Free-Roving Subsea Cable Inspection Drone : A Technical Feasibility Study

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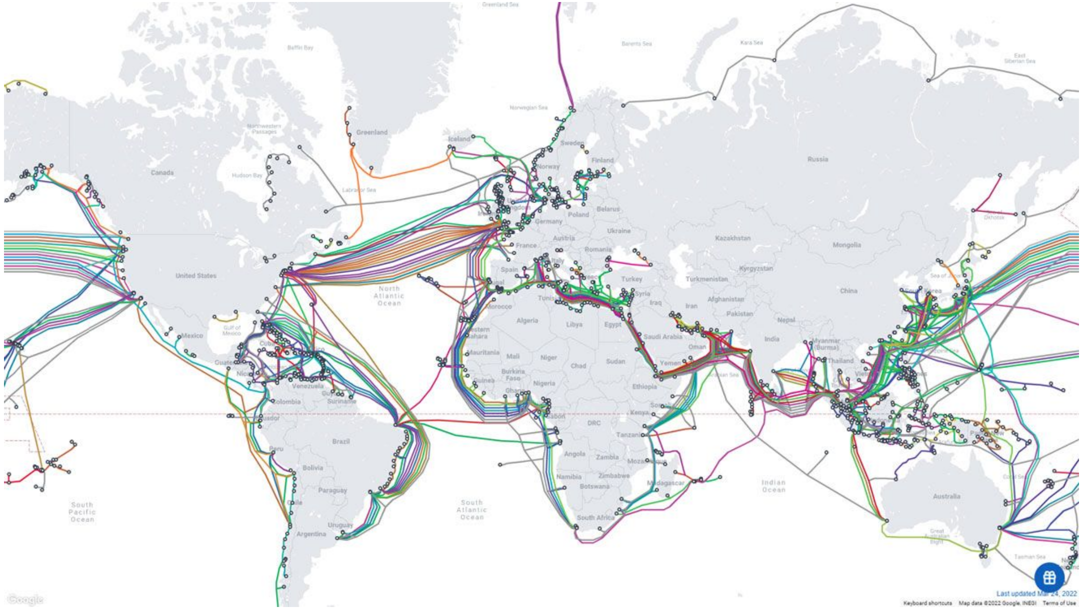
The Problem - Subsea Cable Inspection

- Backbone of the modern internet infrastructure, carrying 97-99% of all intercontinental data traffic.
- 500+ cables worldwide , a total of 14 million kilometers
- Around 2-5 cm in diameter,



The Problem - Subsea Cable Inspection

- Averages 200 faults a year, particularly in shallow waters (~200m)
  - Shetland Islands cutoff in 2022
- Traditional inspection methods use tethered ROVs, which can limit motion and increase cost

Problem Definition

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"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. "

Operating Environment

- ρgh gives ~25 bar pressure, ~4 °C seawater, insulation for electronics and waterproofing
- Saltwater corrosion & biofouling, limited to plastic materials
- Far below the surface, limited visibility. Not affected by surface wave currents driven by wind
- High signal attenuation

Problem Definition

Hydrodynamics

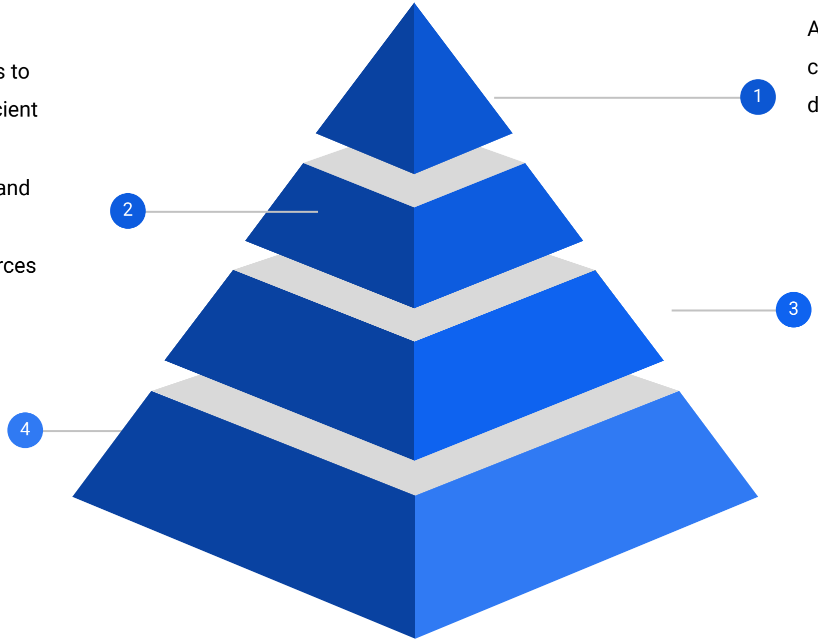
Analyze underwater drag forces to estimate thrust needed for efficient movement.

- Degrees of freedom and stability control
- Drag and resistive forces

Mechanical Design

Develop the mechanical system ensuring all components fit within the 25kg weight limit.

- Buoyancy system
- Structural integrity



Communication and Control

Assess feasibility of underwater wireless communication methods for control and data transfer.

- Attenuation in seawater
- Navigation and mapping

Power Consumption

Identify energy storage limits to define mission duration and vehicle size within constraints.

- 2 hours continuous operation
- Support 30W load as well as communications and mechanical systems

Existing Solutions

Iver3 by L3Harris

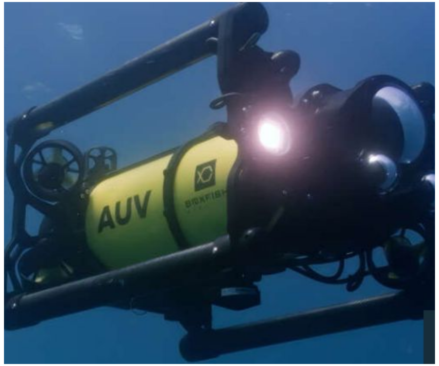
- Rated at 200m
- 27-40kg depending on configuration
- 8-14-hour endurance by 784 WHr of rechargeable lithium-ion batteries
- Single thruster, fins for pitch/yaw control

ecoSUB

- Rated at 500m
- 4kg depending on configuration
- 10-hour endurance by alkaline batteries
- Single thruster, fins for pitch/yaw control

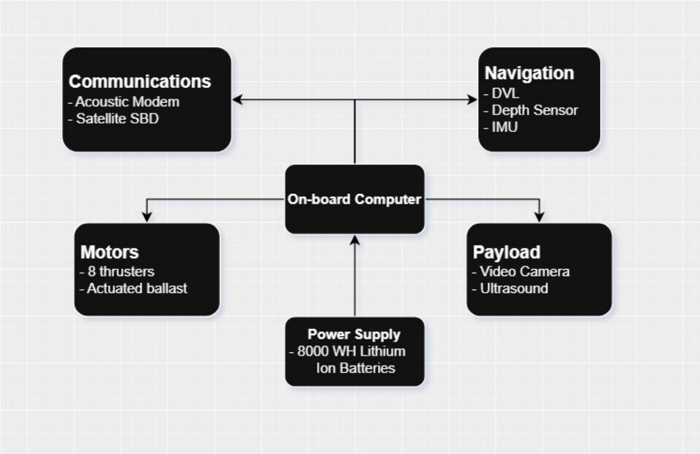
Boxfish AUV

- Rated up to 600m
- 25kg with Salt water ballast
- Up to 10 hours by 600Whr Lithium Polymer batteries
- 8 3D-vectored thrusters allowing 6 DoF



Technical Approach

System Design



- Autonomous/programmable solution to remove the need for high-quality real-time data transmission which limits untethered ROVs
- 8-thruster design for stability and hovering capabilities for detailed inspection
- Reinforced acrylic casing for

Communications and Control

- Underwater Communication :
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Communications and Control

- Autonomous control with on-board IMU and DVL for real-time navigation and mapping

Surface :

- RF transmitter : WiFi 802.11n Ethernet standard (possibly needs a base station / emitter on the boat)
- Satellite : Iridium SBD for retrieval and

Underwater :

- Signal attenuation due to water :
    - Received power = Transmitted power - Transmission loss + Array gain
    - Transmission Loss (TL) = $20\log_{10}(R) + \alpha R \times 10^{-3}$ Where: R = range (m)
    - α = absorption coefficient ≈ 3 dB/km at 25 kHz
    - For R = 500m: TL = $20\log_{10}(500) + 3 \times 0.5 = 54 + 1.5 = 55.5$ dB
    - Source level: 180 dB re 1 μPa at 1m
    - Noise level: 60 dB (sea state 3)
    - Array gain: 10 dB
    - Required SNR: 10 dB
    - Received level = 180 - 55.5 + 10 = 134.5 dB
    - Margin = 134.5 - 60 - 10 = 64.5 dB ✓
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Hydrodynamics

Thruster profiling :

- To keep control and power consumption low, we opted for a single thruster design with fins for pitch and yaw control

Power Consumption

Mechanical Design

- Ballast design :
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Cost and Feasibility

Conclusion