

II. RELATED WORK AND EVALUATION CONTEXT

ROV development has a long history ranging from inspection-class systems to research platforms with advanced navigation and manipulation. Capocci et al. reviewed inspection-class ROVs and described the role of these systems in underwater observation and intervention [1]. He et al. reviewed ROV configurations and control models, emphasizing that vehicle design and control depend strongly on the intended motion and application [2]. Aguirre-Castro et al. reported an ROV developed specifically for underwater exploration and real-time video, demonstrating the feasibility of compact student/research platforms for underwater observation [3].

Low-cost underwater robotics has also been investigated for visual inspection. Manjunatha et al. presented a low-cost underwater robot for external pipeline-surface inspection and considered buoyancy, stability, and propeller configuration during development [4]. This is relevant to the present work because the project similarly prioritizes a practical inspection function while keeping the hardware architecture simple. Carreras et al. described a visual underwater inspection system in which an underwater robot acquires images close to an inspection surface, illustrating the value of real-time visual feedback in inspection tasks [5].

More recent work demonstrates how low-cost ROV platforms can be extended with localization and dynamic positioning. Bartlett et al. presented a low-cost dynamic-positioning system for an ROV using additional underwater sensing [6]. Such systems show the direction of advanced ROV development, but the present ROV intentionally does not include depth, inertial, acoustic, or position sensors. Satoh et al. further demonstrated the practical use of a mini-ROV in underwater ecological surveying, showing

that small ROVs can support specialized observation tasks when the platform is matched to the mission [7].

The literature therefore supports the general engineering premise of using tethered underwater robots for remote observation, while also showing the large gap between a simple manually controlled platform and advanced inspection systems. The present project occupies the low-cost, manually operated end of that spectrum and focuses on fabrication, basic propulsion, operator control, and visual monitoring.

TABLE-I
SELECTED LITERATURE RELEVANT TO THE PRESENT ROV

Ref.	Publication focus	Relevance to present work
[1]	Inspection-class ROV review	ROV architecture and inspection applications
[2]	ROV designs and control models	Design/control trade-offs
[3]	ROV for underwater exploration	Compact video-based exploration
[4]	Low-cost underwater pipeline inspection robot	Low-cost propulsion and inspection
[5]	Visual underwater inspection using robotics	Camera-based inspection
[6]	Low-cost ROV dynamic positioning	Advanced future-control direction
[7]	Mini-ROV for underwater survey	Practical small-ROV application

III. ROV SYSTEM UNDER EVALUATION

The design was developed around the requirement for a compact and simple vehicle that can be manually controlled from the surface. The architecture is centered on a transparent ABS enclosure that contains the main electronics and battery, while two horizontal thrusters provide propulsion. The camera is mounted at the front of

the vehicle so that the operator can observe the underwater environment during movement.

A. Mechanical Structure

The central enclosure is a transparent ABS junction box, model JB2, with stated dimensions of $220 \times 190 \times 100$ mm and an enclosure-only weight of 680 g. It has a transparent cover and an internal mounting plate. The manufacturer specifies an IP65/IP67 protection rating for the enclosure. This rating is reported here only as a product specification; it is not treated as certification of the complete fabricated ROV because the assembled vehicle contains modified openings, cable connections, external mounts, and ROV sealing.



Fig. 1. Internal system arrangement showing the ABS enclosure, battery, Arduino Uno, L293D circuit, and wiring.

The external structure is a lightweight plastic/polymer frame supporting the enclosure and the two horizontal thrusters. The available project information does not establish the exact polymer type, overall vehicle dimensions, or complete

assembled mass, so those quantities are not stated as measured specifications in this paper.

Hot glue is used around relevant cable/opening areas as a ROV sealing method.

B. Propulsion System

Propulsion is provided by two identical brushed DC underwater thrusters mounted horizontally. The supplied component information specifies a 12–16 V operating range, a stated current specification of up to 5 A, a 10–60 W power range, approximately 5000 rpm, and a 35 mm propeller. Each thruster is

listed at approximately 130 g. The experimental system uses the two thrusters only for horizontal propulsion.

Two joystick modules provide operator inputs. Joystick 1 is assigned to Thruster 1 and Joystick 2 to Thruster 2. The control path is joystick input → Arduino Uno → L293D H-bridge → corresponding thruster. Forward and reverse operation were confirmed during system testing. The Arduino Uno provides the control logic while the L293D supplies the motor-driver interface.

The L293D represents an important design limitation. The manufacturer specifies 600 mA output-current capability per channel, while the selected thruster information states a current specification up to 5 A [5]. The present experiment confirms that the ROV operates through the L293D, but it does not establish that the driver can continuously deliver the maximum stated thruster current. This is therefore treated as a hardware limitation and an area for future measurement and improvement.

C. Power and Communication

The ROV uses a 12 V, 3000 mAh IKO1230 battery and a rocker switch for the main ON/OFF function. The nominal stored energy is calculated from the rated voltage and capacity as:

$$E_{\text{nom}} = V \times Q = 12 \times 3 = 36 \text{ Wh}$$

This is a nominal stored-energy calculation and is not a measured runtime. The Arduino Uno is used as the controller; its official specification identifies the ATmega328P microcontroller, 5 V operating voltage, and 14 digital I/O pins [6].

A 15-ft (approximately 4.57 m) tether connects the vehicle to the surface operator. The tether carries the required power, control, and camera/video connections. A USB capture card transfers the camera signal to a laptop for live monitoring.

Parameter	Specification used in the ROV
Enclosure	Transparent ABS JB2; $220 \times 190 \times 100$ mm; 680 g enclosure-only mass
Thrusters	$2 \times$ brushed DC underwater thrusters; horizontal mounting
Controller	Arduino Uno / ATmega328P
Motor driver	L293D H-bridge
Operator input	2 joystick modules
Battery	12 V, 3000 mAh
Tether	15 ft (≈ 4.57 m)
Camera interface	Front camera → USB capture card → laptop

D. Power System

The system uses an IKO1230 battery rated at 12 V and 3000 mAh (3 Ah). A rocker switch serves as the main ON/OFF switch. The 12 V battery supplies the motor-driver/propulsion circuit and the Arduino Uno through its DC barrel input. No separate buck converter or voltage regulator is currently used.

The nominal battery energy can be written as $E_{nom} = VQ = 12 \times 3 = 36 \text{ Wh}$. This is a nominal stored-energy calculation, not a measured runtime. Actual operating time depends on load, discharge behavior, wiring losses, and operating duty cycle and has not been measured for the present ROV.

E. Tether and Communication

The ROV is completely wired. A 15-ft tether, approximately 4.57 m long, connects the vehicle to the surface operator. The tether carries power, control, and camera/video connections. There is no Bluetooth, Wi-Fi, or other wireless control method. The system is therefore a tethered, manually operated ROV.

F. Camera and Visual Monitoring

A waterproof automotive/rear-view type camera is mounted at the front of the ROV. Its purpose is real-time visual monitoring for underwater exploration and inspection. The video path is camera → video cable → USB capture card → laptop, where a camera application is used for viewing. The camera also has built-in LED illumination around the lens. Camera resolution, frame rate, focal length, field of view, and depth rating have not been established in the supplied project information and are therefore not claimed.

Camera	Front waterproof automotive/rear-view type camera
Video monitoring	USB capture card → laptop camera application

IV. EXPERIMENTAL METHODOLOGY

Fabrication focused on assembling the enclosure, frame, propulsion units, electronics, tether, and camera into a compact ROV. The transparent ABS enclosure provides a protected location for the Arduino Uno, battery, L293D circuit, and wiring while allowing the internal arrangement to be visually inspected during development.

The two thrusters are mounted horizontally on opposite sides of the central enclosure. Their physical arrangement establishes the available propulsion direction and keeps the propellers outside the enclosure. The front camera is mounted on the forward face of the vehicle so that the operator receives a direct view of the underwater environment. The tether is routed from the vehicle toward the surface operator, while internal wires connect the battery, switch, controller, motor driver, and propulsion branches.



Fig. 2. Assembled ROV showing the two horizontal thrusters and front-mounted camera.

During implementation, the control circuit is assembled on a breadboard. The wiring arrangement is therefore appropriate for a development ROV but is also a point for future improvement in mechanical support, strain relief, and packaging. Hot glue is used around relevant cable/opening locations as the present ROV sealing method. The enclosure's manufacturer-specified IP65/IP67 rating should not be interpreted as proof that the assembled modified enclosure remains certified to that rating.

The fabrication approach emphasizes accessibility and low cost. The design does not require autonomous navigation hardware, depth sensors, wireless communication, or advanced perception equipment. This reduction in subsystem count simplifies the ROV and keeps the main engineering problem focused on manual propulsion and visual observation.

TABLE-II
ACTUAL SYSTEM ARCHITECTURE

Subsystem	Actual implementation
Operator control	Two joystick modules; one joystick per thruster
Controller	Arduino Uno
Motor driver	L293D H-bridge
Propulsion	Two horizontal brushed DC underwater thrusters
Power	12 V, 3000 mAh IKO1230 battery + rocker switch
Tether	15 ft wired connection carrying power, control, camera/video



V. ENGINEERING ANALYSIS

A. Buoyancy Evaluation

Buoyancy is governed by Archimedes' principle. For a submerged body, the buoyancy force is expressed as:

$$F_b = \rho g V$$

where ρ is water density, g is gravitational acceleration, and V is displaced volume. The vehicle weight is $W = mg$, and the ideal neutral-buoyancy condition is $F_b \approx W$. Because the complete assembled vehicle mass and displaced volume were not measured, a numerical buoyancy margin was not calculated. Instead, the completed ROV was observed in the water tank.

During the reported water-tank test, the ROV was observed to remain at an approximately neutral-buoyancy condition. In practical terms, the vehicle remained submerged at approximately the same level rather than continuously returning to the surface or sinking rapidly to the tank bottom. This observation is important for the present two-horizontal-thruster configuration because the propulsion system is not intended to provide dedicated vertical thrust.

B. Propulsion Considerations

The horizontal thrusters must provide sufficient force to overcome hydrodynamic resistance and tether effects during forward or reverse motion. A simple drag relationship is:

$$F_D = 1/2 \rho C_D A v^2$$

where C_D is the drag coefficient, A is projected area, and v is vehicle speed. None of the parameters required for a numerical drag calculation have been measured for the completed ROV. The equation is therefore used only to describe the governing engineering relationship, not to generate an unsupported speed or thrust result.

C. Electrical Power

For an electrical branch, input power can be represented by $P = VI$. The present ROV does not include measured operating current data. The 5 A value associated with the selected thrusters is a supplied component specification and should not be confused with measured current drawn by the assembled system.

D. Motor-Driver Consideration

A significant engineering limitation is the relationship between the selected thrusters and the L293D motor-driver stage. The supplied thruster information states a current specification of up to 5 A, whereas the L293D is a low-current H-bridge device. The ROV has nevertheless been successfully operated through the L293D for forward and reverse control. The present paper therefore does not claim continuous full-current delivery through the L293D. A higher-current motor driver is a logical future improvement if measured operating current demonstrates that the present driver is inadequate under the intended load.

E. Nominal Battery Energy

With a nominal battery voltage of 12 V and a rated capacity of 3 Ah, the nominal energy is 36 Wh. This value is useful for describing the scale of the power source, but it cannot be converted into runtime without measured electrical demand and an operating duty cycle.

VI. RESULTS AND DISCUSSION

The current ROV provides several confirmed functional outcomes. Both horizontal thrusters operate through the L293D motor-driver stage. Forward operation has been confirmed, and reverse operation has also been confirmed. Each joystick independently controls its corresponding thruster, establishing the intended one-to-one operator control arrangement.

The control architecture is fully wired. The 15-ft tether provides the physical connection between the ROV and the operator and carries the required power, control, and camera/video connections. This architecture avoids wireless communication and keeps the operator directly connected to the vehicle. The camera system provides a separate visual feedback path through the USB capture card and laptop, allowing the operator to observe the underwater scene while controlling the thrusters.

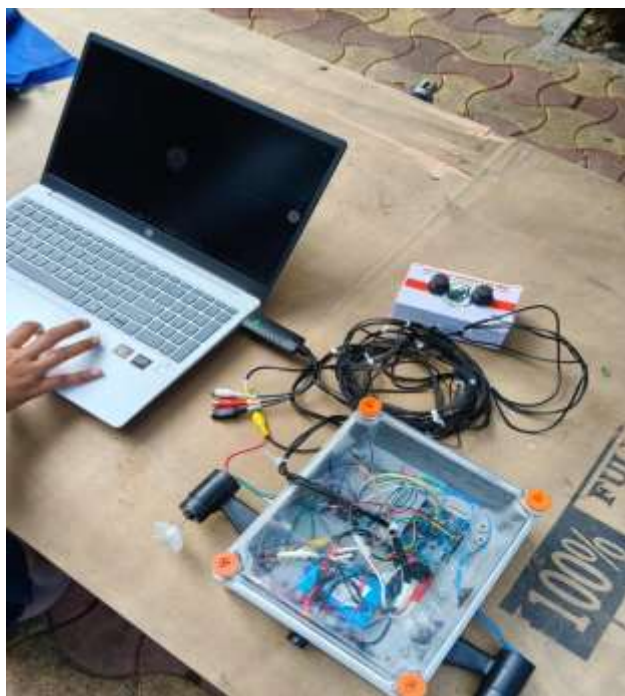


Fig. 4. ROV connected to the laptop and operator-side video/camera interface.

Mechanically, the developed ROV combines a transparent ABS enclosure with a lightweight external frame and two horizontally mounted thrusters. The front-mounted camera supports the project's inspection objective by placing the viewing direction ahead of the enclosure. The enclosure provides a compact location for the Arduino, battery, L293D circuit, and associated wiring.



Fig. 3. Underwater testing of the developed ROV in a controlled water tank.

The results must be interpreted within the limits of the available data. No numerical forward speed, underwater thrust, operating current, battery runtime, maximum depth, leakage duration, buoyancy margin, or quantitative camera-performance result has been supplied. These values are therefore not presented as experimental results. This distinction is important because component ratings do not automatically represent complete-vehicle performance.

The approximate recorded component cost is ₹12,330. This cost supports the characterization of the ROV as a low-cost ROV, while the absence of a separately recorded frame-material cost and the inclusion of miscellaneous components should be retained in the cost record for transparency.

TABLE-III
APPROXIMATE ROV COST

Item	Approx. cost (₹)
Arduino Uno	400
Two underwater thrusters	4,300
L293D	50
Two joystick modules	90
12 V, 3000 mAh battery	500
ABS enclosure	950
Camera	950
USB capture card	500
15-ft tether	500
Rocker switch	30
Breadboard	60
Frame/structural material	Not separately recorded
Wires/connectors	600
Hot glue/sealing materials	400
Other/miscellaneous components	4,000
Total	13,330

VII. APPLICATIONS, LIMITATIONS, AND FUTURE SCOPE

A. Applications

The present ROV is suited to basic visual exploration and preliminary inspection in controlled environments. Potential applications include water-tank inspection, observation of submerged surfaces, small-scale research and demonstration, and educational underwater robotics. The camera can provide a first-level visual view of an underwater target without requiring the operator to enter the water.

The system should not be represented as a replacement for professional divers or certified nondestructive testing. Its two-horizontal-thruster configuration, manual control, limited tether length, and absence of depth sensing constrain the range of tasks that can be performed reliably.



B. Limitations

The main limitations follow directly from the actual ROV architecture. The two horizontal thrusters provide propulsion but do not provide dedicated vertical thrust or active depth control. There is no depth sensor, position sensor, inertial measurement unit, autonomous navigation, obstacle avoidance, or wireless communication. Manual operation therefore depends on the operator's visual feedback and control inputs.

The tether limits the physical range to its available length and can introduce drag or handling constraints. The camera provides a forward visual perspective, so the operator's situational awareness depends on the camera view and vehicle orientation. The ROV enclosure is manufacturer-specified as IP65/IP67, but the complete fabricated ROV has not been independently certified to that rating. Similarly, the maximum safe underwater depth has not been established and should not be inferred from the enclosure rating.

The L293D is another important limitation because the selected thrusters have a stated current specification of up to 5 A. Although the ROV has demonstrated forward and reverse operation, the paper does not claim that the driver can continuously deliver the full stated thruster current. Measured current under actual operating conditions is required before selecting a final driver rating.

C. Future Scope

Future development can focus first on improving the electrical and mechanical robustness of the present architecture. A higher-current motor driver could replace the L293D if measured motor current warrants it. Improved waterproof cable glands, strain relief, and sealing could also increase reliability. Dedicated underwater lighting and a higher-quality camera could improve visual observation.

Additional thrusters could be considered in a future version if vertical motion or improved maneuverability is required. A depth sensor and position/depth monitoring could then support controlled depth operation. Longer tethering could extend the working range, although tether mass and drag would need to be considered. These are future-work concepts and are not features of the present ROV.

More advanced development could add data logging, current monitoring, image enhancement, or computer-vision assistance on the surface laptop. Such additions should be introduced only after the

basic mechanical, electrical, and waterproofing reliability of the current ROV has been experimentally characterized.

VIII. CONCLUSION

This paper presented the design and fabrication of a low-cost, manually operated, tethered underwater ROV for basic exploration and visual inspection. The actual ROV uses a transparent ABS JB2 enclosure, two horizontal brushed DC underwater thrusters, an Arduino Uno, an L293D H-bridge motor-driver stage, two independent joystick modules, a 12 V 3000 mAh IKO1230 battery, a 15-ft wired tether, and a front-mounted waterproof automotive/rear-view type camera with laptop-based video monitoring.

The confirmed ROV observations are that both thrusters operate through the L293D, forward and reverse operation are available, and each joystick controls its corresponding thruster. The design therefore demonstrates the intended basic manual propulsion and visual-monitoring concept. The recorded approximate project cost of ₹12,330 further supports the low-cost character of the ROV.

The analysis also identifies clear boundaries of the present system. The ROV has no vertical thrusters, depth sensor, autonomous navigation, obstacle avoidance, six-degree-of-freedom control, Bluetooth, or Wi-Fi. No numerical claims are made for speed, thrust, runtime, maximum depth, buoyancy margin, or leakage duration because those quantities have not been measured. The main future opportunities are higher-current motor driving, improved sealing, additional propulsion if required, depth monitoring, improved lighting/camera capability, and more systematic experimental validation.

The value of the ROV is therefore its practical and accessible implementation of a tethered underwater visual-inspection platform. It provides a foundation for further mechanical refinement and experimental study without overstating the capabilities of the current design.



IX. SYSTEM TESTING AND QUALITY ASSURANCE

Verification was conducted at the level supported by the available ROV observations. The purpose of this section is to distinguish confirmed functional behavior from performance quantities that remain unmeasured. The following matrix records the current state without converting component specifications into vehicle-level results.

Verification item	Basis
Thruster-1 operation	ROV operation through L293D
Thruster2 operation	ROV operation through L293D
Forward operation	Observed with joystick control
Reverse operation	Observed with joystick control
Independent joystick control	Each joystick assigned to one thruster
Wired tether control	15-ft tether used in ROV
Camera → capture card → laptop	Video architecture present
Nominal battery capacity	12 V, 3000 mAh IKO1230
Complete ROV mass	Enclosure mass only is known: 680 g
Vehicle speed/thrust	No vehicle-level measurements supplied
Runtime	No operating-current test supplied
Maximum depth	No depth test supplied
Complete-ROV certification	IP IP65/IP67 applies to enclosure specification

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