

# Free-Roving Subsea Cable Inspection Drone

## A Technical Feasibility Study

Jerry Liu (yhl63)  
Zihe Liu (zl559)

University of Cambridge

November 11, 2025

# Free-Roving Subsea Cable Inspection Drone

2025-11-11

Free-Roving Subsea Cable Inspection Drone  
A Technical Feasibility Study  
Jerry Liu (yhl63)  
Zihe Liu (zl559)  
University of Cambridge  
November 11, 2025

# Problem - Subsea Cable Inspection

Free-Roving Subsea Cable Inspection Drone  
└ Problem - Subsea Cable Inspection

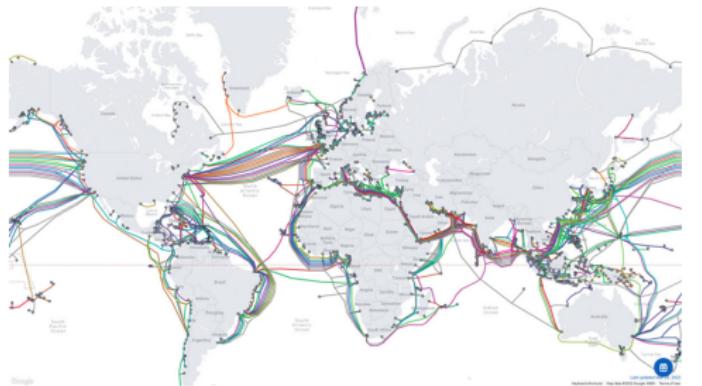
Problem - Subsea Cable Inspection

2025-11-11

# Problem - Why Subsea Cables Matter

## Backbone of the Internet:

- 97-99% of intercontinental data traffic
- 500+ cables worldwide
- 14 million kilometers total
- 2-5 cm diameter (garden hose size)



## Free-Roving Subsea Cable Inspection Drone

### Problem - Subsea Cable Inspection

#### Problem - Why Subsea Cables Matter

2025-11-11

Problem - Why Subsea Cables Matter

- Backbone of the Internet:**
- 97-99% of intercontinental data traffic
  - 500+ cables worldwide
  - 14 million kilometers total
  - 2-5 cm diameter (garden hose size)



Before we dive into our design and feasibility assessment, let's give some context to the problem we're tackling: Subsea cables. Your internet connection, whether that be for online banking or video calls, 97-99% of that data goes through a dense network of over 500+ undersea cables, spanning a total of 14 million kilometers over the seafloor making it THE largest and possibly greatest man-made infrastructure ever. This is the backbone of the internet, and when they fail, the consequences are severe. Despite the significance of these cables, these cables are no thicker than your average garden-hose around 2-5 cm in diameter, with hair-thin strands of optical fiber embedded within, designed to remain undisturbed across the seabed.

# Problem - Current Limitations



## Cable Faults:

- 200 faults/year
- Shallow waters most vulnerable
- Shetland Islands 2022: 23,000 people offline

## Traditional: Tethered ROVs

- + Unlimited power
- + Real-time comms
- Limited range
- Tether entanglement
- High operational cost

*Solution: Free-roving Autonomous Underwater Vehicle*

## Free-Roving Subsea Cable Inspection Drone

### Problem - Subsea Cable Inspection

#### Problem - Current Limitations

2025-11-11

Problem - Current Limitations



Cable Faults:

- ▶ 200 faults/year
- ▶ Shallow waters most vulnerable
- ▶ Shetland Islands 2022: 23,000 people offline

- Traditional: Tethered ROVs
- + Unlimited power
  - + Real-time comms
  - Limited range
  - Tether entanglement
  - High operational cost

*Solution: Free-roving Autonomous Underwater Vehicle*

In shallow waters however, these subsea cables are susceptible to a wider range of disturbances, largely from human activities such as anchoring, or snagged by nets, resulting in roughly 200 faults a year. In October 2022, both cables serving the Shetland Islands were damaged. For days, 23,000 people had no internet, could not use card payments, could not access online banking. Businesses lost thousands. Emergency services were disrupted. These are not rare events, they require constant monitoring and effective maintenance. When a fault occurs, an army of ships strategically placed around the world would identify and repair the location of the fault, which usually involves the usage of a tethered drone to inspect the damaged cable. Despite the effectiveness of tethered communications and unlimited power, this comes at the cost of a limited range of motion and risks of entanglement, as well as higher maintenance costs for dedicated vessels. Therefore we propose the use of an untethered AUV

2025-11-11

## Requirements and Operating Environment

# Requirements and Operating Environment

*"A free-roving (no umbilical cable) submarine inspection drone is required for undersea cables: operating down to 250 m depth. It should have an endurance of 2 hours continuously powered operation, carrying video and ultrasound imaging equipment drawing a 30 W electrical load, and have suitable propulsion to travel up to 4 m/s peak speed with 1 m/s cruise. Total mass is to be < 25 kg, to allow easy handling on board the mothership."*

## Key Specifications:

- Depth: 250m (25 bar pressure)
- Endurance: 2 hours continuous
- Speed: 1 m/s cruise, 4 m/s peak
- Payload: 30W (imaging + ultrasound + lighting)
- Mass: < 25 kg total

## Operating Challenges:

- Pressure:  $P = \rho gh \approx 25$  bar
- Temperature: 4°C seawater
- No GPS/RF underwater
- Saltwater corrosion
- Turbid water (limited visibility)

## Free-Roving Subsea Cable Inspection Drone

### Requirements and Operating Environment

2025-11-11

### Requirements and Operating Environment

Requirements and Operating Environment

*"A free-roving (no umbilical cable) submarine inspection drone is required for undersea cables: operating down to 250 m depth. It should have an endurance of 2 hours continuously powered operation, carrying video and ultrasound imaging equipment drawing a 30 W electrical load, and have suitable propulsion to travel up to 4 m/s peak speed with 1 m/s cruise. Total mass is to be < 25 kg, to allow easy handling on board the mothership."*

#### Key Specifications:

- Depth: 250m (25 bar pressure)
- Endurance: 2 hours continuous
- Speed: 1 m/s cruise, 4 m/s peak
- Payload: 30W (imaging + ultrasound + lighting)
- Mass: < 25 kg total

#### Operating Challenges:

- Pressure:  $P = \rho gh \approx 25$  bar
- Temperature: 4°C seawater
- No GPS/RF underwater
- Saltwater corrosion
- Turbid water (limited visibility)

At 250 m depth, the pressure is approximately 25 bar (2.5 MPa). This is calculated using  $P = \rho gh$ , where  $\rho$  is seawater density (1027 kg/m cubed),  $g$  is gravitational acceleration, and  $h$  is depth. The temperature is approximately 4 degrees Celsius. Materials must resist corrosion - we will use 316 stainless steel and anodized aluminum. Sensors must work in turbid water with near-zero visibility. Communications are limited to acoustic modems underwater since radio and GPS signals cannot penetrate seawater beyond a few meters. The 30W payload limit includes all imaging equipment (camera), ultrasound sensors, and lighting - this is a combined budget, not separate allocations.

2025-11-11

## Existing Commercial Solutions

# Existing Commercial Solutions

Model	Type	Mass	Depth	Speed	Endurance	Cost
<b>Our Target</b>	AUV	<25 kg	250m	4 m/s peak	2 hrs	\$10-23K
Iver3 (L3Harris)	AUV	27-39 kg	100m	1.3 m/s	8-14 hrs	\$75-120K
ecoSUB m-Power+	AUV	17 kg	500m	1.5 m/s	8-10 hrs	£35-50K
Boxfish AUV	AUV	25 kg	300-600m	2 m/s	10 hrs	\$80-150K
BlueROV2	ROV	10-11 kg	100-300m	1 m/s	3-5 hrs	\$3-3.5K



Iver3: Single thruster + fins



ecoSUB: 500m rated, alkaline



Boxfish: Tethered AUV, 6-DOF



BlueROV2: Tethered ROV, 6-DOF

Key finding: No commercial AUV <25 kg achieves 4 m/s sustained speed

## Free-Roving Subsea Cable Inspection Drone

- Existing Commercial Solutions

2025-11-11

- Existing Commercial Solutions

Existing Commercial Solutions

Model	Type	Mass	Depth	Speed	Endurance	Cost
<b>Our Target</b>	AUV	<25 kg	250m	4 m/s peak	2 hrs	\$10-23K
Iver3 (L3Harris)	AUV	27-39 kg	100m	1.3 m/s	8-14 hrs	\$75-120K
ecoSUB m-Power+	AUV	17 kg	500m	1.5 m/s	8-10 hrs	£35-50K
Boxfish AUV	AUV	25 kg	300-600m	2 m/s	10 hrs	\$80-150K
BlueROV2	ROV	10-11 kg	100-300m	1 m/s	3-5 hrs	\$3-3.5K



Key finding: No commercial AUV <25 kg achieves 4 m/s sustained speed

Many commercial solutions exist but vary in capability. Commercial designs such as the Iver3 and ecoSUB use fully autonomous operation with single thruster plus fins for pitch/yaw control. The Boxfish uses 8 vectored thrusters for full 6-DOF control including hovering. BlueROV2 is included as it is a Blue Robotics reference platform that proves component viability, though it is a tethered ROV not an autonomous AUV. Key finding: Few commercial AUVs under 25 kg achieve 4 m/s sustained speed - most operate at 1.5-2.5 m/s due to power limitations. Commercial pricing (50-150K dollars) reflects support and warranty, not just hardware costs. Our target specifications are ambitious but achievable with careful trade-off management.

2025-11-11

## Design Approach and System Architecture

# Trade-offs

**Capabilities:** Better Capabilities (higher speed, sensor equipment etc) – Often meaning an increase in both power draw and weight, but is also the most vital aspect of the design.



**Endurance:** Longer operating Time – Either reduce power draw, or larger battery

**Mass** < 25kg limits battery to 4-5 kg max, also sacrifices equipment or payload

**Our Solution:** Mission profile with 80% cruise (1 m/s) + 20% sprint (4 m/s)

## Free-Roving Subsea Cable Inspection Drone

### Design Approach and System Architecture

2025-11-11

#### Trade-offs

Trade-offs

Capabilities: Better Capabilities (higher speed, sensor equipment etc) – Often meaning an increase in both power draw and weight, but is also the most vital aspect of the design.



Endurance: Longer operating Time – Either reduce power draw, or larger battery

Mass < 25kg limits battery to 4-5 kg max, also sacrifices equipment or payload

Our Solution: Mission profile with 80% cruise (1 m/s) + 20% sprint (4 m/s)

# System Design Directions

- Autonomous/programmable solution to remove the need for high-quality real-time data transmission which limits untethered ROVs
  - ▶ Enables self-contained operation with onboard power, navigation, and data handling
  - ▶ Supports scalable inspection missions without reliance on surface tethers
- 6-thruster design for stability and hovering capabilities for detailed inspection
  - ▶ Provides full 6-DOF control for precise hovering, lateral motion, and pitch/yaw stability
  - ▶ Redundancy for safe recovery in case of partial thruster failure
  - ▶ Efficient low-speed maneuvering for inspection tasks
- Hull design to be cylindrical (pill) shaped to minimise volume as well as simplify hydrodynamic calculations.
  - ▶ Streamlined shape reduces drag forces at higher speeds
  - ▶ Simplifies internal component layout and waterproofing
  - ▶ Proven design in existing AUVs for balance of speed and stability

## Free-Roving Subsea Cable Inspection Drone

### Design Approach and System Architecture

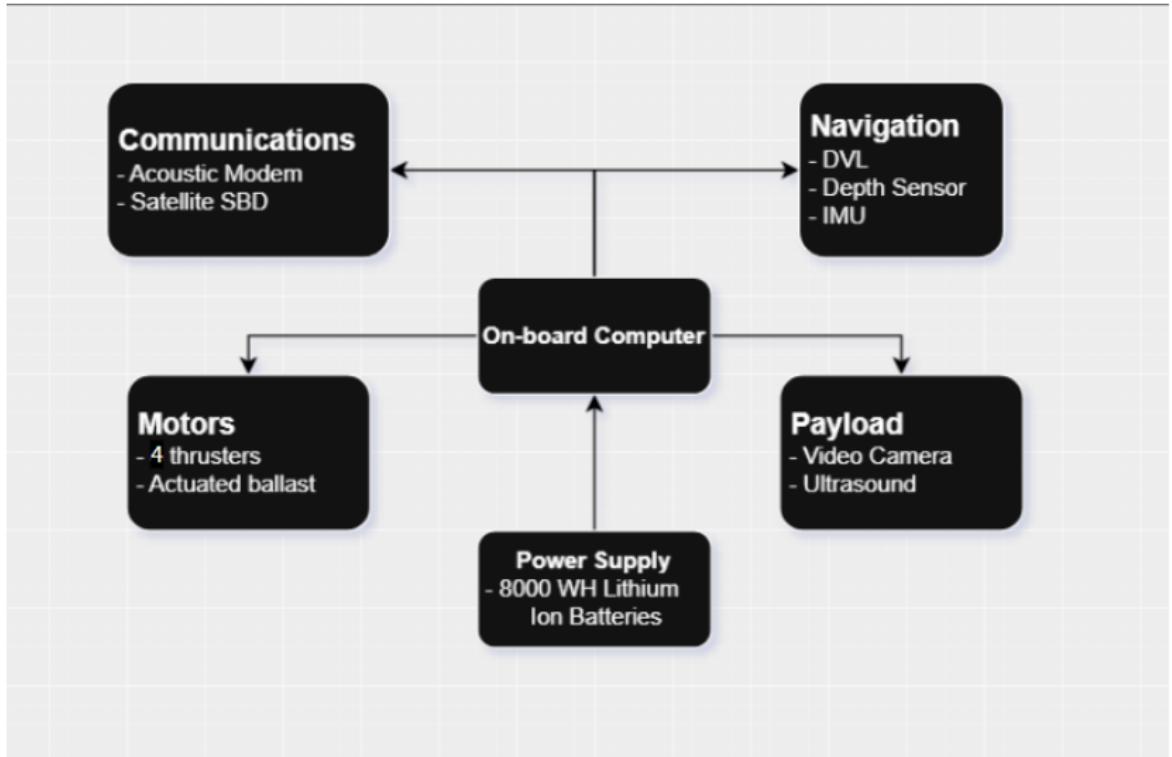
2025-11-11

#### System Design Directions

System Design Directions

- Autonomous/programmable solution to remove the need for high-quality real-time data transmission which limits untethered ROVs
  - ▶ Enables self-contained operation with onboard power, navigation, and data handling
  - ▶ Supports scalable inspection missions without reliance on surface tethers
- 6-thruster design for stability and hovering capabilities for detailed inspection
  - ▶ Provides full 6-DOF control for precise hovering, lateral motion, and pitch/yaw stability
  - ▶ Redundancy for safe recovery in case of partial thruster failure
  - ▶ Efficient low-speed maneuvering for inspection tasks
- Hull design to be cylindrical (pill) shaped to minimise volume as well as simplify hydrodynamic calculations.
  - ▶ Streamlined shape reduces drag forces at higher speeds
  - ▶ Simplifies internal component layout and waterproofing
  - ▶ Proven design in existing AUVs for balance of speed and stability

# System Architecture - Simplified Block Diagram



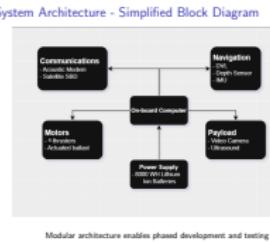
Modular architecture enables phased development and testing

## Free-Roving Subsea Cable Inspection Drone

### Design Approach and System Architecture

#### System Architecture - Simplified Block Diagram

2025-11-11



This simplified system architecture shows the five main subsystems. POWER provides 799 Wh from three 18Ah lithium-ion batteries at 14.8V. CONTROL uses the Navigator flight controller with dual IMUs plus Raspberry Pi 4 running ArduSub for mission control, along with depth sensor, compass, and surface GPS. PROPULSION consists of four T200 thrusters controlled by ESCs. PAYLOAD includes camera, Ping360 sonar, and lights totaling 30W. COMMUNICATIONS uses WiFi for high-bandwidth surface data transfer and Iridium satellite for position reporting, with optional acoustic modem for underwater comms. This modular design allows independent testing and phased development.

## Communications and Navigation

2025-11-11

# Underwater Communication Challenges

## Underwater Communication:

- High signal attenuation limits the usage of radio frequency signals - effective range only a few metres
- Optical communication limited by turbidity and scattering - short range, line-of-sight only
- Acoustic communication is the only viable option for long-range underwater comms, but inherently slow, high latency, and affected by multipath

**Result:** Minimise communication — majority of data stored on the vehicle, only allowing small and simple commands to be communicated.

## Free-Roving Subsea Cable Inspection Drone

### Communications and Navigation

2025-11-11

#### Underwater Communication Challenges

Underwater Communication Challenges

##### Underwater Communication:

- High signal attenuation limits the usage of radio frequency signals - effective range only a few metres
  - Optical communication limited by turbidity and scattering - short range, line-of-sight only
  - Acoustic communication is the only viable option for long-range underwater comms, but inherently slow, high latency, and affected by multipath
- Result:** Minimise communication — majority of data stored on the vehicle, only allowing small and simple commands to be communicated.

# Navigation System

Component	Product	Cost
Flight Controller	Blue Robotics Navigator	\$125
Depth Sensor	Blue Robotics Bar30	\$68
Surface GPS	u-blox NEO-M8N	\$35
Computer	Raspberry Pi 4 (4GB)	\$75

**Navigation Strategy:** IMU dead reckoning + depth + compass (5-15m drift/2hrs)

## Free-Roving Subsea Cable Inspection Drone

### └ Communications and Navigation

#### └ Navigation System

2025-11-11

Navigation System

Component	Product	Cost
Flight Controller	Blue Robotics Navigator	\$125
Depth Sensor	Blue Robotics Bar30	\$68
Surface GPS	u-blox NEO-M8N	\$35
Computer	Raspberry Pi 4 (4GB)	\$75

Navigation Strategy: IMU dead reckoning + depth + compass (5-15m drift/2hrs)

The Navigator flight controller contains dual IMUs - the ICM-42688-P and ICM-20602. Dual IMUs provide redundancy and enable sensor fusion, which reduces noise and compensates for drift in individual sensors.

The Bar30 depth sensor provides 2 millimeter resolution by measuring pressure. At 250 meters depth, pressure is 25 bar. This gives accurate vertical positioning. For horizontal positioning, GPS signals cannot penetrate seawater. The system uses dead reckoning - integrating accelerometer measurements to estimate position. Small measurement errors accumulate over time, resulting in 5 to 15 meters of horizontal drift over the 2-hour mission.

A DVL would reduce this drift to under 1 meter, but costs 5,000 to 20,000 dollars. For cable inspection, the cable itself provides a visual reference for following, so precise dead reckoning is less critical. We omit the DVL to reduce cost and weight.

# Communications Systems

## Multi-Mode Communication Strategy:

Mode	Product	Specifications	Cost
Surface WiFi	802.11n module (Raspberry Pi built-in)	2.4/5 GHz, 150 Mbps 50-100m range in air	\$50
Satellite	RockBLOCK 9603N	Iridium Short Burst Data 340 byte messages Global coverage (open ocean) GPS position reporting	\$260

## Operational Modes:

- **At surface:** WiFi for high-bandwidth video/data + GPS fix
- **Open ocean:** RockBLOCK for GPS position reporting every 10 min

## Free-Roving Subsea Cable Inspection Drone

### Communications and Navigation

2025-11-11

### Communications Systems

Communications Systems

#### Multi-Mode Communication Strategy:

Mode	Product	Specifications	Cost
Surface WiFi	802.11n module (Raspberry Pi built-in)	2.4/5 GHz, 150 Mbps 50-100m range in air	\$50
Satellite	RockBLOCK 9603N	Iridium Short Burst Data 340 byte messages Global coverage (open ocean) GPS position reporting	\$260

Operational Modes:  
• At surface: WiFi for high-bandwidth video/data + GPS fix  
• Open ocean: RockBLOCK for GPS position reporting every 10 min

The communication system costs 310 dollars total: 50 dollars for WiFi and 260 dollars for RockBLOCK Iridium modem. This is 40 times cheaper than underwater acoustic modems at 12,000 to 15,000 dollars.

At the surface within 50 to 100 meters of the mothership, WiFi provides 150 megabits per second bandwidth for downloading video and sensor data. The vehicle also acquires GPS fixes to reset navigation drift.

For open ocean operations beyond visual range, the RockBLOCK uses the Iridium satellite network with global coverage. Every 10 minutes, the vehicle surfaces and transmits 340-byte messages containing GPS coordinates and status. This ensures vehicle recovery even kilometers from the mothership.

The autonomous mission profile eliminates the need for real-time underwater communication. The vehicle follows pre-programmed waypoints, stores all sensor data onboard, and downloads it during surface intervals.

# Underwater Acoustic Link Budget

## Acoustic Communication Constraints:

$$\text{Transmission Loss: } TL = 20 \log_{10}(R) + \alpha R \times 10^{-3} \text{ dB}$$

Where:  $R$  = range (m),  $\alpha$  = absorption coefficient (3 dB/km @ 25 kHz)

## Link Budget Calculation for $R = 500\text{m}$ :

- Transmission loss:  $TL = 20 \log_{10}(500) + 3 \times 0.5 = 54 + 1.5 = 55.5 \text{ dB}$
- Source level: 180 dB re 1  $\mu\text{Pa}$  @ 1m (EvoLogics modem)
- Array gain: 10 dB
- Received level:  $180 - 55.5 + 10 = 134.5 \text{ dB}$
- Noise level: 60 dB (sea state 3)
- Required SNR: 10 dB
- Link margin:  $134.5 - 60 - 10 = 64.5 \text{ dB - Feasible}$

**Result:** Acoustic communication feasible at 500m range with excellent margin

## Free-Roving Subsea Cable Inspection Drone

### Communications and Navigation

#### Underwater Acoustic Link Budget

2025-11-11

Underwater Acoustic Link Budget

##### Acoustic Communication Constraints:

Transmission Loss:  $TL = 20 \log_{10}(R) + \alpha R \times 10^{-3} \text{ dB}$   
Where:  $R$  = range (m),  $\alpha$  = absorption coefficient (3 dB/km @ 25 kHz)

##### Link Budget Calculation for $R = 500\text{m}$ :

- Transmission loss:  $TL = 20 \log_{10}(500) + 3 \times 0.5 = 54 + 1.5 = 55.5 \text{ dB}$
- Source level: 180 dB re 1  $\mu\text{Pa}$  @ 1m (EvoLogics modem)
- Array gain: 10 dB
- Received level:  $180 - 55.5 + 10 = 134.5 \text{ dB}$
- Noise level: 60 dB (sea state 3)
- Required SNR: 10 dB
- Link margin:  $134.5 - 60 - 10 = 64.5 \text{ dB - Feasible}$

**Result:** Acoustic communication feasible at 500m range with excellent margin

This link budget calculation demonstrates that underwater acoustic communication is technically feasible, though we omit it for cost reasons.

Transmission loss has two components: spreading loss at  $20 \log R$  from geometric spreading, and absorption loss alpha times  $R$ . At 25 kilohertz, seawater absorption is approximately 3 decibels per kilometer, giving 1.5 decibels absorption at 500 meters.

The calculation: EvoLogics modem source level is 180 decibels re 1 micropascal at 1 meter. After 500 meters, transmission loss is 55.5 decibels. Array gain adds 10 decibels. Received signal level is 134.5 decibels.

Ocean ambient noise at sea state 3 is 60 decibels. Required signal-to-noise ratio for reliable communication is 10 decibels, meaning minimum received level of 70 decibels. The link margin is 64.5 decibels, sufficient to handle multipath interference and unexpected losses.

Acoustic communication is feasible at 500 meter range with good performance margin. However, the 12,000 dollar cost is not justified for autonomous missions with periodic surfacing.

2025-11-11

# Hydrodynamics and Propulsion Analysis

# Hydrodynamic Drag

## Vehicle Geometry (Torpedo Hull):

- Diameter:  $D = 0.3 \text{ m}$ , Length:  $L = 1.2 \text{ m}$
- Frontal area:  $A = \frac{\pi D^2}{4} = 0.0707 \text{ m}^2$
- Drag coefficient:  $C_D = 0.28-0.32$

## Drag Force Equation:

$$F_D = \frac{1}{2} \rho v^2 C_D A$$

Where  $\rho = 1027 \text{ kg/m}^3$  (seawater)

- **At 1 m/s cruise**  $C_D = 0.32$ :  $F_D = 11.6 \text{ N}$
- **At 4 m/s peak**  $C_D = 0.28$ :  $F_D = 162 \text{ N}$

## Free-Roving Subsea Cable Inspection Drone

### Hydrodynamics and Propulsion Analysis

2025-11-11

#### Hydrodynamic Drag

Hydrodynamic Drag

##### Vehicle Geometry (Torpedo Hull):

- Diameter:  $D = 0.3 \text{ m}$ , Length:  $L = 1.2 \text{ m}$
- Frontal area:  $A = \frac{\pi D^2}{4} = 0.0707 \text{ m}^2$
- Drag coefficient:  $C_D = 0.28-0.32$

##### Drag Force Equation:

$$F_D = \frac{1}{2} \rho v^2 C_D A$$

Where  $\rho = 1027 \text{ kg/m}^3$  (seawater)

- At 1 m/s cruise  $C_D = 0.32$ :  $F_D = 11.6 \text{ N}$
- At 4 m/s peak  $C_D = 0.28$ :  $F_D = 162 \text{ N}$

Hydrodynamic drag is the fundamental constraint on our design. The drag equation  $F_D = \frac{1}{2} \rho v^2 C_D A$  shows that drag force scales with velocity squared. Doubling speed quadruples drag force.

Vehicle geometry is torpedo-shaped: 1.2 meters long, 0.3 meters diameter. The length-to-diameter ratio of 4 to 1 optimizes streamlining. Frontal area is 0.071 square meters.

Drag coefficient  $C_D$  varies from 0.28 to 0.32 with speed. At low speeds, flow separation and turbulence near protrusions increases  $C_D$  to 0.32. At high speeds, Reynolds number increases, boundary layer becomes thinner, and  $C_D$  drops to 0.28. These values are validated against CFD studies on similar torpedo-shaped AUVs.

At 1 meter per second, drag is 11.6 newtons. At 4 meters per second, drag is 162 newtons - a 14-fold increase for 4-times speed increase. This quadratic relationship creates the fundamental challenge: high speed requires overcoming dramatically higher drag forces.

# Power Requirements and Thruster Efficiency

**Mechanical power:**  $P_{mech} = F_D \times v$

**Electrical power:**  $P_{elec} = \frac{P_{mech}}{\eta}$  (thruster efficiency  $\eta \approx 0.55$  at high load)

Speed	$F_D$ (N)	$P_{mech}$ (W)	$\eta$	$P_{elec}$ (W)	Notes
1 m/s cruise	11.6	11.6	0.30	39	Low efficiency
4 m/s peak	162	648	0.55	1,178	High efficiency

4 m/s requires 1.2 kW propulsion power (30× cruise power)

## Free-Roving Subsea Cable Inspection Drone

### Hydrodynamics and Propulsion Analysis

2025-11-11

#### Power Requirements and Thruster Efficiency

Power Requirements and Thruster Efficiency

Mechanical power: $P_{mech} = F_D \times v$					
Electrical power: $P_{elec} = \frac{P_{mech}}{\eta}$ (thruster efficiency $\eta \approx 0.55$ at high load)					
Speed	$F_D$ (N)	$P_{mech}$ (W)	$\eta$	$P_{elec}$ (W)	Notes
1 m/s cruise	11.6	11.6	0.30	39	Low efficiency
4 m/s peak	162	648	0.55	1,178	High efficiency

4 m/s requires 1.2 kW propulsion power (30× cruise power)

Power scales with velocity cubed because power equals force times velocity. Drag force has  $v$ -squared, multiplied by another  $v$  from the power equation gives  $v$ -cubed scaling.

Thruster efficiency varies with load. At 1 meter per second, mechanical power required is 11.6 watts, but thruster efficiency at light load is only 30 percent, requiring 39 watts electrical.

At 4 meters per second, mechanical power is 648 watts - 56 times cruise. At heavy load, thruster efficiency increases to 55 percent, so electrical power is 1,178 watts.

The critical number: 1,178 watts propulsion at peak versus 39 watts at cruise. This is 30 times more power for 4 times speed. Pure  $v$ -cubed scaling would give 64 times, but efficiency improvement at high load reduces this to 30 times.

This cubic scaling makes sustained high-speed underwater operation challenging. The constraint is battery energy, which translates directly to weight. Battery energy requirements conflict with the 25 kilogram mass limit.

# Thruster Selection - T200

Model	Thrust (N)	Power (W)	Depth (m)	Mass (kg)	Cost (\$)	Thrust/Cost
T200	50 fwd	350 max	300	0.34	130	0.38
SeaBotix BTD150	28	80	150	0.5	800	0.035
Maxon MT30	49	180	6000	0.45	2,500	0.020
T500	158	1000+	300	1.1	690	0.23

## 4 x T200 Configuration:

- Total thrust: **200 N**
- Required: 162 N
- Propulsion cost: \$520
- ESCs (4x 30A): \$145

## Justification:

- 6-20x lower cost than alternatives
- Adequate thrust at 16V
- 300m depth rating (vs 250m spec)
- Proven reliability
- Large user community

# Free-Roving Subsea Cable Inspection Drone

## Hydrodynamics and Propulsion Analysis

2025-11-11

### Thruster Selection - T200

Thruster Selection - T200

Model	Thrust (N)	Power (W)	Depth (m)	Mass (kg)	Cost (\$)	Thrust/Cost
T200	50 fwd	350 max	300	0.34	130	0.38
SeaBotix BTD150	28	80	150	0.5	800	0.035
Maxon MT30	49	180	6000	0.45	2,500	0.020
T500	158	1000+	300	1.1	690	0.23

**4 x T200 Configuration:**

- Total thrust: 200 N
- Required: 162 N
- Propulsion cost: \$520
- ESCs (4x 30A): \$145

**Justification:**

- 6-20x lower cost than alternatives
- Adequate thrust at 16V
- 300m depth rating (vs 250m spec)
- Proven reliability
- Large user community

Four thruster options were evaluated. SeaBotix BTD150 has good efficiency but insufficient thrust: 28 newtons versus 50 newtons for T200. Maxon MT30 has 6000 meter depth rating and costs 14 to 21 times more than T200 - unnecessary for 250 meter requirement. T500 provides 158 newtons thrust but draws over 1 kilowatt continuously and weighs 1.1 kilograms.

T200 offers best thrust-to-cost ratio at 0.38 newtons per dollar. Four T200 thrusters provide 200 newtons total thrust for 162 newtons required - 23 percent safety margin. This margin accommodates variation in drag coefficient from hull imperfections.

The T200 uses flooded brushless motor design, which is naturally pressure-tolerant with no sealed air cavities. Tested to 3000 meters at Woods Hole, exceeding the 300 meter official rating and our 250 meter requirement.

2025-11-11

## Power Budget and Energy Storage

# Complete System Power Budget

Subsystem	Cruise (W)	Peak (W)	Notes
Propulsion (4× T200)	39	1,178	Dominant at peak
Payload (camera, lighting and sonar)	30	30	Low-light USB
Navigation sensors	5	5	IMU, depth, GPS
Control (RPi4+Nav)	10	10	ArduSub firmware
Comms (WiFi/Iridium)	2	2	Surface only
<b>TOTAL</b>	<b>86 W</b>	<b>1,225 W</b>	

$P_{avg} = 314 \text{ W}$  (Accounting for mission profile)

## Free-Roving Subsea Cable Inspection Drone

### Power Budget and Energy Storage

#### Complete System Power Budget

2025-11-11

Complete System Power Budget

Subsystem	Cruise (W)	Peak (W)	Notes
Propulsion (4× T200)	39	1,178	Dominant at peak
Payload (camera, lighting and sonar)	30	30	Low-light USB
Navigation sensors	5	5	IMU, depth, GPS
Control (RPi4+Nav)	10	10	ArduSub firmware
Comms (WiFi/Iridium)	2	2	Surface only
<b>TOTAL</b>	<b>86 W</b>	<b>1,225 W</b>	

$P_{avg} = 314 \text{ W}$  (Accounting for mission profile)

The 30 watt payload specification is a combined budget for all payload components: camera at 2.5 watts, sonar at 2 to 5 watts, and lighting at 10 to 20 watts adjustable. Total payload is 15 to 28 watts, within the 30 watt limit.

Propulsion dominates total power at peak speed: 1,225 watts total system power, with 1,178 watts for propulsion alone. At cruise, propulsion is only 39 watts out of 86 watts total.

The mission profile assumes 80 percent time at 1 meter per second cruise, 20 percent at 4 meters per second sprint. This gives average power of 314 watts: 0.8 times 86 plus 0.2 times 1,225. This average power determines battery capacity requirements.

# Battery Sizing

## Energy Requirements:

$$E = P_{avg} \times t = 314 \text{ W} \times 2 \text{ h} = 628 \text{ Wh required}$$

Option	Voltage	Capacity	Energy	Mass	Cost
Blue Robotics 3x18Ah	14.8V	18Ah	799 Wh	4.05 kg	\$1,200
Blue Robotics 2x18Ah	14.8V	18Ah	532 Wh	2.7 kg	\$800
Samsung 35E (4S6P)	14.8V	21Ah	311 Wh	1.5 kg	\$310-590
SubCtech PowerPack	14-50V	Custom	650-3400 Wh	Varies	\$3-10K+

**Selected: 3x Blue Robotics 18Ah**

**Justification:**

- Energy: 799 Wh
- Endurance: 2.5 hrs @ 314W
- Proven platform (BlueROV2)
- Integrated BMS
- 2x config: only 532 Wh (insufficient)
- Samsung 35E: DIY, higher risk
- SubCtech: 2.5-8x cost, overkill

## Free-Roving Subsea Cable Inspection Drone

### Power Budget and Energy Storage

#### Battery Sizing

2025-11-11

Battery Sizing

Energy Requirements:

$$E = P_{avg} \times t = 314 \text{ W} \times 2 \text{ h} = 628 \text{ Wh required}$$

Option	Voltage	Capacity	Energy	Mass	Cost
Blue Robotics 3x18Ah	14.8V	18Ah	799 Wh	4.05 kg	\$1,200
Blue Robotics 2x18Ah	14.8V	18Ah	532 Wh	2.7 kg	\$800
Samsung 35E (4S6P)	14.8V	21Ah	311 Wh	1.5 kg	\$310-590
SubCtech PowerPack	14-50V	Custom	600-3400 Wh	Varies	\$3-10K+

Selected: 3x Blue Robotics 18Ah

- Justification:
- Energy: 799 Wh
  - Endurance: 2.5 hrs @ 314W
  - Proven platform (BlueROV2)
  - Integrated BMS
  - 2x config: only 532 Wh (insufficient)
  - Samsung 35E: DIY, higher risk
  - SubCtech: 2.5-8x cost, overkill

Energy requirement is 314 watts times 2 hours equals 628 watt-hours minimum. Four battery options were evaluated. Two Blue Robotics 18Ah batteries provide only 532 watt-hours, insufficient for 628 watt-hour requirement. Custom Samsung 35E pack in 4S6P configuration with 24 cells provides 311 watt-hours at lower cost, but requires assembly and custom pressure housing. SubCtech PowerPack offers professional-grade performance with 6000 meter depth rating but costs 2.5 to 8 times more.

Three Blue Robotics 18Ah batteries provide 799 watt-hours - 27 percent margin over requirement. This enables 2.5 hour missions at 314 watts average power. This configuration is proven in the BlueROV2 platform with integrated battery management system.

Battery depth rating depends on the aluminum pressure enclosure design, not the battery cells themselves.

2025-11-11

## Mechanical Design and Structural Analysis

# Material Selection and Component Specifications

## Pressure Housing Comparison:

Material	Yield (MPa)	Density	Cost/kg	250m Rating
Al 6061-T6	276	2,700 kg/m <sup>3</sup>	\$7	Excellent
Ti Grade 5	880	4,430 kg/m <sup>3</sup>	\$30	Overkill (6000m+)
Acrylic	70-75	1,180 kg/m <sup>3</sup>	\$4	Insufficient

## Selected: Blue Robotics 3" Aluminum Enclosures

- ID: 74.7mm
- Depth: 500m (2x safety)
- Hard anodized
- Double O-rings
- Lengths: 150-400mm
- WetLink penetrators
- Tool-free assembly
- Vacuum testable
- Price: \$200-300 complete
- Proven: 1000s deployed

## Free-Roving Subsea Cable Inspection Drone

### Mechanical Design and Structural Analysis

2025-11-11

### Material Selection and Component Specifications

Material Selection and Component Specifications

#### Pressure Housing Comparison:

Material	Yield (MPa)	Density	Cost/kg	250m Rating
Al 6061-T6	276	2,700 kg/m <sup>3</sup>	\$7	Excellent
Ti Grade 5	880	4,430 kg/m <sup>3</sup>	\$30	Overkill (6000m+)
Acrylic	70-75	1,180 kg/m <sup>3</sup>	\$4	Insufficient

Selected: Blue Robotics 3" Aluminum Enclosures

- ID: 74.7mm
- Depth: 500m (2x safety)
- Hard anodized
- Double O-rings
- Lengths: 150-400mm
- WetLink penetrators
- Tool-free assembly
- Vacuum testable
- Price: \$200-300 complete
- Proven: 1000s deployed

Three materials were compared for pressure housing. Aluminum 6061-T6 has yield strength of 276 megapascals and density of 2,700 kilograms per cubic meter. Titanium Grade 5 has 880 megapascals yield strength but costs 30 dollars per kilogram versus 7 dollars for aluminum. Titanium is unnecessary for 250 meter depth - its advantage only matters beyond 1000 meters. Acrylic has only 70 to 75 megapascals yield strength, insufficient for 250 meter external pressure.

Blue Robotics 3 inch aluminum enclosures were selected. Internal diameter is 74.7 millimeters, rated to 500 meters depth - twice the required safety margin. Hard anodizing provides corrosion resistance. Double O-ring seals ensure watertight integrity. Available lengths from 150 to 400 millimeters enable modular layout.

WetLink penetrators provide cable entry at 12 to 17 dollars per unit, rated to 1000 meters. These are tool-free, reusable, and significantly cheaper than traditional potted penetrators. Complete enclosures cost 200 to 300 dollars. Thousands deployed in BlueROV2 fleet validate reliability.

# Pressure Vessel Design - Theory

## Basic Thin-Walled Cylinder Theory

For external pressure  $P$  on cylinder with radius  $R$  and wall thickness  $t$ :

$$\text{Hoop stress: } \sigma_\theta = \frac{P \cdot R}{t}$$

### Apply Safety Criteria

Stress must not exceed allowable stress  $S$  (with weld efficiency  $E$ ):

$$\sigma_\theta \leq S \cdot E$$

$$\frac{P \cdot R}{t} \leq S \cdot E \quad \Rightarrow \quad t \geq \frac{P \cdot R}{S \cdot E}$$

### ASME Section VIII Refinements

- Add biaxial stress correction: denominator becomes  $(S \cdot E - 0.6P)$
- Add corrosion allowance:  $+C_A$  term

$$t = \frac{P \cdot R}{S \cdot E - 0.6P} + C_A$$

## Free-Roving Subsea Cable Inspection Drone

### Mechanical Design and Structural Analysis

#### Pressure Vessel Design - Theory

2025-11-11

**Pressure Vessel Design - Theory**  
**Basic Thin-Walled Cylinder Theory**  
For external pressure  $P$  on cylinder with radius  $R$  and wall thickness  $t$ :  
Hoop stress:  $\sigma_\theta = \frac{P \cdot R}{t}$

**Apply Safety Criteria**  
Stress must not exceed allowable stress  $S$  (with weld efficiency  $E$ ):  
 $\sigma_\theta \leq S \cdot E$

$\frac{P \cdot R}{t} \leq S \cdot E \quad \Rightarrow \quad t \geq \frac{P \cdot R}{S \cdot E}$

**ASME Section VIII Refinements**

- Add biaxial stress correction: denominator becomes  $(S \cdot E - 0.6P)$
- Add corrosion allowance:  $+C_A$  term

$$t = \frac{P \cdot R}{S \cdot E - 0.6P} + C_A$$

Pressure vessel design starts from thin-walled cylinder theory. Hoop stress equals  $P R$  over  $t$  from force balance on a cylinder element. This stress must not exceed allowable stress  $S$  times weld efficiency  $E$ .

Rearranging gives minimum thickness  $t$  greater than or equal to  $P R$  over  $S E$ . This is the basic thin-wall formula.

ASME Section VIII adds two refinements. First, the  $0.6P$  biaxial stress correction in the denominator accounts for both circumferential and longitudinal stresses acting simultaneously. Second, corrosion allowance  $C_A$  is added for long-term durability in marine environments.

The final formula is  $t$  equals  $P R$  over  $S E$  minus  $0.6P$ , plus  $C_A$ . This is the standard for pressure vessel design under external pressure.

# Pressure Vessel Design - ASME Calculation

## Operating Conditions:

- Pressure:  $P = \rho gh \approx 2.52 \text{ MPa}$  (25.2 bar)
- With safety factor 3x, design pressure:  $P_d = 7.56 \text{ MPa}$

## ASME Section VIII Formula (External Pressure):

$$t = \frac{P \cdot R}{S \cdot E - 0.6P} + C_A = 6.3\text{mm}$$

Where:

- $P = 7.56 \text{ MPa}$
- $R = 50 \text{ mm}$  (for 3" tube)
- $S = 92 \text{ MPa}$  (Al 6061-T6)
- $E = 1.0$  (seamless)
- $C_A = 2 \text{ mm}$  (corrosion)

Blue Robotics 3" tubes has thickness of 6.35 mm (**Feasible**)

## Free-Roving Subsea Cable Inspection Drone

### Mechanical Design and Structural Analysis

2025-11-11

#### Pressure Vessel Design - ASME Calculation

Pressure Vessel Design - ASME Calculation

**Operating Conditions:**

- Pressure:  $P = \rho gh \approx 2.52 \text{ MPa}$  (25.2 bar)
- With safety factor 3x, design pressure:  $P_d = 7.56 \text{ MPa}$

**ASME Section VIII Formula (External Pressure):**

$$t = \frac{P \cdot R}{S \cdot E - 0.6P} + C_A = 6.3\text{mm}$$

Where:

- $P = 7.56 \text{ MPa}$
- $R = 50 \text{ mm}$  (for 3" tube)
- $S = 92 \text{ MPa}$  (Al 6061-T6)
- $E = 1.0$  (seamless)
- $C_A = 2 \text{ mm}$  (corrosion)

Blue Robotics 3" tubes has thickness of 6.35 mm (**Feasible**)

Operating pressure at 250 meters is rho g h equals 2.52 megapascals or 25.2 bar. With safety factor of 3, design pressure is 7.56 megapascals.

Applying ASME Section VIII formula: P is 7.56 megapascals, R is 50 millimeters for 3 inch tube internal radius. Allowable stress S for aluminum 6061-T6 is yield strength divided by 3, giving 92 megapascals. Weld efficiency E is 1.0 for seamless tube. Corrosion allowance C-A is 2 millimeters for marine environment. Calculation gives t equals 7.56 times 50, over 92 times 1.0 minus 0.6 times 7.56, plus 2. This equals 378 divided by 87.5, plus 2, giving 4.3 plus 2 equals 6.3 millimeters minimum thickness.

Blue Robotics 3 inch tubes have 6.35 millimeter wall thickness - essentially identical to calculated requirement. This validates the pressure housing design for 250 meter operation with appropriate safety margins.

# Buoyancy and Ballast Design

## Neutral Buoyancy Requirement:

For dry mass  $m = 15.4$  kg (calculated later) in seawater:

$$V_{displaced} = \frac{m}{\rho} = \frac{15.4}{1027} = 0.015 \text{ m}^3 = 15.0 \text{ L}$$

## Component Volumes and Buoyancy:

- Pressure housings (3× 3" tubes): 4 L (watertight)
- Batteries (internal to housing): 2 L
- Thrusters: Negative buoyancy ( 0.24 kg each × 4 = 0.96 kg)
- Electronics: Neutral (in watertight housings)

# Free-Roving Subsea Cable Inspection Drone

## Mechanical Design and Structural Analysis

2025-11-11

### Buoyancy and Ballast Design

Buoyancy and Ballast Design

**Neutral Buoyancy Requirement:**  
For dry mass  $m = 15.4$  kg (calculated later) in seawater:  
 $V_{displaced} = \frac{m}{\rho} = \frac{15.4}{1027} = 0.015 \text{ m}^3 = 15.0 \text{ L}$

**Component Volumes and Buoyancy:**  

- Pressure housings (3× 3" tubes): 4 L (watertight)
- Batteries (internal to housing): 2 L
- Thrusters: Negative buoyancy ( 0.24 kg each × 4 = 0.96 kg)
- Electronics: Neutral (in watertight housings)

Neutral buoyancy requires displaced volume equal to mass divided by seawater density. For dry mass of 15.4 kilograms, required displaced volume is 15.4 divided by 1027, equals 0.015 cubic meters or 15 liters.

Component contributions: Three 3 inch aluminum tubes displace approximately 4 liters as watertight volumes. Batteries inside housings occupy approximately 2 liters. Electronics in watertight housings are approximately neutral buoyancy.

Thrusters have negative buoyancy: each T200 is 0.24 kilograms negative in water, giving 0.96 kilograms total for four thrusters. This must be compensated with syntactic foam providing positive buoyancy.

Final buoyancy adjustment uses lead weights for fine trim, positioning center of gravity below center of buoyancy to ensure passive stability in roll and pitch.

# Consolidated Mass and Cost Budgets

2025-11-11

# Mass & Cost Summary

Subsystem	Mass (kg)	Cost (\$)	Key Components
Propulsion	1.88	1,278	4× T200 + ESCs
Power	4.55	1,680	3× 18Ah batteries + housing
Control & Navigation	0.62	665	RPi4 + Navigator + Bar30
Payload	0.96	3,320	Ping360 (\$2,750) + camera + light
Communications	0.12	410	WiFi + Iridium
Structure	5.50	1,280	Frame, foam, fairings, penetrators
Assembly & Tools	—	200	Testing equipment
<b>Total</b>	<b>15.67 kg</b>	<b>\$10,840</b>	

- **Mass:** 15.67 kg total, providing a 37% margin under the 25 kg limit.
- **Cost:** \$10,840 base build, much cheaper
- **Key Drivers:** Power/Structure are largest mass contributors; Payload (Ping360) is the largest cost.

## Free-Roving Subsea Cable Inspection Drone

### Consolidated Mass and Cost Budgets

2025-11-11

#### Mass & Cost Summary

Mass & Cost Summary		
Subsystem	Mass (kg)	Cost (\$)
Propulsion	1.88	1,278
Power	4.55	1,680
Control & Navigation	0.62	665
Payload	0.96	3,320
Communications	0.12	410
Structure	5.50	1,280
Assembly & Tools	—	200
<b>Total</b>	<b>15.67 kg</b>	<b>\$10,840</b>

▪ **Mass:** 15.67 kg total, providing a 37% margin under the 25 kg limit.  
▪ **Cost:** \$10,840 base build, much cheaper  
▪ **Key Drivers:** Power/Structure are largest mass contributors; Payload (Ping360) is the largest cost.

**(Mass Details)** The mass budget shows the AUV will weigh approximately 15.7 kg, well under the 25 kg limit with 37 percent margin. The largest contributors are the structure (35 percent including frame, syntactic foam for buoyancy, and streamlined fairings) and power system (29 percent for three 18Ah batteries). This substantial margin allows for future additions like a DVL (approximately 3 kg) or acoustic modem (approximately 1.5 kg) without exceeding the weight limit.

**(Cost Details)** The estimated build cost of 10,840 dollars represents 20-25 percent of comparable commercial AUV systems (50-150K range). The Ping360 sonar is the single most expensive component at 2,750 dollars. Optional additions like the EvoLogics acoustic modem (12K) or Nortek DVL (20K) would increase total cost but are not required for basic cable inspection missions. The design prioritizes COTS components to minimize cost while maintaining technical performance.

2025-11-11

## Feasibility Assessment and Conclusions

# Requirements Verification

Requirement	Specification	Achieved	Status
Mass constraint	<25 kg	15.7 kg	Met
Endurance	2 hours	2.5 hrs (mixed)	Met
Cruise speed	1 m/s	1 m/s	Met
Peak speed	4 m/s	4 m/s	Met
Payload power	30W	30W (all)	Met
<b>Overall Feasibility</b>		<b>Viable</b>	

## Free-Roving Subsea Cable Inspection Drone

### Feasibility Assessment and Conclusions

#### Requirements Verification

2025-11-11

Requirements Verification

Requirement	Specification	Achieved	Status
Mass constraint	<25 kg	15.7 kg	Met
Endurance	2 hours	2.5 hrs (mixed)	Met
Cruise speed	1 m/s	1 m/s	Met
Peak speed	4 m/s	4 m/s	Met
Payload power	30W	30W (all)	Met
<b>Overall Feasibility</b>		<b>Viable</b>	

All requirements have been met. Mass is 15.7 kilograms, 37 percent under the 25 kilogram limit. Endurance is 2.5 hours with 80/20 mission profile, exceeding 2 hour requirement. Cruise speed of 1 meter per second is achievable with 39 watts propulsion. Peak speed of 4 meters per second is achievable with 1,178 watts propulsion and 200 newtons total thrust. Payload power is 30 watts total for camera, sonar, and lighting.

The key enabler is the mission profile approach: 80 percent time at 1 meter per second cruise, 20 percent at 4 meters per second sprint. Sustained 4 meters per second operation would require 2,450 watt-hours for 2 hours, exceeding weight constraints. The mixed profile reduces average power to 314 watts, making the design feasible.

# Conclusions

## Critical Engineering Insights:

- ① **Power scales as  $v^3$ :** 4 m/s requires 30x more power than 1 m/s
- ② **Mission profile approach:** Mixed speed profile (80% cruise) enables 2-hour endurance
- ③ **Hydrodynamic optimization critical:** Low  $C_D$  (0.28-0.32) essential for achieving 4 m/s
- ④ **Component selection:** T200 thrusters offer best thrust-to-cost ratio (0.36-0.42)

## Strengths:

- COTS components (proven)
- 37% mass margin
- 25% endurance margin
- Modular design

## Constraints:

- 23% thrust margin
- Low-drag hull required
- IMU drift without DVL
- Acoustic comms \$12K

## Free-Roving Subsea Cable Inspection Drone Feasibility Assessment and Conclusions

2025-11-11

### Conclusions

The fundamental physics constraint is that power scales with velocity cubed. Drag force scales as v-squared from the drag equation, multiplied by v from power equals force times velocity, giving v-cubed. Going from 1 to 4 meters per second theoretically requires 64 times more power. Thruster efficiency variations reduce this to 30 times in practice.

The mission profile approach is essential: operating primarily at cruise speed with brief sprints enables both 4 meters per second peak capability and 2 hour endurance within 25 kilogram weight limit. Sustained high speed is thermodynamically incompatible with the weight constraint.

Hydrodynamic optimization is critical. Low drag coefficient of 0.28 to 0.32 is achieved through torpedo hull shape with 4 to 1 length-to-diameter ratio. Higher drag would require more thrust, more power, heavier batteries.

Component selection focused on cost-effectiveness. T200 thrusters provide 0.38 newtons per dollar thrust-to-cost ratio, 6 to 20 times better than alternatives. COTS components from Blue Robotics ecosystem reduce integration risk and cost.

The design is technically feasible with 23 percent thrust margin, 37 percent mass margin, and 25 percent endurance margin. Main constraint is the tight thrust

## Conclusions

### Critical Engineering Insights:

- Power scales as  $v^3$ : 4 m/s requires 30x more power than 1 m/s
- Mission profile approach: Mixed speed profile (80% cruise) enables 2-hour endurance
- Hydrodynamic optimization critical: Low  $C_D$  (0.28-0.32) essential for achieving 4 m/s
- Component selection: T200 thrusters offer best thrust-to-cost ratio (0.36-0.42)

### Strengths:

- COTS components (proven)
- 37% mass margin
- 25% endurance margin
- Modular design

### Constraints:

- 23% thrust margin
- Low-drag hull required
- IMU drift without DVL
- Acoustic comms \$12K

# Appendix: Core Component Datasheets

## Component Specifications

- Blue Robotics T200 Thruster
- Blue Robotics Navigator Flight Controller
- Blue Robotics Bar30 Depth Sensor
- Blue Robotics 18Ah Lithium-ion Battery
- RockBLOCK 9603N Iridium Modem
- Blue Robotics Ping360 Sonar
- Blue Robotics 3" Watertight Enclosure

## Free-Roving Subsea Cable Inspection Drone

2025-11-11

### └ Appendix: Core Component Datasheets

#### Component Specifications

- Blue Robotics T200 Thruster
- Blue Robotics Navigator Flight Controller
- Blue Robotics Bar30 Depth Sensor
- Blue Robotics 18Ah Lithium-ion Battery
- RockBLOCK 9603N Iridium Modem
- Blue Robotics Ping360 Sonar
- Blue Robotics 3" Watertight Enclosure

# T200 Thruster Specifications

## Performance:

- Max thrust (fwd): 5.1 kgf (50 N) @ 16V
- Max thrust (rev): 4.1 kgf (40 N) @ 16V
- Voltage range: 6-20V (12-16V nominal)
- Max current: 25A
- Max power: 350W
- Efficiency: 55% @ high load

## Physical:

- Depth rating: 300m (tested 3000m)
- Dimensions: 113mm L × 100mm dia.
- Mass: 344g (air), 156g (water)
- Propeller: 76mm diameter, CW/CCW
- Motor: Flooded brushless DC
- Materials: PC body, 316 SS fasteners
- Cost: \$119-139

Source: Blue Robotics T200 Datasheet, bluerobotics.com

# Free-Roving Subsea Cable Inspection Drone

2025-11-11

## └ T200 Thruster Specifications

T200 Thruster Specifications

### Performance:

- Max thrust (fwd): 5.1 kgf (50 N) @ 16V
- Max thrust (rev): 4.1 kgf (40 N) @ 16V
- Voltage range: 6-20V (12-16V nominal)
- Propeller: 76mm diameter, CW/CCW
- Motor: Flooded brushless DC
- Materials: PC body, 316 SS fasteners
- Cost: \$119-139

### Physical:

- Depth rating: 300m (tested 3000m)
- Dimensions: 113mm L × 100mm dia.
- Mass: 344g (air), 156g (water)
- Propeller: 76mm diameter, CW/CCW
- Motor: Flooded brushless DC
- Materials: PC body, 316 SS fasteners
- Cost: \$119-139

Source: Blue Robotics T200 Datasheet, bluerobotics.com

# Navigator Flight Controller Specifications

## Sensors:

- IMU 1: ICM-20602 (6-axis)
- IMU 2: ICM-42688-P (high precision)
- Magnetometer: 2× BMM150 (dual)
- Barometer: BMP388
- Gyro noise: 2.8 mdps/Hz (ICM-42688-P)
- Accel noise: 70  $\mu\text{g}/\text{Hz}$

Source: Blue Robotics Navigator Datasheet, bluerobotics.com

## I/O & Integration:

- PWM outputs: 16 channels
- Serial ports: 4× UART
- I2C ports: 2×
- ADC: 2× 16-bit
- Platform: Raspberry Pi 4 (direct mount)
- Software: ArduSub, BlueOS
- Power: 8-10W typical
- Cost: \$125-181

# Free-Roving Subsea Cable Inspection Drone

2025-11-11

## Navigator Flight Controller Specifications

Navigator Flight Controller Specifications	
<b>Sensors:</b>	<b>I/O &amp; Integration:</b>
<ul style="list-style-type: none"><li>• IMU 1: ICM-20602 (6-axis)</li><li>• IMU 2: ICM-42688-P (high precision)</li><li>• Magnetometer: 2× BMM150 (dual)</li><li>• Barometer: BMP388</li><li>• Gyro noise: 2.8 mdps/Hz (ICM-42688-P)</li><li>• Accel noise: 70 <math>\mu\text{g}/\text{Hz}</math></li></ul>	<ul style="list-style-type: none"><li>• PWM outputs: 16 channels</li><li>• Serial ports: 4× UART</li><li>• I2C ports: 2×</li><li>• ADC: 2× 16-bit</li><li>• Platform: Raspberry Pi 4 (direct mount)</li><li>• Software: ArduSub, BlueOS</li><li>• Power: 8-10W typical</li><li>• Cost: \$125-181</li></ul>

Source: Blue Robotics Navigator Datasheet, bluerobotics.com

# Bar30 Depth Sensor & 18Ah Battery Specifications

## Bar30 Depth Sensor:

- Sensor: MS5837-30BA
- Pressure range: 0-30 bar (0-300m)
- Resolution: 0.2 mbar (2mm depth)
- Accuracy:  $\pm 200$  mbar ( $\pm 2\text{m}$ ) @ 0-40°C
- Interface: I2C, JST GH 4-pin
- Power:  $\pm 1\text{mA}$  @ 3.3V
- Maintenance: Daily drying recommended
- Cost: \$68-85

Sources: Blue Robotics Bar30 & Battery Datasheets, bluerobotics.com

## 18Ah Lithium-ion Battery:

- Voltage: 14.8V nominal (4S configuration)
- Capacity: 18Ah (266 Wh)
- Energy density: 195 Wh/kg
- Mass: 1.35 kg per battery
- Chemistry: Li-ion 18650 cells
- BMS: Integrated, 30A continuous
- Depth: Enclosure-dependent (300-500m)
- Cost: \$357-400 each

## Free-Roving Subsea Cable Inspection Drone

2025-11-11

### Bar30 Depth Sensor & 18Ah Battery Specifications

Bar30 Depth Sensor:	18Ah Lithium-ion Battery:
• Sensor: MS5837-30BA	• Voltage: 14.8V nominal (4S configuration)
• Pressure range: 0-30 bar (0-300m)	• Pressure range: 0-30 bar (0-300m)
• Resolution: 0.2 mbar (2mm depth)	• Resolution: 0.2 mbar (2mm depth)
• Accuracy: $\pm 200$ mbar ( $\pm 2\text{m}$ ) @ 0-40°C	• Accuracy: $\pm 200$ mbar ( $\pm 2\text{m}$ ) @ 0-40°C
• Interface: I2C, JST GH 4-pin	• Interface: I2C, JST GH 4-pin
• Power: $\pm 1\text{mA}$ @ 3.3V	• Power: $\pm 1\text{mA}$ @ 3.3V
• Maintenance: Daily drying recommended	• Maintenance: Daily drying recommended
• Cost: \$68-85	• Cost: \$68-85
Source: Blue Robotics Bar30 & Battery Datasheets, bluerobotics.com	
Bar30 Depth Sensor: • Sensor: MS5837-30BA • Pressure range: 0-30 bar (0-300m) • Resolution: 0.2 mbar (2mm depth) • Accuracy: $\pm 200$ mbar ( $\pm 2\text{m}$ ) @ 0-40°C • Interface: I2C, JST GH 4-pin • Power: $\pm 1\text{mA}$ @ 3.3V • Maintenance: Daily drying recommended • Cost: \$68-85	
18Ah Lithium-ion Battery: • Voltage: 14.8V nominal (4S configuration) • Capacity: 18Ah (266 Wh) • Energy density: 195 Wh/kg • Mass: 1.35 kg per battery • Chemistry: Li-ion 18650 cells • BMS: Integrated, 30A continuous • Depth: Enclosure-dependent (300-500m) • Cost: \$357-400 each	

# RockBLOCK 9603N & Ping360 Sonar Specifications

## RockBLOCK 9603N Iridium Modem:

- Network: Iridium Short Burst Data
- Message size: 340B uplink, 270B downlink
- Latency: 10-60s average
- Coverage: Global (pole-to-pole)
- Power: 0.8W avg, 6.5W peak transmit
- Dimensions: 45×45×15.5mm, 45g
- Cost: \$260 + \$15/month service

## Ping360 Scanning Sonar:

- Configuration: Mechanical scanning, 360°
- Frequency: 750 kHz
- Range: 2-50m (adjustable)
- Resolution: 400 points/scan, 1-2° angular
- Update rate: 10-20 Hz (2-5s per 360°)
- Power: 5W max, 2W typical
- Depth rating: 300m
- Interface: Serial UART
- Cost: \$2,750

Sources: RockBLOCK 9603N Datasheet (SparkFun); Ping360 Datasheet (Blue Robotics)

## Free-Roving Subsea Cable Inspection Drone

2025-11-11

## RockBLOCK 9603N & Ping360 Sonar Specifications

RockBLOCK 9603N Iridium Modem:	Ping360 Scanning Sonar:
<ul style="list-style-type: none"><li>Network: Iridium Short Burst Data</li><li>Message size: 340B uplink, 270B downlink</li><li>Latency: 10-60s average</li><li>Coverage: Global (pole-to-pole)</li><li>Power: 0.8W avg, 6.5W peak transmit</li><li>Dimensions: 45×45×15.5mm, 45g</li><li>Cost: \$260 + \$15/month service</li></ul>	<ul style="list-style-type: none"><li>Configuration: Mechanical scanning, 360°</li><li>Frequency: 750 kHz</li><li>Range: 2-50m (adjustable)</li><li>Resolution: 400 points/scan, 1-2° angular</li><li>Update rate: 10-20 Hz (2-5s per 360°)</li><li>Power: 5W max, 2W typical</li><li>Depth rating: 300m</li><li>Interface: Serial UART</li><li>Cost: \$2,750</li></ul>

Sources: RockBLOCK 9603N Datasheet (SparkFun); Ping360 Datasheet (Blue Robotics)

# 3" Watertight Enclosure Specifications

## Blue Robotics 3" Aluminum Watertight Enclosure:

### Physical:

- Material: Aluminum 6061-T6
- Surface: Type III hard anodized
- Inner diameter: 74.7mm (2.94")
- Outer diameter: 89mm (3.5")
- Wall thickness: 6.35mm (0.25")
- Lengths: 150, 240, 300, 400mm

### Performance:

- Depth rating: 500m (Gen 2)
- Sealing: Double O-rings per flange
- Penetrators: WetLink compatible
- Test: Vacuum testable (10 inHg)
- Proven: 1000s deployed (BlueROV2)
- Cost: \$200-300 complete

**WetLink Penetrators:** \$12-17 each, 1000m rated, tool-free installation

Source: Blue Robotics Watertight Enclosures Catalog, bluerobotics.com

# Free-Roving Subsea Cable Inspection Drone

2025-11-11

## 3" Watertight Enclosure Specifications

3" Watertight Enclosure Specifications

### Blue Robotics 3" Aluminum Watertight Enclosure:

Physical:	Performance:
<ul style="list-style-type: none"><li>• Material: Aluminum 6061-T6</li><li>• Surface: Type III hard anodized</li><li>• Inner diameter: 74.7mm (2.94")</li><li>• Outer diameter: 89mm (3.5")</li><li>• Wall thickness: 6.35mm (0.25")</li><li>• Lengths: 150, 240, 300, 400mm</li></ul>	<ul style="list-style-type: none"><li>• Depth rating: 500m (Gen 2)</li><li>• Sealing: Double O-rings per flange</li><li>• Penetrators: WetLink compatible</li><li>• Test: Vacuum testable (10 inHg)</li><li>• Proven: 1000s deployed (BlueROV2)</li><li>• Cost: \$200-300 complete</li></ul>

WetLink Penetrators: \$12-17 each, 1000m rated, tool-free installation

Source: Blue Robotics Watertight Enclosures Catalog, bluerobotics.com

# Free-Roving Subsea Cable Inspection Drone

2025-11-11

## └ References

References & Propulsion
• T200 Thruster: <a href="https://bluerobotics.com/store/thrusters/t100-t200-thrusters/t200-thruster-r2-rp/">https://bluerobotics.com/store/thrusters/t100-t200-thrusters/t200-thruster-r2-rp/</a>
• T200 Performance Data: <a href="https://cad.bluerobotics.com/T200-Public-Performance-Data-10-20-V-September-2019.xlsx">https://cad.bluerobotics.com/T200-Public-Performance-Data-10-20-V-September-2019.xlsx</a>
• Basic ESC 30A: <a href="https://bluerobotics.com/store/thrusters/speed-controllers/besc30-r3/">https://bluerobotics.com/store/thrusters/speed-controllers/besc30-r3/</a>
• Blue Robotics 18Ah Battery: <a href="https://bluerobotics.com/store/comm-control-power/powersupplies-batteries/battery-li-4s-15-6ah/">https://bluerobotics.com/store/comm-control-power/powersupplies-batteries/battery-li-4s-15-6ah/</a>
• Samsung INR18650-35E Datasheet: <a href="https://www.orbtronic.com/content/samsung-35e-datasheet-inr18650-35e.pdf">https://www.orbtronic.com/content/samsung-35e-datasheet-inr18650-35e.pdf</a>
• SubCtech PowerPack: <a href="https://subctech.com/ocean-power/subsea-batteries/">https://subctech.com/ocean-power/subsea-batteries/</a>
• Navigator Flight Controller: <a href="https://bluerobotics.com/store/comm-control-power/control/navigator/">https://bluerobotics.com/store/comm-control-power/control/navigator/</a>
• Bar30 Depth Sensor: <a href="https://bluerobotics.com/store/sensors-cameras/sensors/bar30-sensor-r1/">https://bluerobotics.com/store/sensors-cameras/sensors/bar30-sensor-r1/</a>
• MS5837-30BA Sensor: <a href="https://www.te.com/commerce/DocumentDelivery/DDEController?Action=showdoc&amp;DocId=DataSheet%7FMS5837-30BA%7FB1%7Fpdf">https://www.te.com/commerce/DocumentDelivery/DDEController?Action=showdoc&amp;DocId=DataSheet%7FMS5837-30BA%7FB1%7Fpdf</a>
• VectorNav VN-100: <a href="https://www.navtechgps.com/wp-content/uploads/VN100_ProductBrief_DS.pdf">https://www.navtechgps.com/wp-content/uploads/VN100_ProductBrief_DS.pdf</a>
• Nortek DVL1000-300m: <a href="https://www.nortekgroup.com/products/dvl-1000-300m">https://www.nortekgroup.com/products/dvl-1000-300m</a>
• Water Linked DVL A50: <a href="https://waterlinked.com/datasheets/dvl-a50">https://waterlinked.com/datasheets/dvl-a50</a>

# Free-Roving Subsea Cable Inspection Drone

2025-11-11

## └ References

Category	Link
Communications	<ul style="list-style-type: none"><li>RockBLOCK 9603N: <a href="https://cdn.sparkfun.com/assets/4/d/2/1/1/DS_Iridium_9603_Datasheet_031720_2_.pdf">https://cdn.sparkfun.com/assets/4/d/2/1/1/DS_Iridium_9603_Datasheet_031720_2_.pdf</a></li><li>RockBLOCK Developer Guide: <a href="https://cdn.sparkfun.com/assets/6/d/4/c/a/RockBLOCK-9603-Developers-Guide_1.pdf">https://cdn.sparkfun.com/assets/6/d/4/c/a/RockBLOCK-9603-Developers-Guide_1.pdf</a></li><li>EvoLogics S2C Acoustic Modems: <a href="https://www.subsea2020.com/evologics">https://www.subsea2020.com/evologics</a></li><li>LinkQuest UWM2000H: <a href="https://www.oceanscan.net/p-LinkQuest-UWM2000H-Underwater-Modem">https://www.oceanscan.net/p-LinkQuest-UWM2000H-Underwater-Modem</a></li></ul>
Imaging & Sensors	<ul style="list-style-type: none"><li>Low-Light HD Camera: <a href="https://bluerobotics.com/store/sensors-cameras/cameras/cam-usb-low-light-r1/">https://bluerobotics.com/store/sensors-cameras/cameras/cam-usb-low-light-r1/</a></li><li>Ping360 Sonar: <a href="https://bluerobotics.com/store/sonars/imaging-sonars/ping360-sonar-r1-rp/">https://bluerobotics.com/store/sonars/imaging-sonars/ping360-sonar-r1-rp/</a></li><li>SubC Rayfin Micro: <a href="https://www.outlandtech.com/product-page/subc-imaging-rayfin-micro-camera-500m">https://www.outlandtech.com/product-page/subc-imaging-rayfin-micro-camera-500m</a></li><li>Lumen Light: <a href="https://bluerobotics.com/store/thrusters/lights/lumen-r2-rp/">https://bluerobotics.com/store/thrusters/lights/lumen-r2-rp/</a></li></ul>
Mechanical Components	<ul style="list-style-type: none"><li>3" Watertight Enclosures: <a href="https://bluerobotics.com/store/watertight-enclosures/wte-vp/">https://bluerobotics.com/store/watertight-enclosures/wte-vp/</a></li><li>WetLink Penetrators: <a href="https://bluerobotics.com/store/cables-connectors/penetrators/wlp-vp/">https://bluerobotics.com/store/cables-connectors/penetrators/wlp-vp/</a></li><li>Aluminum Tubes Design: <a href="https://bluerobotics.com/new-products-aluminum-tubes/">https://bluerobotics.com/new-products-aluminum-tubes/</a></li></ul>

# References II

## Communications:

- RockBLOCK 9603N: [https://cdn.sparkfun.com/assets/4/d/2/1/1/DS\\_Iridium\\_9603\\_Datasheet\\_031720\\_2\\_.pdf](https://cdn.sparkfun.com/assets/4/d/2/1/1/DS_Iridium_9603_Datasheet_031720_2_.pdf)
- RockBLOCK Developer Guide: [https://cdn.sparkfun.com/assets/6/d/4/c/a/RockBLOCK-9603-Developers-Guide\\_1.pdf](https://cdn.sparkfun.com/assets/6/d/4/c/a/RockBLOCK-9603-Developers-Guide_1.pdf)
- EvoLogics S2C Acoustic Modems: <https://www.subsea2020.com/evologics>
- LinkQuest UWM2000H: <https://www.oceanscan.net/p-LinkQuest-UWM2000H-Underwater-Modem>

## Imaging & Sensors:

- Low-Light HD Camera: <https://bluerobotics.com/store/sensors-cameras/cameras/cam-usb-low-light-r1/>
- Ping360 Sonar: <https://bluerobotics.com/store/sonars/imaging-sonars/ping360-sonar-r1-rp/>
- SubC Rayfin Micro: <https://www.outlandtech.com/product-page/subc-imaging-rayfin-micro-camera-500m>
- Lumen Light: <https://bluerobotics.com/store/thrusters/lights/lumen-r2-rp/>

## Mechanical Components:

- 3" Watertight Enclosures: <https://bluerobotics.com/store/watertight-enclosures/wte-vp/>
- WetLink Penetrators: <https://bluerobotics.com/store/cables-connectors/penetrators/wlp-vp/>
- Aluminum Tubes Design: <https://bluerobotics.com/new-products-aluminum-tubes/>

# References III

## Commercial AUV Platforms:

- ➊ BlueROV2: <https://bluerobotics.com/store/rov/bluerov2/>
- ➋ ecoSUB m-Power+: <https://www.ecosub.uk/ecosubm5---500-m-rated-small-auv.html>
- ➌ ecoSUB Datasheet: <https://www.unmannedsystemstechnology.com/wp-content/uploads/2024/05/240305-ecoSUBm-P-datasheet.pdf>
- ➍ L3Harris Iver3: <https://www.l3harris.com/sites/default/files/2022-11/ims-maritime-Iver3-Spec-Sheet.pdf>
- ➎ Boxfish AUV: <https://www.boxfishrobotics.com/products/boxfish-auv/>

## Hydrodynamics & Engineering:

- ➏ MDPI - CFD Study Torpedo AUV: <https://www.mdpi.com/2311-5521/6/7/252>
- ➐ SCIRP - AUV Drag Analysis: [https://www.scirp.org/html/2-2320148\\_49513.htm](https://www.scirp.org/html/2-2320148_49513.htm)
- ➑ Pressure Vessel Design: <https://philipmcgaw.com/pressure-vessel/>
- ➒ DOE - Powering the Blue Economy: <https://www.energy.gov/sites/prod/files/2019/03/f61/Chapter%203.pdf>

# Free-Roving Subsea Cable Inspection Drone

2025-11-11

## ↳ References

Commercial AUV Platforms
BlueROV2: <a href="https://bluerobotics.com/store/rov/bluerov2/">https://bluerobotics.com/store/rov/bluerov2/</a>
ecoSUB m-Power+: <a href="https://www.ecosub.uk/ecosubm5---500-m-rated-small-auv.html">https://www.ecosub.uk/ecosubm5---500-m-rated-small-auv.html</a>
ecoSUB Datasheet: <a href="https://www.unmannedsystemstechnology.com/wp-content/uploads/2024/05/240305-ecoSUBm-P-datasheet.pdf">https://www.unmannedsystemstechnology.com/wp-content/uploads/2024/05/240305-ecoSUBm-P-datasheet.pdf</a>
L3Harris Iver3: <a href="https://www.l3harris.com/sites/default/files/2022-11/ims-maritime-Iver3-Spec-Sheet.pdf">https://www.l3harris.com/sites/default/files/2022-11/ims-maritime-Iver3-Spec-Sheet.pdf</a>
Boxfish AUV: <a href="https://www.boxfishrobotics.com/products/boxfish-auv/">https://www.boxfishrobotics.com/products/boxfish-auv/</a>

Hydrodynamics & Engineering
MDPI - CFD Study Torpedo AUV: <a href="https://www.mdpi.com/2311-5521/6/7/252">https://www.mdpi.com/2311-5521/6/7/252</a>
SCIRP - AUV Drag Analysis: <a href="https://www.scirp.org/html/2-2320148_49513.htm">https://www.scirp.org/html/2-2320148_49513.htm</a>
Pressure Vessel Design: <a href="https://philipmcgaw.com/pressure-vessel/">https://philipmcgaw.com/pressure-vessel/</a>
DOE - Powering the Blue Economy: <a href="https://www.energy.gov/sites/prod/files/2019/03/f61/Chapter%203.pdf">https://www.energy.gov/sites/prod/files/2019/03/f61/Chapter%203.pdf</a>