Technology
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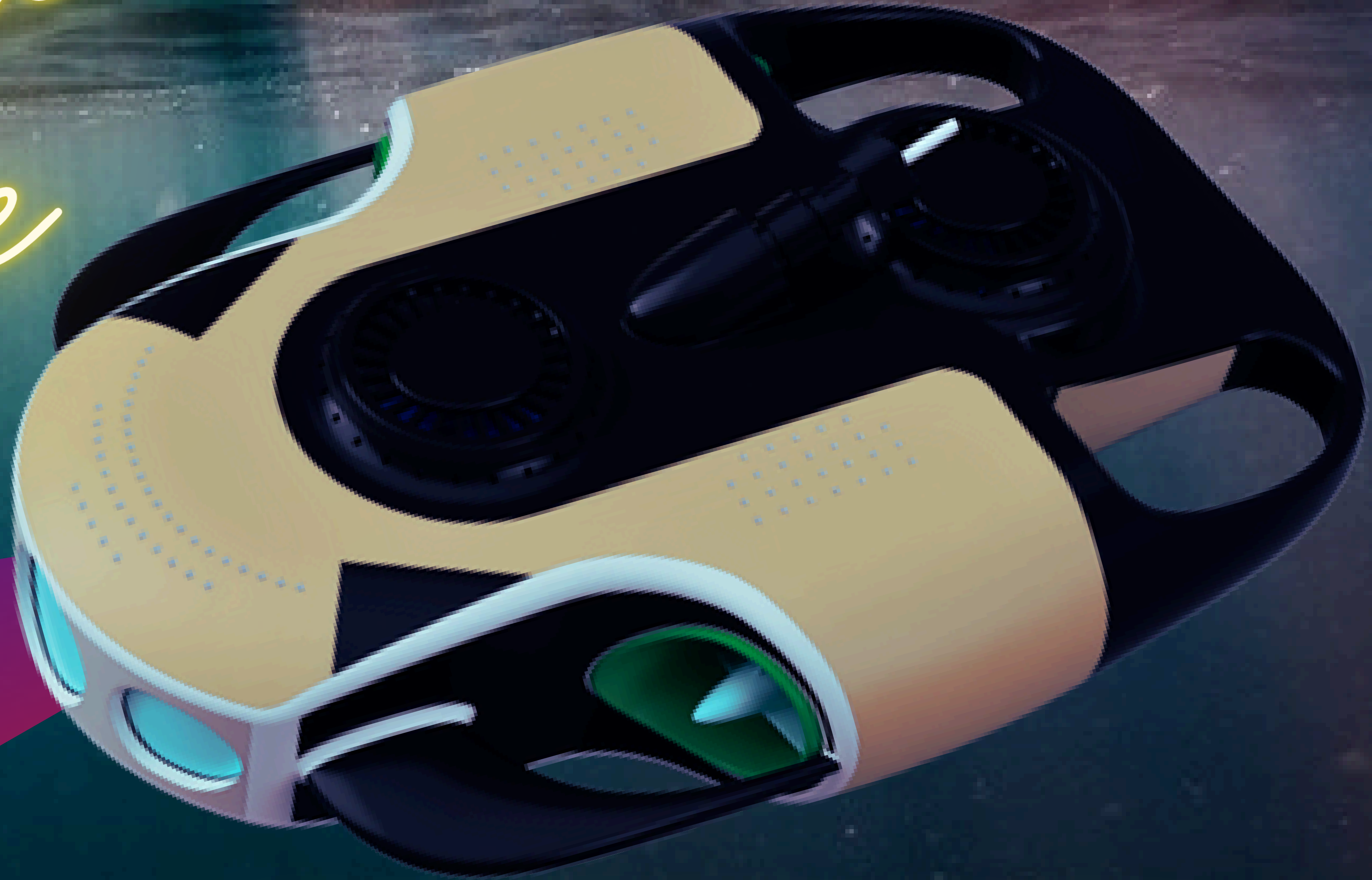
Underwater Vehicle Design Challenge



POSEIDON

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MARINA TRENCH

The Mariana Trench, shown in this breathtaking picture, stands as the deepest section of the Earth's oceans, reaching an impressive depth of around 36,000 feet (10,994 meters) at its lowest spot, named Challenger Deep. This extensive, curved trench in the Earth's crust spans more than 1,550 miles (2,500 kilometers) long and 45 miles (70 kilometers) wide, showcasing the remote and enigmatic nature of this underwater chasm.

LOCATION

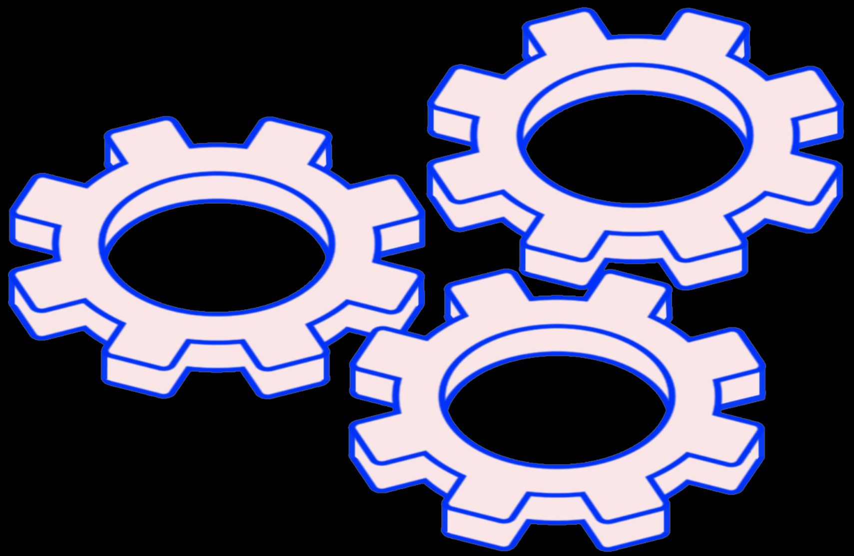
36,000 feet (10,994 meters) at its Challenger Deep

TEMPERATURE

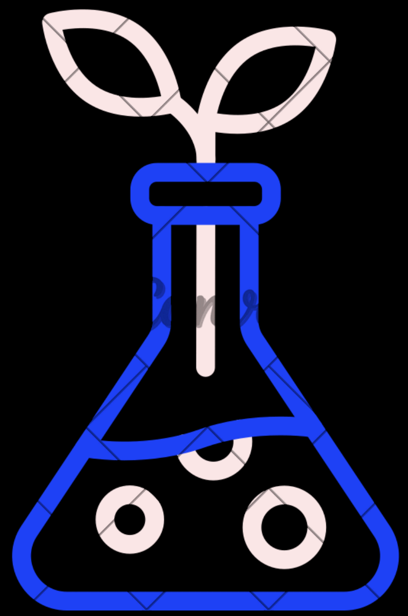
1 to 4°C

POSEIDON

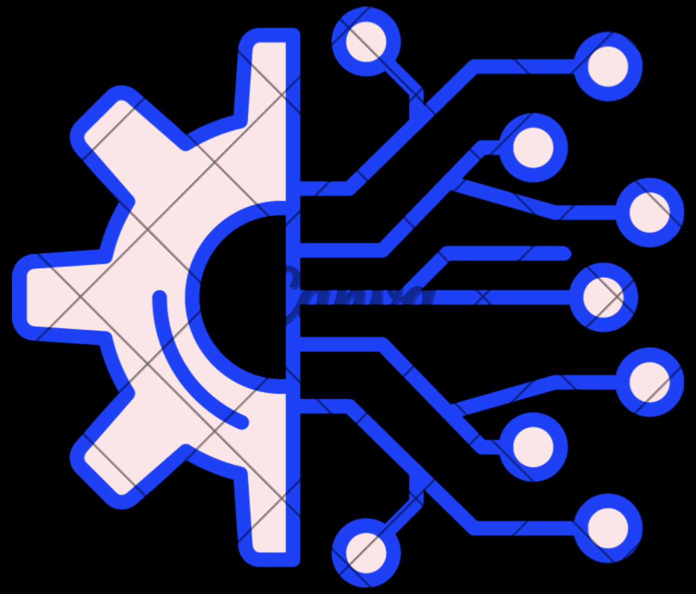
MECHANICAL MODULE



BIOSCIENCE MODULE

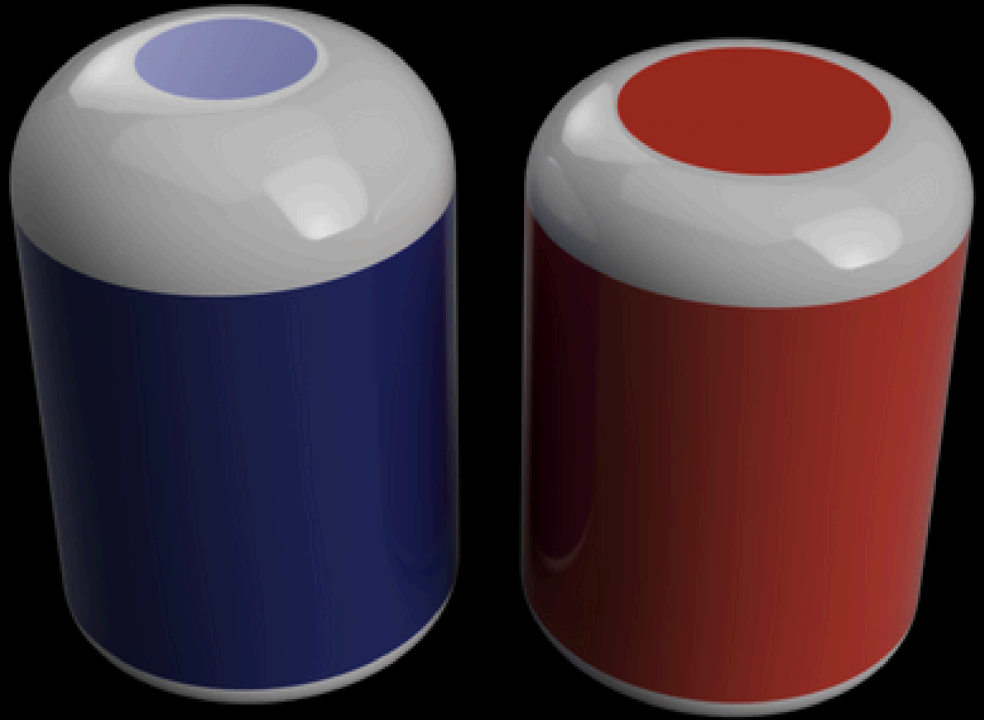


ELECTRONICS & SOFTWARE MODULE

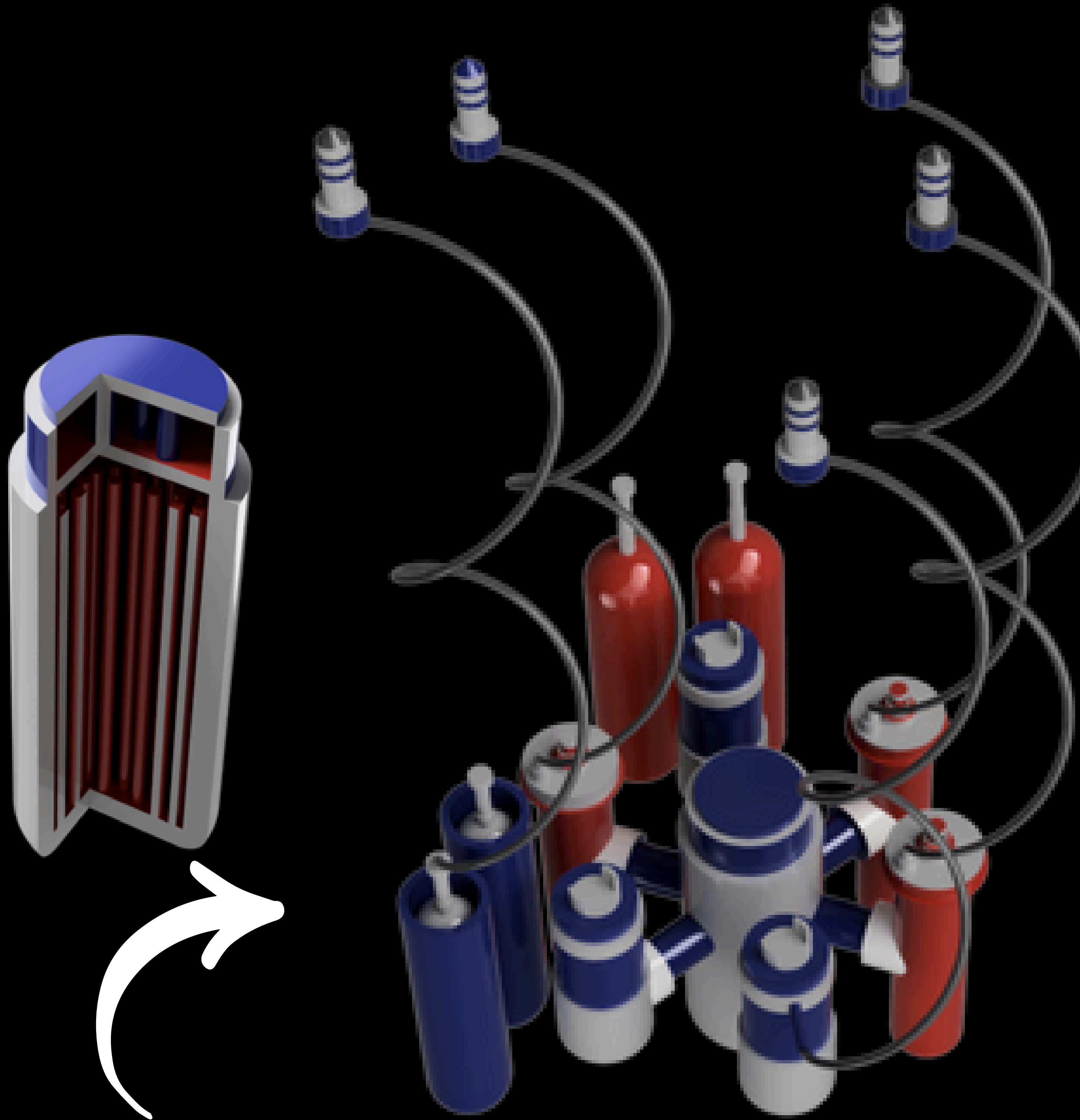


PRIMARY COMPONENTS

Chassis

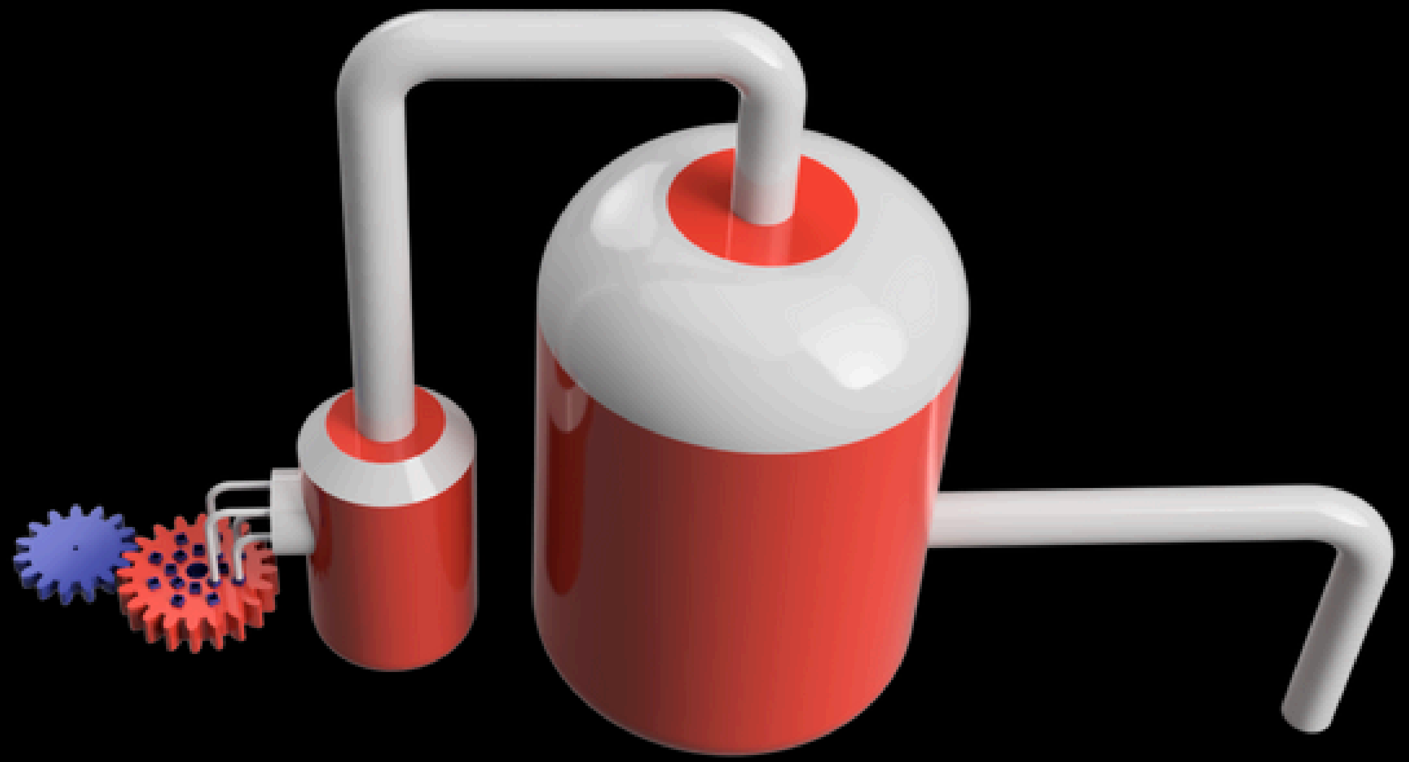


Ballast Tanks

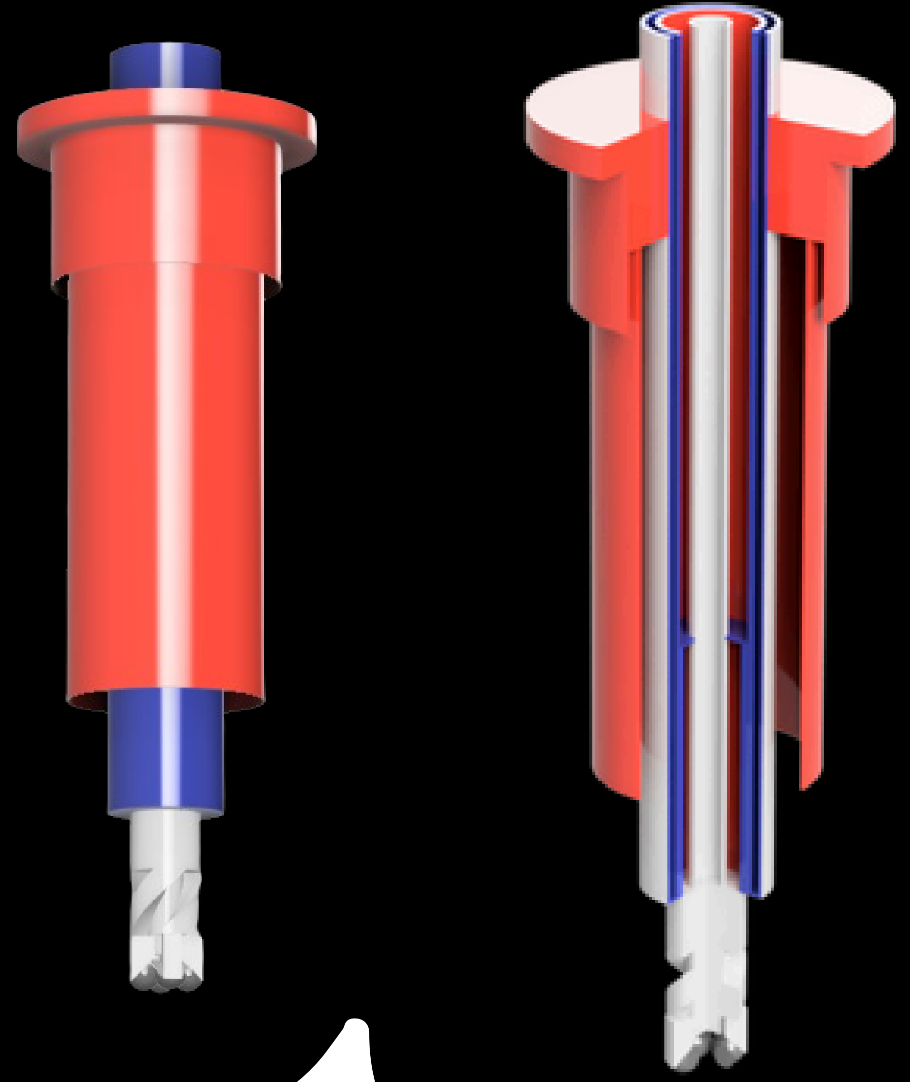


Nuclear Reactor

SECONDARY COMPONENTS



Bio Assembly



Riser Drilling System

Suction Gripper

01

MECHANICAL MODULE

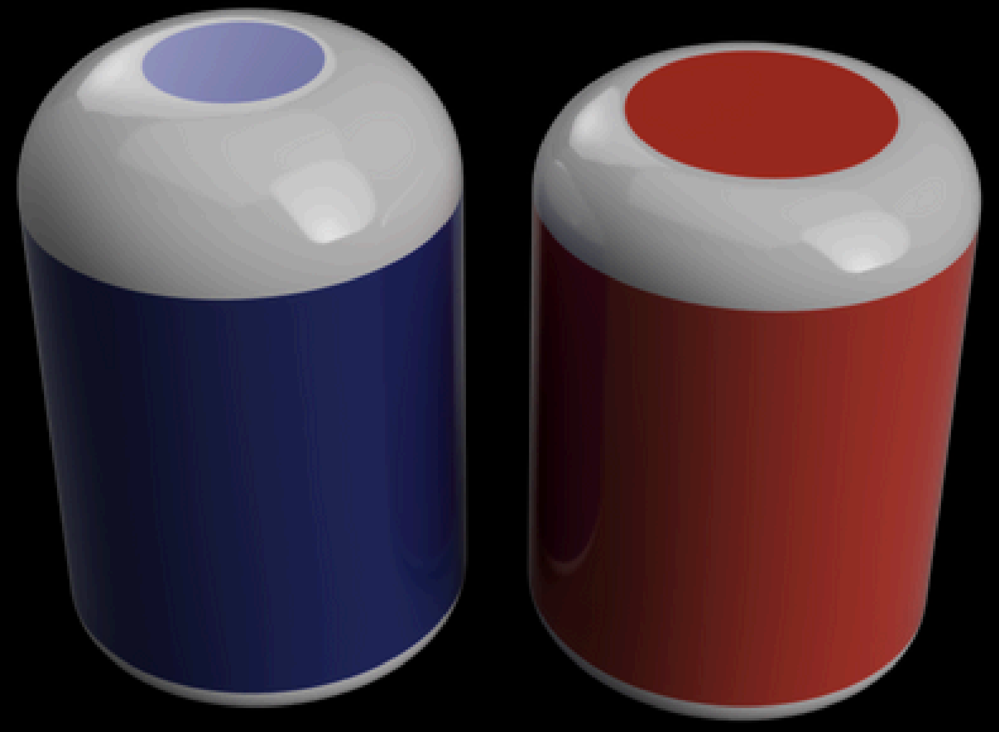
- Provide Structural Integrity
- Provide Protection from harsh environment
- Houses all subsystems and components

CHASSIS

- 50 mm thick shell made of Titanium Vanadium Alloy Ti6AlV4.
- Designed for minimal drag and maximum efficiency.
- Factor of Safety of 5.74 and max displacement 0.072 mm under depth of 15kms of Hydrostatic Load.

BALLAST SYSTEM

- Variable Ballast system designed for pressure at 11km depth
- Controlled via 2 water and 2 compressed air tanks.
- Features automated control, sensors, and redundancy to ensure reliable operation under immense pressure and in emergency situations



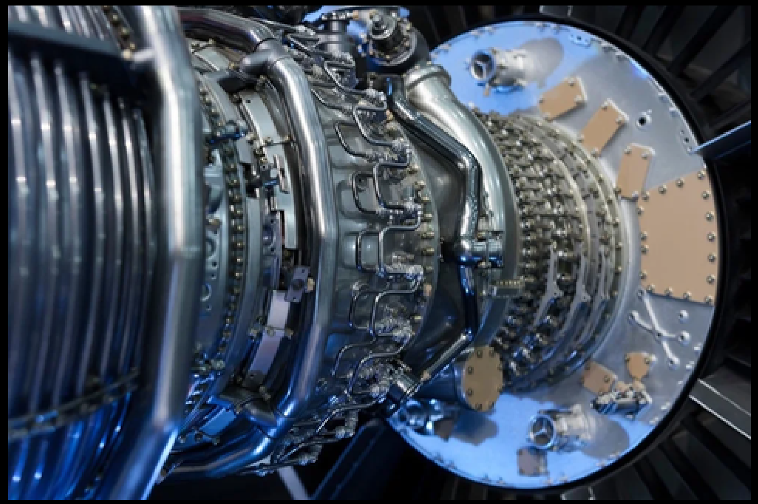
THRUSTERS

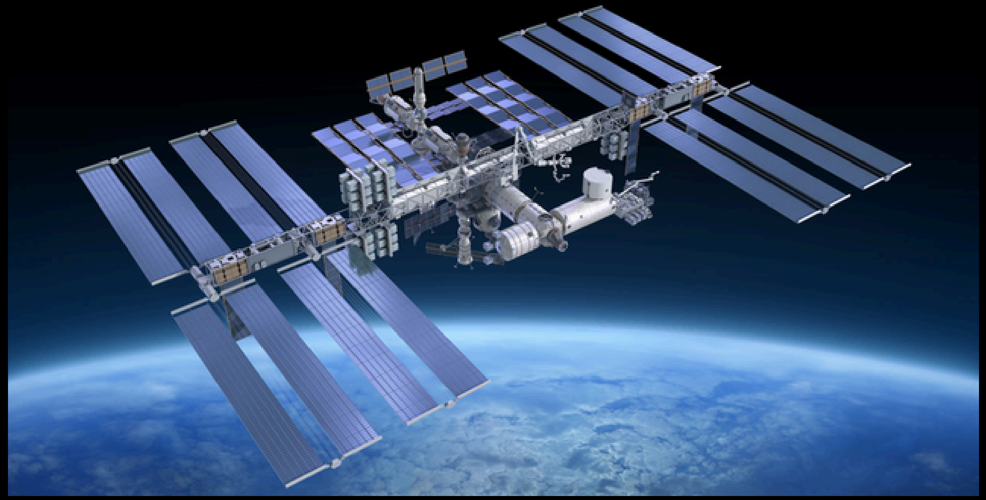
Depth Rating

- Plastic - 500m
- Aluminium - 6000m
- Titanium-Vanadium - 12000m

MATERIALS USED

	TITANIUM VANADIUM ALLOY	2219-T6 ALUMINIUM ALLOY
Pressure Resistance	✓	
Lightweight design		✓
Corrosion Resistance	✓	
Strength to Wt Ratio	✓	





02

BIOSCIENCE MODULE

- Identification and Collection of samples.
- Experimentation and Analysis of collected samples
- Develop a scientific understanding of the geology of the exploration site

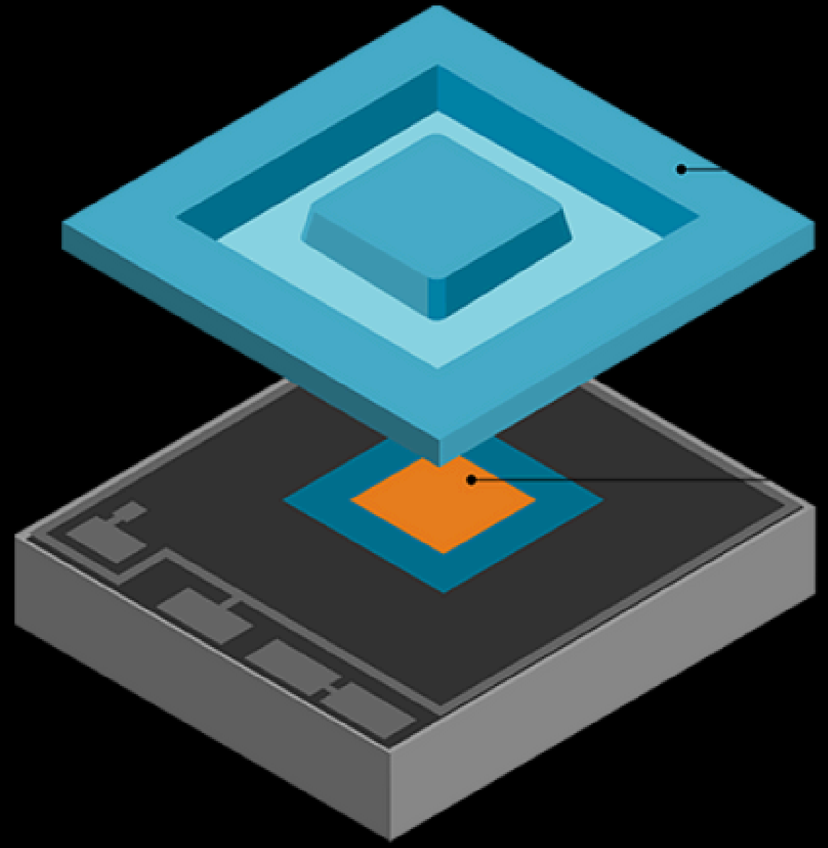
COMPONENTS

DRILL ASSEMBLY

TESTING ASSEMBLY

- Environmental Analysis
- Soil and Rock Analysis
- Subsurface Analysis
- Marine biological analysis

ENVIRONMENT SENSORY ANALYSIS STATION (ESAS)



LOCATION

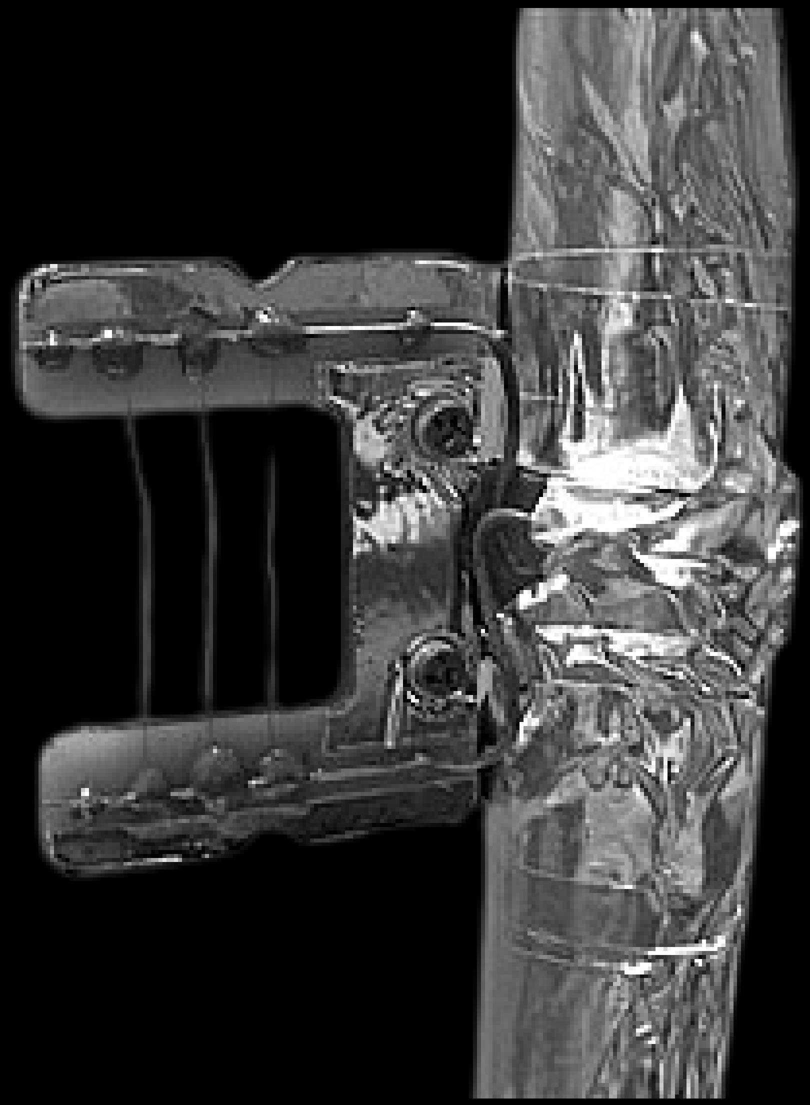
Rover Deck and mast

01 Air Temperature Sensor

02 Pressure Sensor

03 Humidity Sensor

04 Wind and dust Sensor



CAMERAS

<u>Blueview BV5000:</u>

The Blueview BV5000 captures high-resolution images and video footage underwater for scientific documentation and monitoring of marine life.

Specs- Maximum range 300m (980ft.)

INERTIAL NAVIGATION SENSOR (INS)

<u>Honeywell HG4930:</u>

The Honeywell HG4930 is a high-performance inertial navigation system that uses accelerometers and gyroscopes to calculate the vehicle's orientation, velocity, and position.

<u>Specs-</u> Gyroscope Operating Range -400°/s to +400°/s^3 Accelerometer Operating Range -20 g to + 20g Operating Temperature Range -54°C to +85°C

RADIATION SENSOR

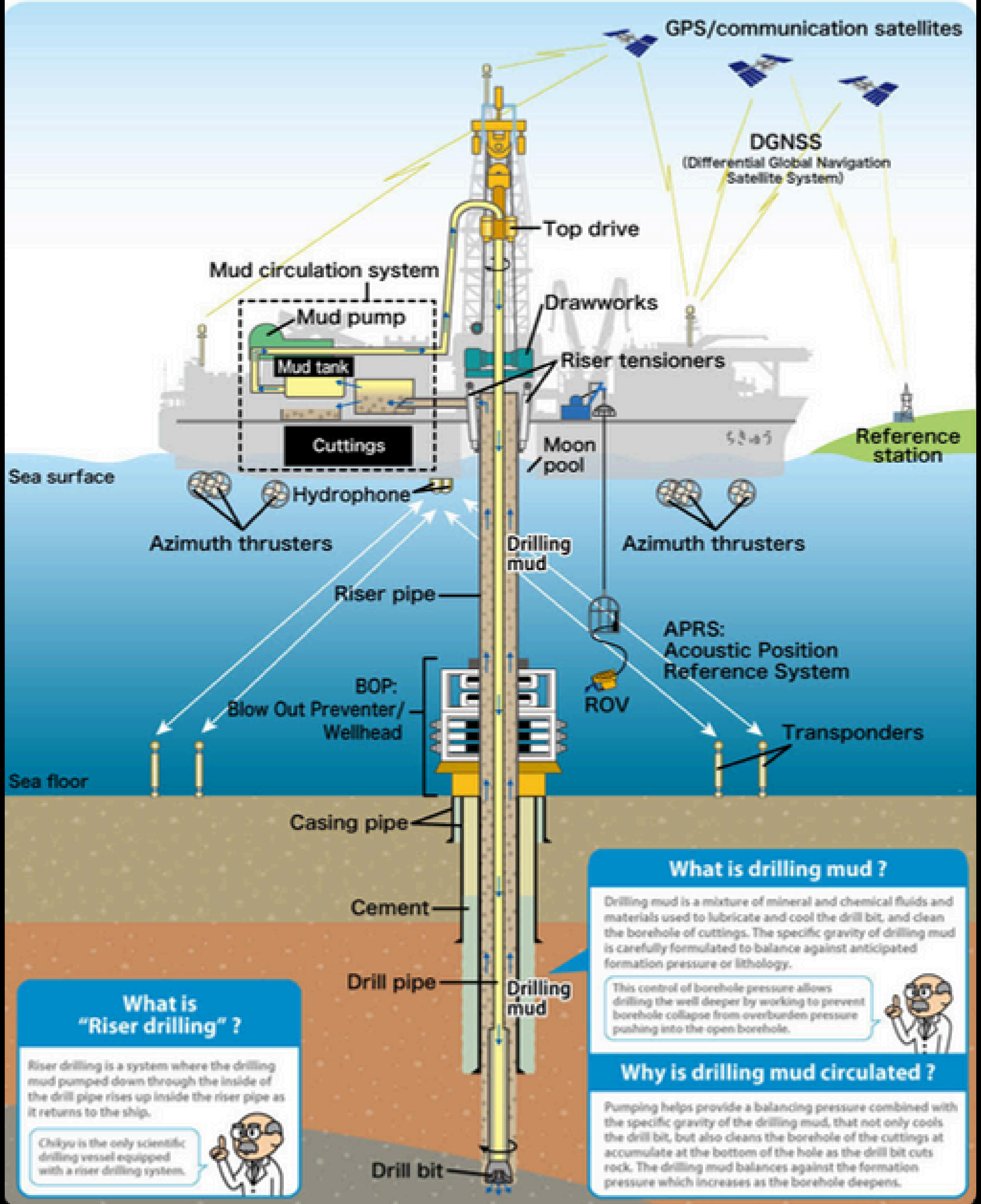
Ludlum Measurements Model 44-10:
This sensor detects and measures radiation levels in the underwater environment, ensuring safety and monitoring for environmental hazards.
Specs-Operating Voltage:500 to 1200 V
Temperature Range-20 to 50 °C (-4 to 122 °F) certified to operate from -40 to 65 °C (-40 to 150 °F)

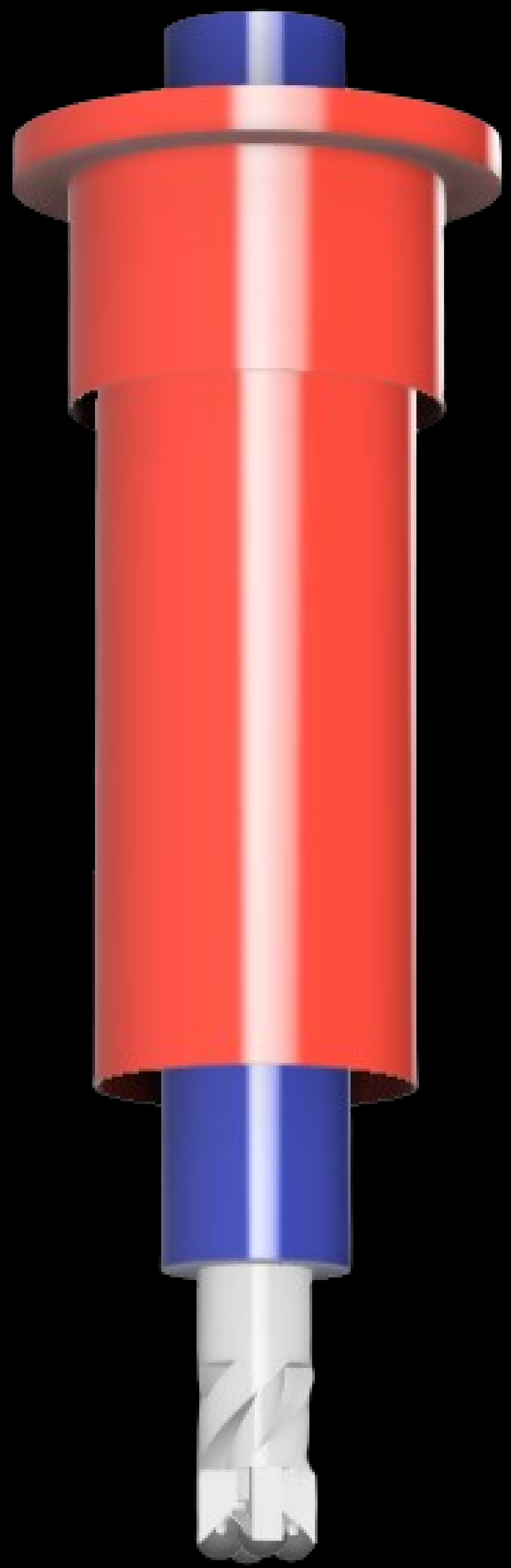
PRESSURE SENSOR

Druck PDCR 1830:
The Druck PDCR 1830 measures the water pressure to determine depth, providing critical data for safe operation.
Specs-Operating Temperature Range -5 to 140 °F (-21 to 60°C)
Output Impedance - 2 kΩ nominal.

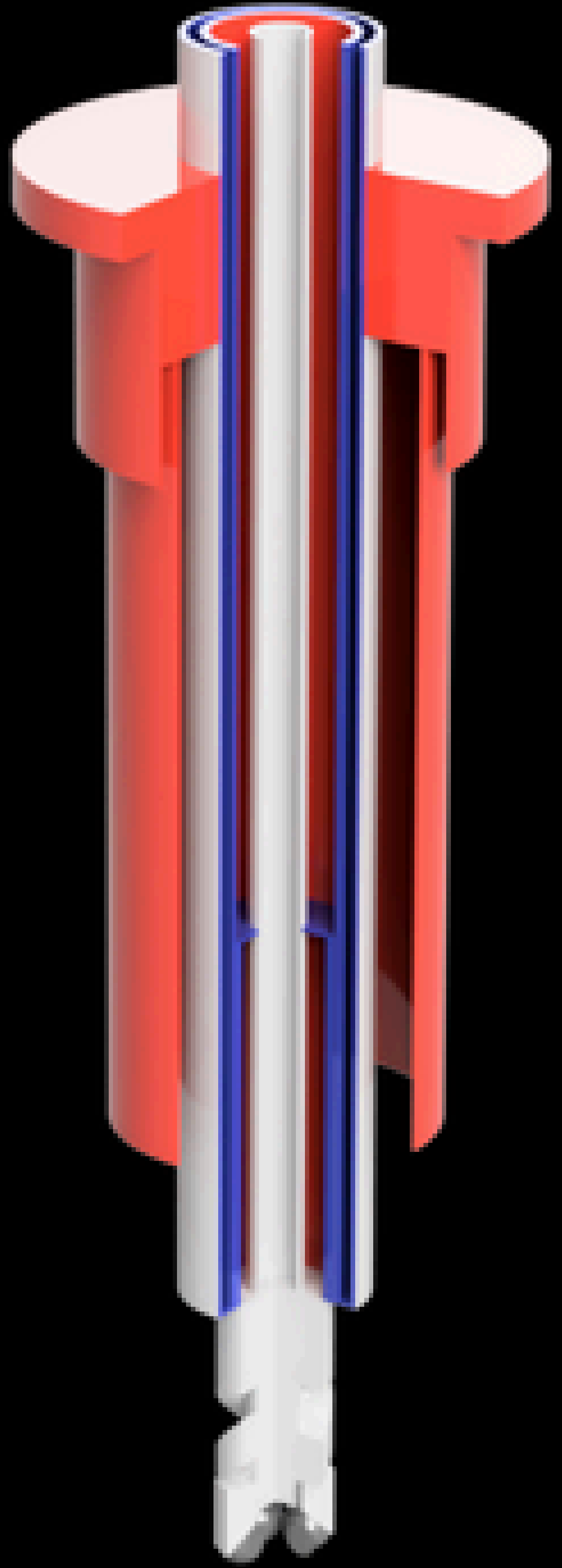
HYDROPHONE

Teledyne Benthos AQ4:
The Teledyne Benthos AQ4 detects underwater sounds and vibrations, helping study marine life communication and geological activity.
Specs - Sensitivity (dBv re 1 uPa @ 20 C):-201.
Frequency Response (+/- 1.5 dB) 1Hz to 10 Khz.


GPS/communication satellites
DGNSS
(Differential Global Navigation Satellite System)
Top drive
Mud circulation system
Mud pump
Drawworks
Mud tank
Riser tensioners
Cuttings
Moon pool
Reference station
Sea surface
Hydrophone
Azimuth thrusters
Azimuth thrusters
Drilling mud
Riser pipe
APRS:
Acoustic Position Reference System
BOP:
Blow Out Preventer/
Wellhead
ROV
Transponders
Sea floor
Casing pipe
What is drilling mud ?
Drilling mud is a mixture of mineral and chemical fluids and materials used to lubricate and cool the drill bit, and clean the borehole of cuttings. The specific gravity of drilling mud is carefully formulated to balance against anticipated formation pressure or lithology.
This control of borehole pressure allows drilling the well deeper by working to prevent borehole collapse from overburden pressure pushing into the open borehole.
Cement
Drill pipe
Drilling mud
What is "Riser drilling" ?
Riser drilling is a system where the drilling mud pumped down through the inside of the drill pipe rises up inside the riser pipe as it returns to the ship.
Chikyu is the only scientific drilling vessel equipped with a riser drilling system.
Why is drilling mud circulated ?
Pumping helps provide a balancing pressure combined with the specific gravity of the drilling mud, that not only cools the drill bit, but also cleans the borehole of the cuttings at accumulate at the bottom of the hole as the drill bit cuts rock. The drilling mud balances against the formation pressure which increases as the borehole deepens.
Drill bit



DRILL ASSEMBLY



RISER DRILLING ASSEMBLY

Key Components of a Riser System:

Marine Riser:

- Vertical pipe extending from the drilling rig to the wellhead.
- Designed to withstand high pressures and harsh marine conditions.

Riser Tensioners:

- Hydraulic/pneumatic systems maintain riser tension, counteracting vessel movement.

Flex Joints:

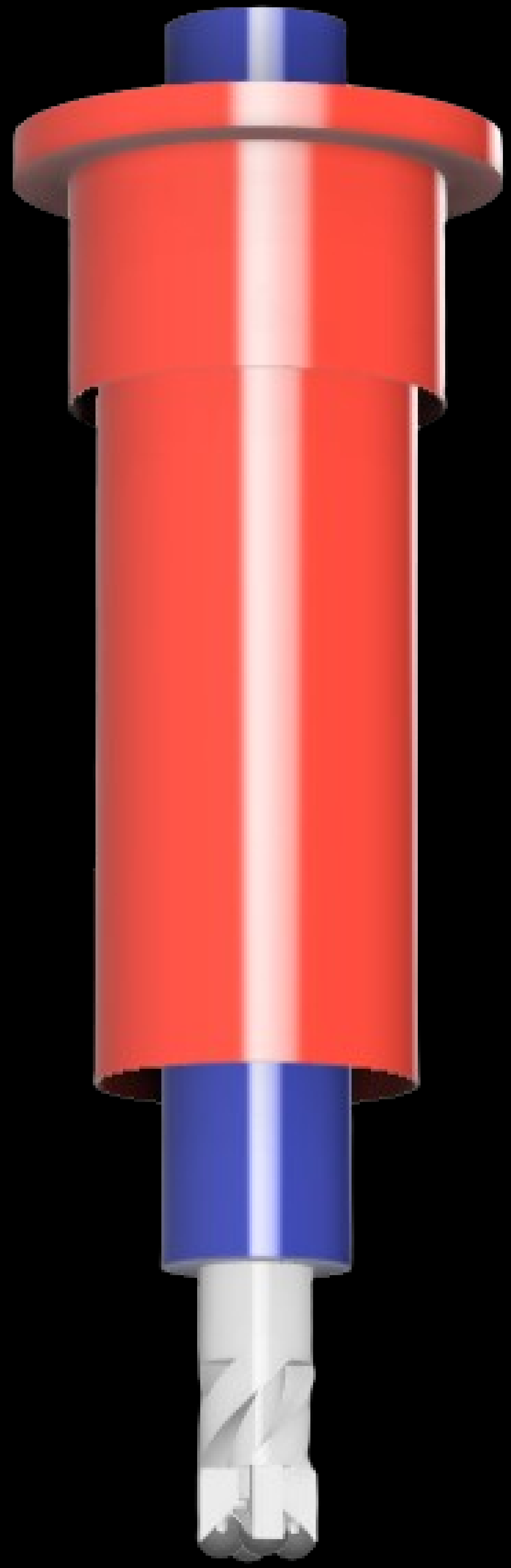
- Located at the top and bottom of the riser.
- Allow bending to accommodate drilling rig movement.

Slip Joint:

- Compensates for vertical movement of the drilling rig relative to the riser.

Riser Functionality:

- Connects the drilling rig on the surface to the wellbore on the seabed.
- Acts as a conduit for drilling fluids (mud) and materials.
- Enables circulation of drilling mud for cooling, cutting transport, and pressure management



Riser Connectors:

- High-strength connectors joining riser sections.

Mud Return Lines:

- Return drilling fluids from the wellbore to the surface.
- Functionality and Operation:

Drilling Fluid Circulation:

- Synthetic-Based Mud (SBM) is pumped down the drill string, cools the drill bit, and transports cuttings to the surface.

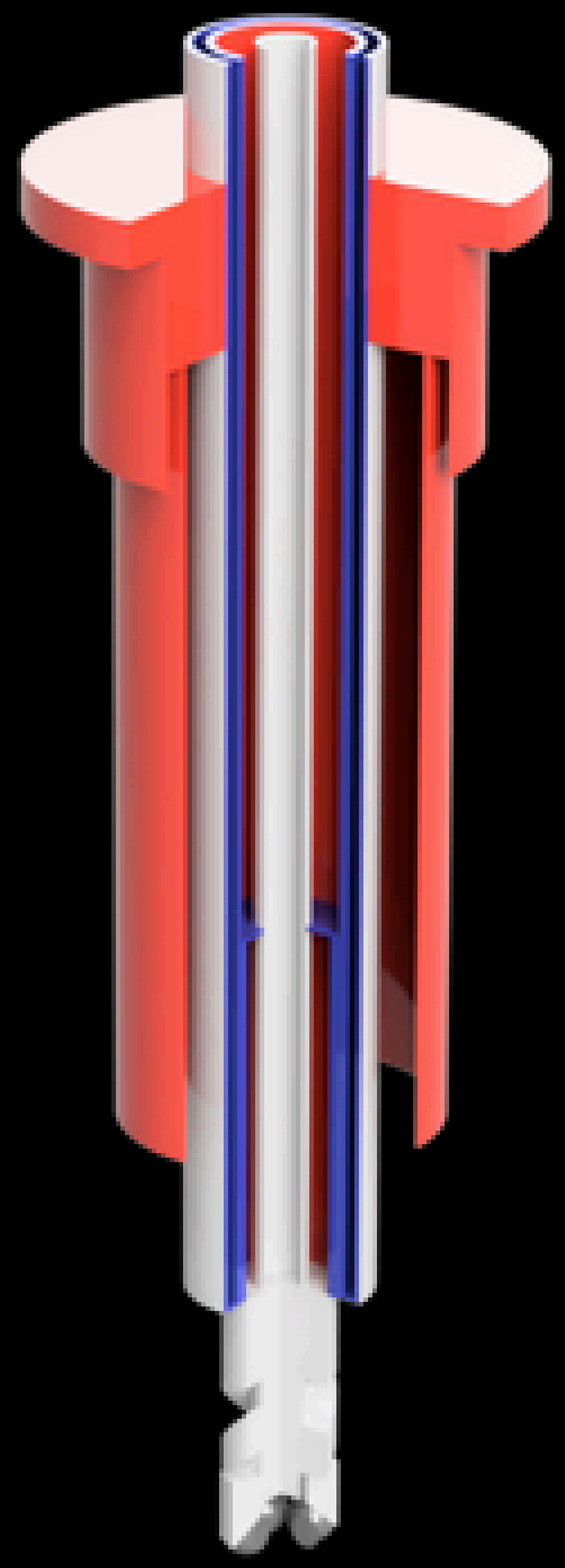
Pressure Management:

- Riser manages wellbore pressure to prevent blowouts.
- Blowout Preventer (BOP): Safety device at the bottom of the riser, controlled from the surface.

SBM for Deep-Sea Drilling:

Ideal for operations exceeding 11 km depth.

Provides thermal stability, pressure resistance, wellbore stability, and reduced environmental impact.



SUCTION GRIPPER

The suction gripper mechanism consists of a thruster encased in a 3D-printed resin housing, designed to generate a controlled suction force.

Thruster:

- Generates controlled suction force.

3D-Printed Resin Housing:

- Durable, corrosion-resistant, and low drag.
- Withstands high-pressure deep-sea environments.

Operational Capabilities:

- Reliable Operation at 11 km Depth:
- Strong suction force for secure handling of delicate samples.
- Versatile and essential for deep-sea exploration and research

Sealing Mechanism:

- High-strength, flexible seals to prevent water ingress.
- Ensures protection and long-term reliability of internal components.

Universal Mounting Interface:

- Modular design for quick attachment/detachment.
- Ideal for various deep-sea sampling missions.

Dimensions & Weight:
Width: 92 mm
Depth: 119 mm
Height: 92 mm
Weight: 300 g

KEY COMPONENTS OF BIO ASSEMBLY

1) Suction Gripper:

- Collects sediment, rock, or biological samples after excavation.
- Transfers samples into the Primary Storage Tank for secure initial storage.

2) Secondary Storage Tank & Vials/Tubes:

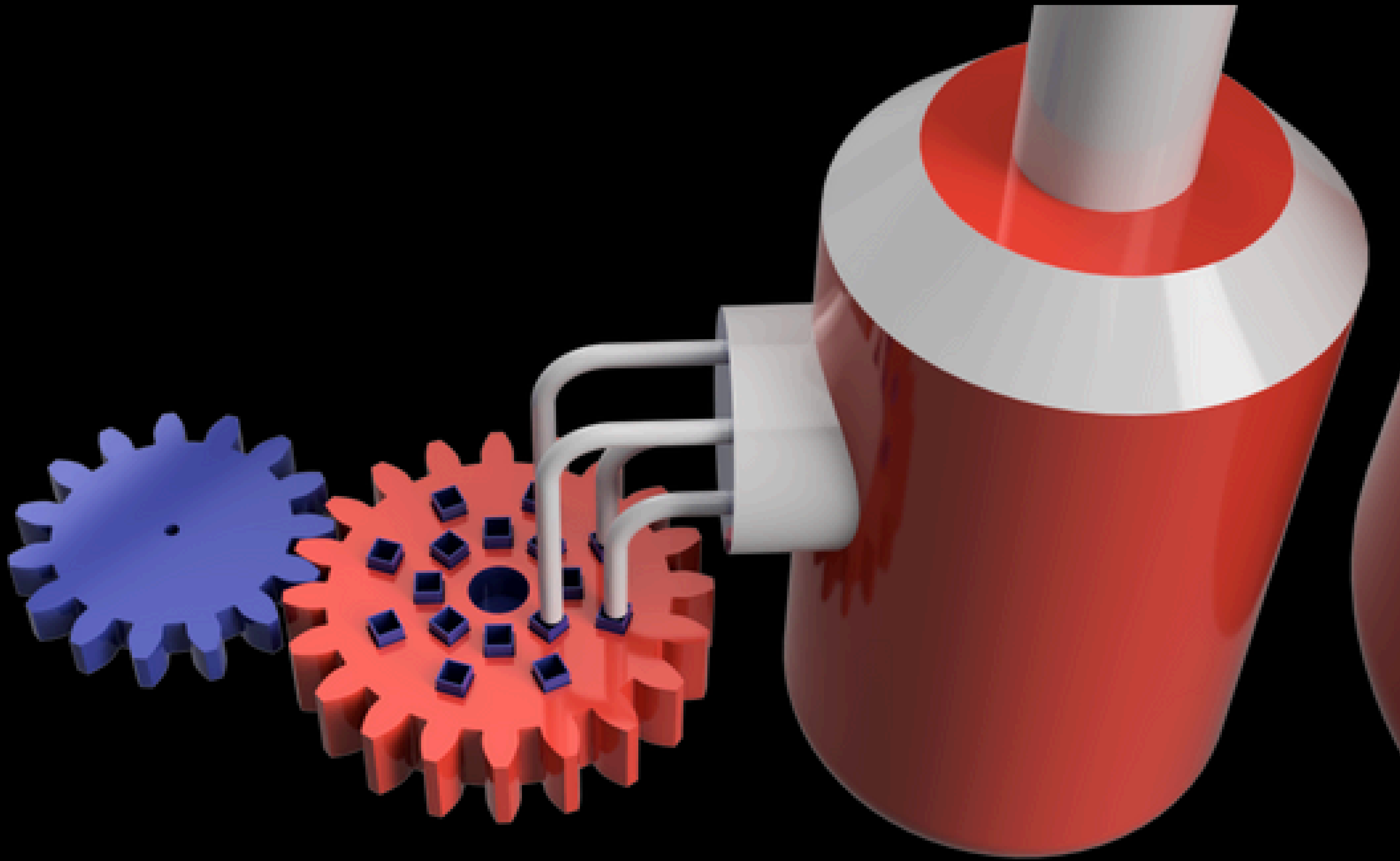
- Samples are moved from the primary tank to a smaller Secondary Storage Tank.
- Distributed into four connected Vials/Tubes for organized storage and contamination prevention.

3) Rotating Test Tube Holder:

- Connects to the vials/tubes and organizes them for sample distribution.
- Rotation mechanism ensures equal distribution, aiding in sample tracking and labeling.

4) Gear Mechanism:

- Controls Test Tube Holder Rotation: Ensures smooth and precise filling of each test tube.
- Maintains sample integrity during collection and distribution, crucial under extreme pressure and temperature conditions.



03

ELECTRONICS MODULE

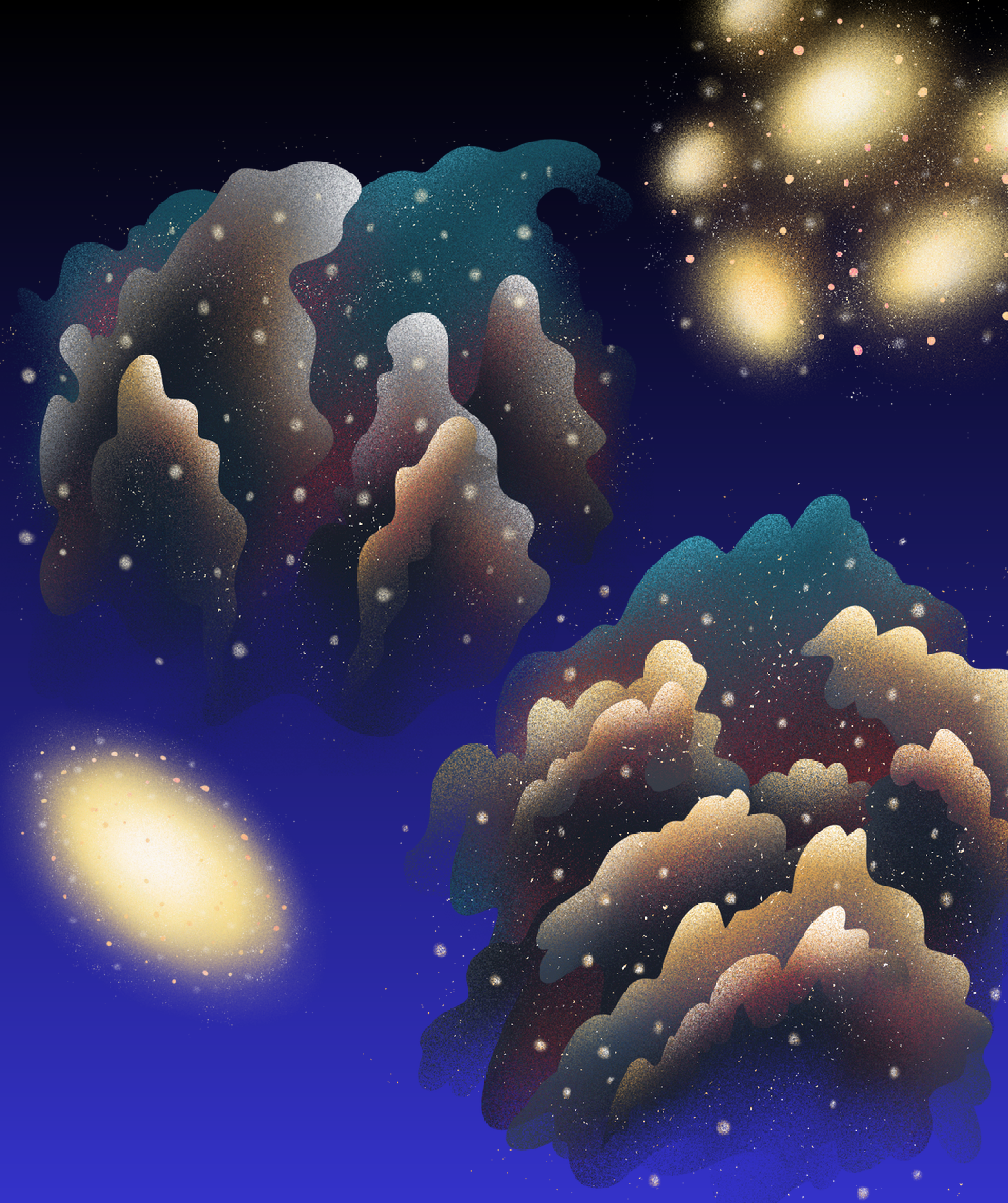
- Driving and controlling the rover.
- Providing Power
- Establish communication.
- Navigation system
- Emergency fail safe.

OBJECTIVES

01 COMMUNICATION

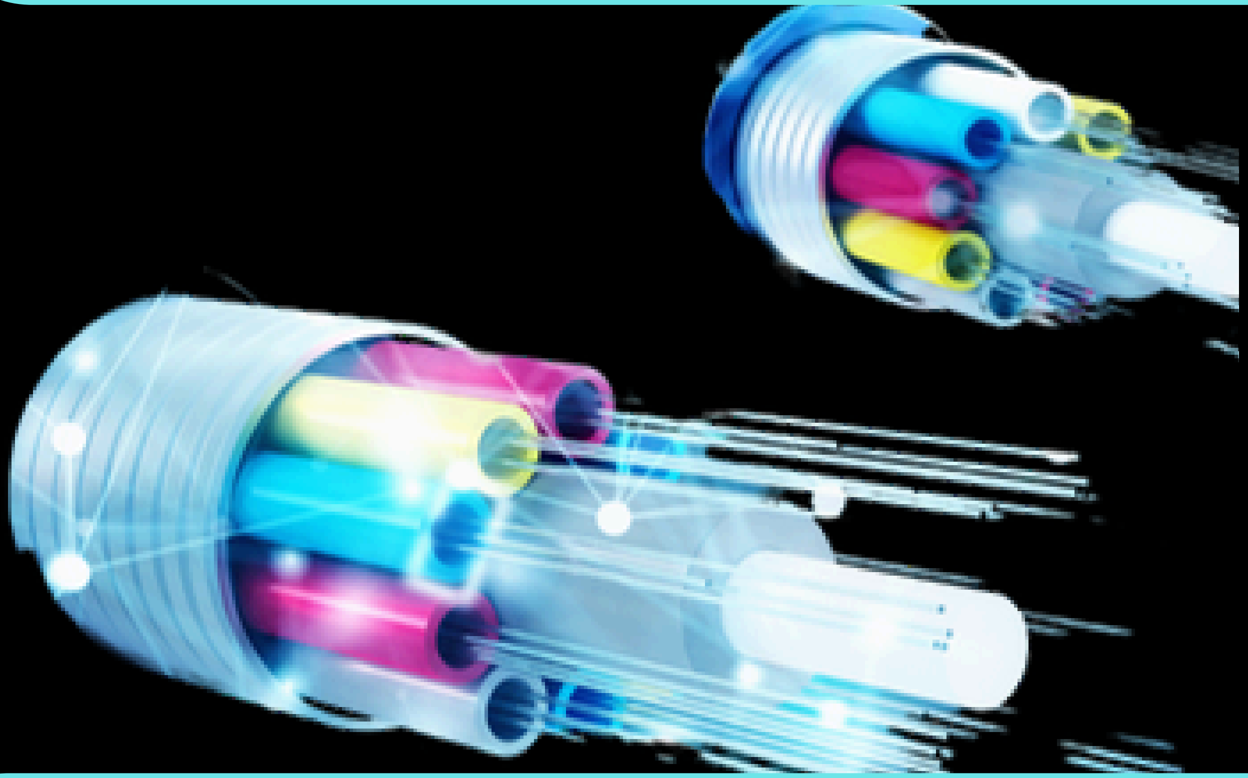
02 POWER SYSTEM AND MANAGEMENT

03 MISSION TRAVERSAL



COMMUNICATION

1. **Signal Transmission Overview**
   - Fiber Optic Communication:
   - Light signals travel through optical fibers via total internal reflection.
   - Enables high-speed, high-bandwidth data transmission with minimal signal loss.



2. **Signal Generation at the Base Station**
   - Laser Diode: Lighthouse 1.5 μm Laser Diode emits light at 1550 nm.
   - Physics of Laser Diodes: Stimulated emission generates coherent light.Wavelength depends on the energy difference between conduction and valence bands.

3. **Transmission through Fiber Optic Cable**
   - Single-Mode Fiber: Corning SMF-28e fiber with low attenuation (~0.2 dB/km at 1550 nm).
   - Physics of Fiber Optics: Light stays in the core due to total internal reflection.

`4. **Receiving Optical Signal at the Underwater Vehicle**

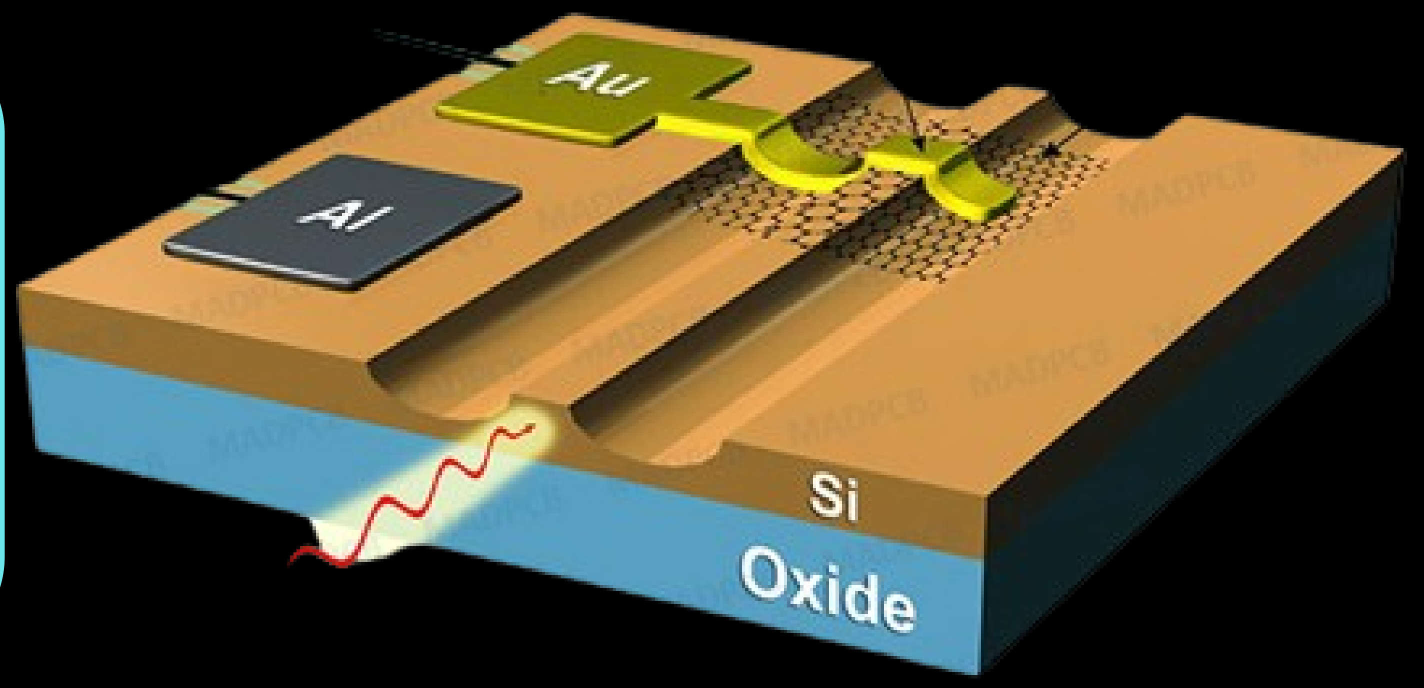
- Photodetector:
- Hamamatsu S1226-18BK Silicon Photodiode: High sensitivity (0.5 A/W at 1550 nm) for detecting infrared signals.
- Physics: Photons generate electron-hole pairs, producing a photocurrent proportional to light intensity.

5. **Conversion to Analog Signal**

- Signal Conditioning:
- Amplification: OPA2134 Op-Amp is used for low noise and high fidelity.
- Filtering: RC Low-Pass Filter removes high-frequency noise, with cutoff frequency set by resistor (R) and capacitor (C) values.

6. **Analog Signal Processing**

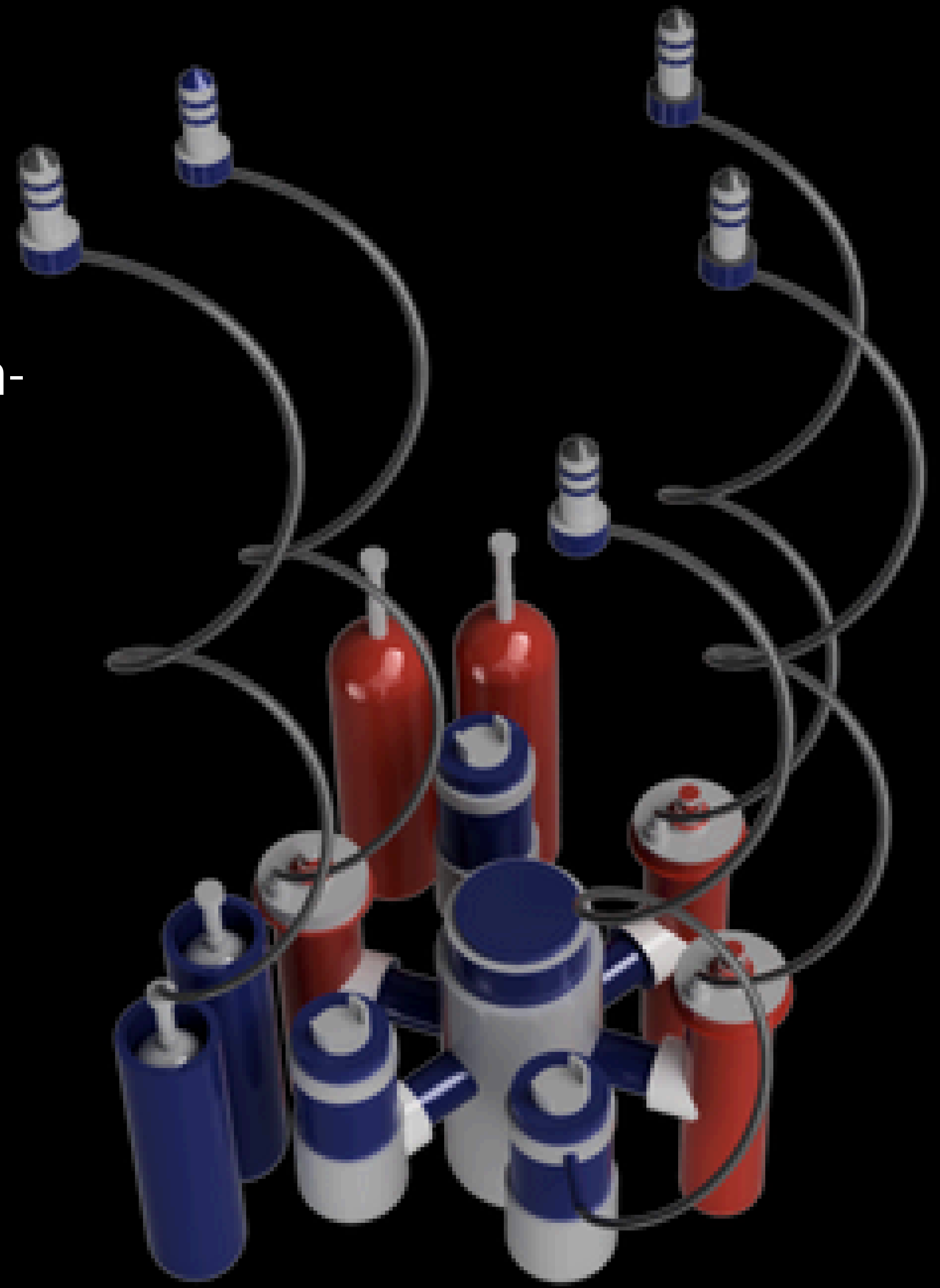
- Analog-to-Digital Conversion:
- Texas Instruments ADS1115 for 16-bit resolution, I2C interface.
- Signal Processing:
- Sony Spresense Microcontroller for data analysis and control tasks.



NUCLEAR REACTOR

Key Features:

- Reactor Core: Uses low-enriched uranium fuel with enhanced safety and non-proliferation measures.
- Cooling System: Combines active and passive safety features, including forced and natural coolant circulation, to maintain reactor stability even in emergencies.
- Safety: Equipped with multiple redundant systems, including emergency shutdowns, core cooling, and barriers to prevent radioactive release.
- Structural Resilience: Built to withstand extreme environmental conditions such as high winds, earthquakes, and impacts.
- Deployment: Targeted for remote locations where conventional power sources are impractical, offering a durable and economically viable solution for generating electricity and heat.



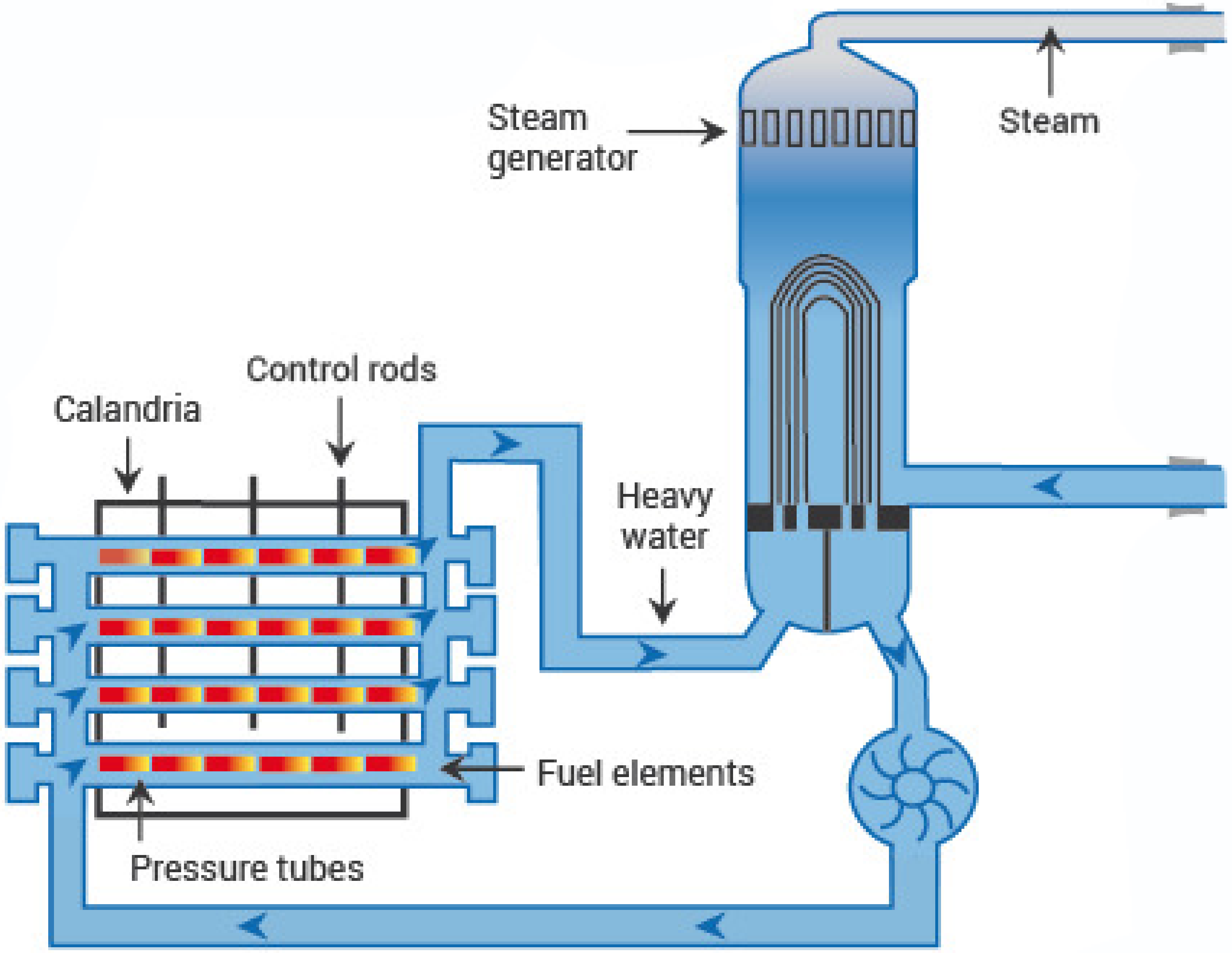
APPLICATION

- The KLT-40S is used in floating nuclear power plants, which are designed to provide electricity and heat to remote areas where traditional power generation methods are not feasible. This makes it an attractive option for powering isolated communities, mining operations, or other industrial activities in the Arctic or other remote regions.

Economic and Environmental Considerations:

- Cost: While the initial capital cost of the KLT-40S is higher than conventional land-based reactors, its ability to operate in extreme conditions and the lower cost of electricity generation in remote areas make it economically viable.
- Environmental Impact: The use of low-enriched uranium reduces the potential environmental impact and the risks associated with nuclear proliferation

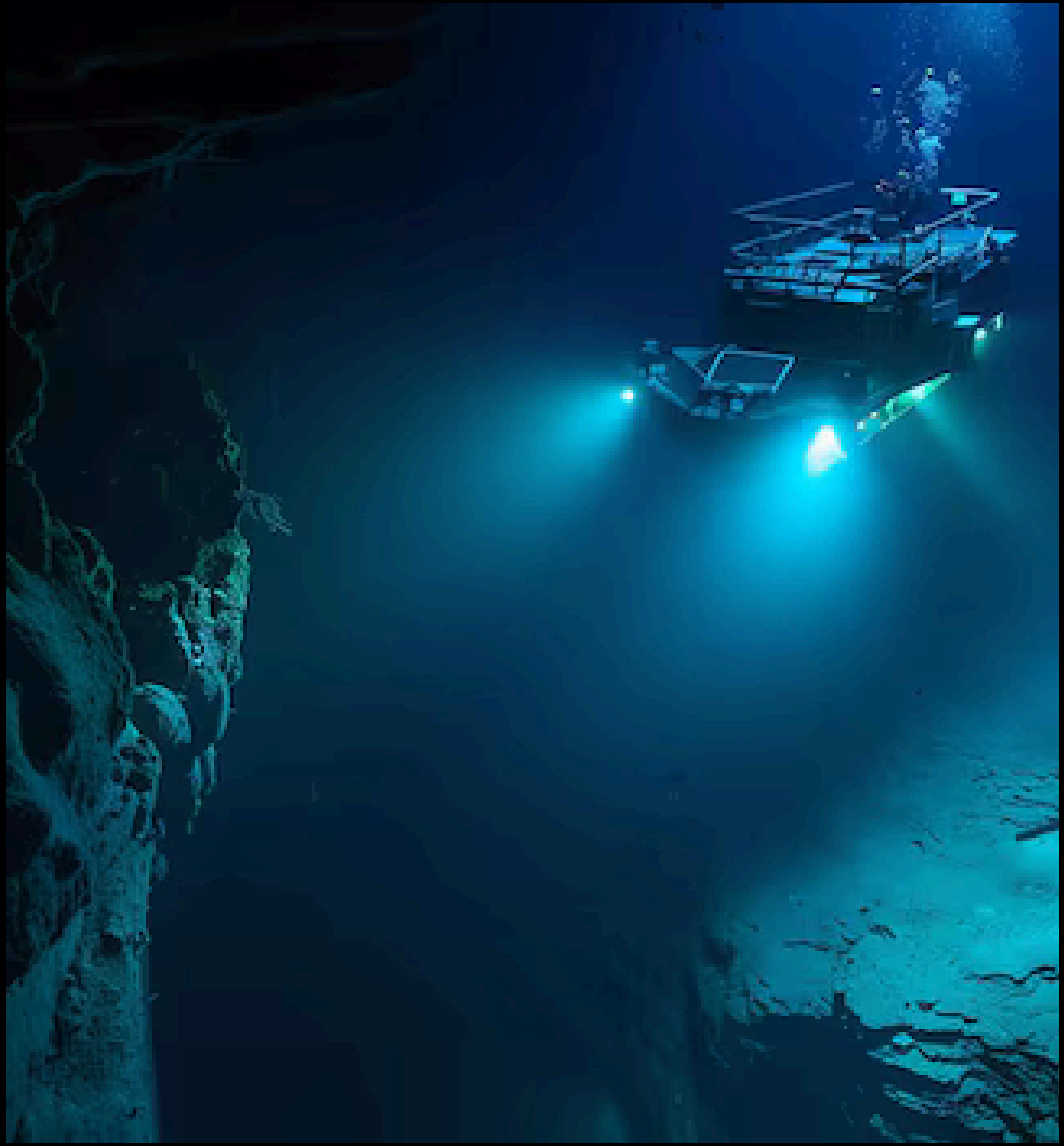
HEAT TRANSFER MECHANISM



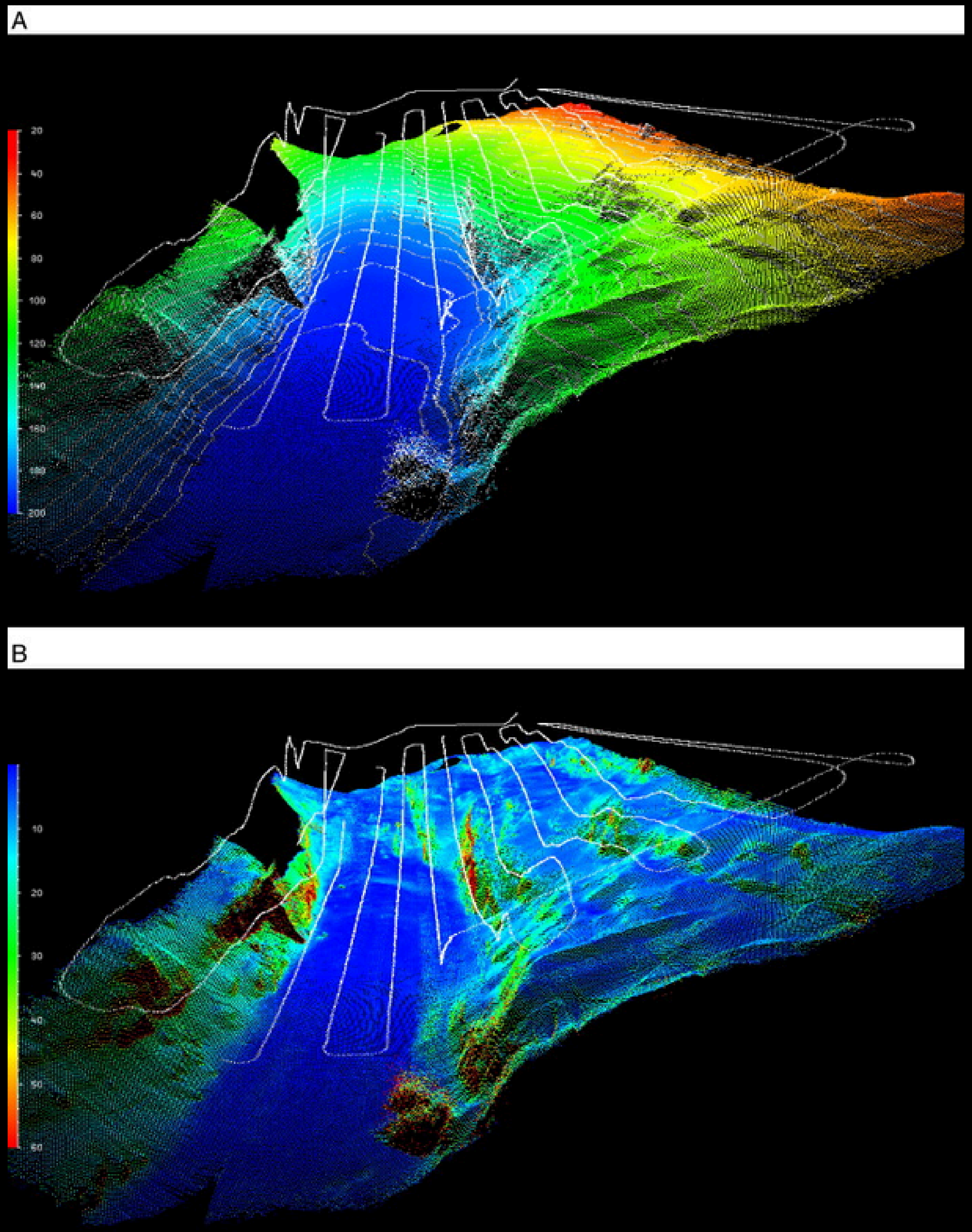
Underwater Navigation

Mapping:

- *Utilized advanced blue light laser technology for precise underwater mapping.*
- *Guided rover to collect samples from the Mariana Trench.*
- *Integrated laser mapping with sample collection for new insights into geology, biology, and ecology.*
- *Blue light lasers, ideal for deep-sea use due to superior water penetration.*
- *Narrow beams scan underwater structures, with reflections recorded via Time of Flight (ToF).*
- *Produced high-resolution 3D maps for detailed surveys of coral reefs, shipwrecks, and other underwater features.*



Path Planning and Obstacle Avoidance



Acoustic Beacons

- Backbone of the GBP2 system, deployed on the seafloor or attached to underwater structures to create a coverage network.
- Equipped with transducers that emit sound waves at specific frequencies, detected by the rover's sensors.

Position Calculation

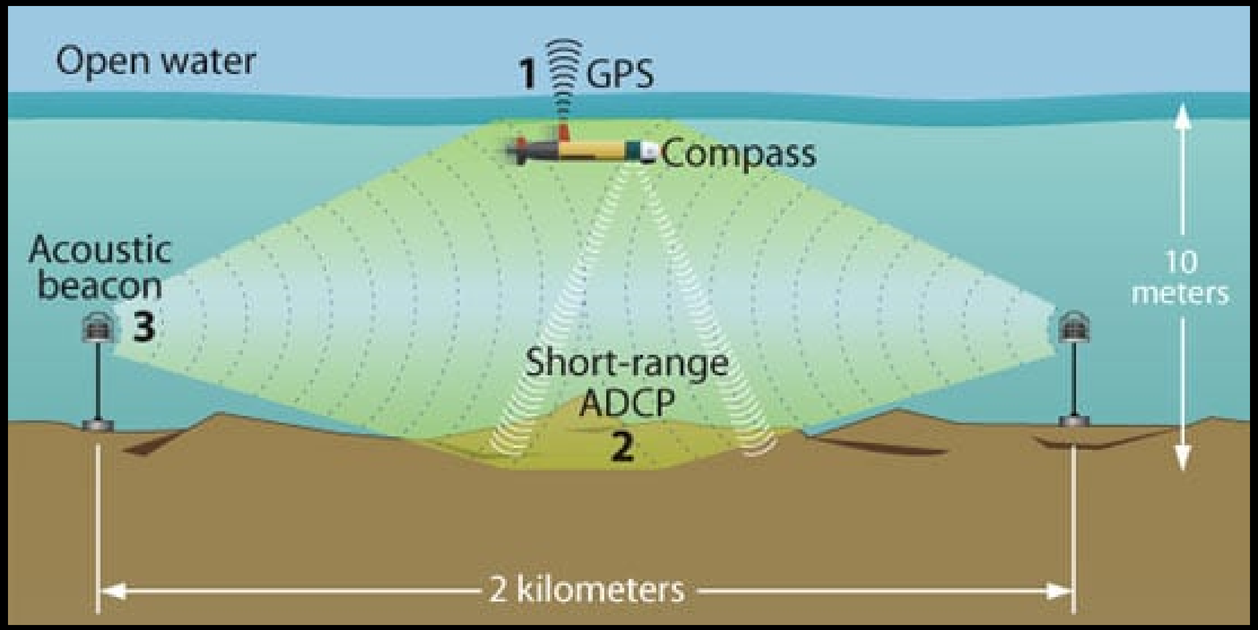
- The system calculates the rover's position based on the time it takes for signals to travel from the beacons to the rover.

Deployment Strategy

- Beacons are arranged in a grid or triangular pattern for optimal coverage and accuracy.
- Placement depends on the exploration area's size and required precision.
- In deep-sea environments, beacons are anchored to the seabed or attached to stationary AUVs.

Signal Propagation

- Sound travels underwater at approximately 1,500 meters per second.
- GBP2 accounts for refraction, scattering, and absorption using advanced signal processing techniques.



Rover-Mounted Acoustic Receivers

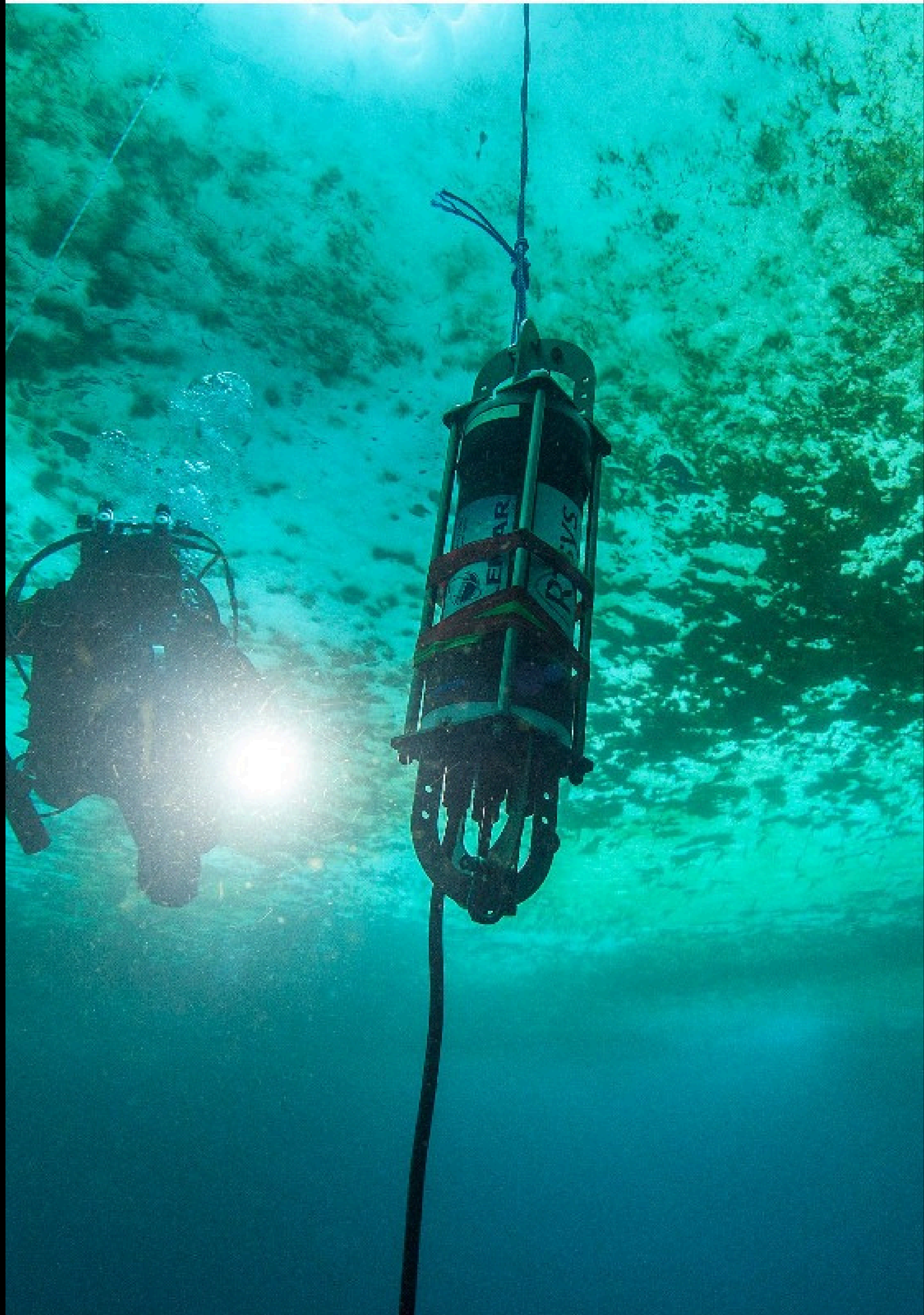
- The underwater rover is equipped with multiple acoustic receivers to detect sound waves from beacons.
- Receivers are strategically placed for optimal signal detection and accuracy.

Time Difference of Arrival (TDOA)

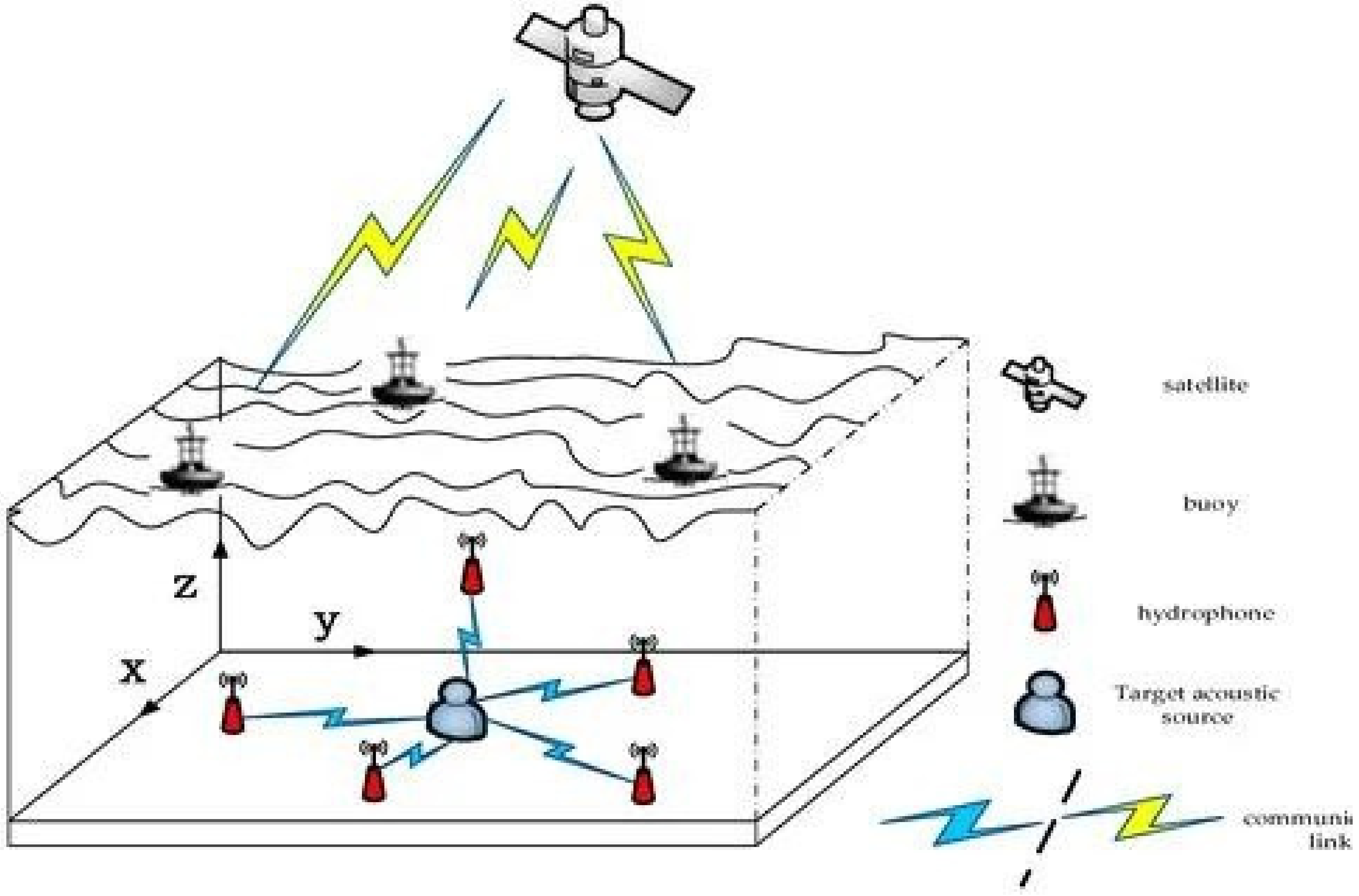
- Receivers measure the time delay between beacon transmission and signal reception.
- TDOA is used to calculate the rover's precise position.

Receiver Configuration

- Designed to handle complexities of underwater sound propagation, detecting signals at varying distances and angles.
- Advanced filtering techniques minimize noise and interference from marine life or equipment vibrations.



Onboard Processing Unit



Computation

System Architecture
NXP i.MX 8M Mini: Manages system operations, communication, lower-priority tasks.
Xilinx Zynq UltraScale+ MPSoC: Handles parallel processing for sensor data.
Texas Instruments TMS320C6678 DSP: Focuses on real-time tasks like sonar data analysis.

- Processor: ARM Cortex-A53 cores + FPGA fabric.
- Operating Conditions: Voltage: 0.85V to 1.0V; Temp: -40°C to +100°C.
- Key Features: Reconfigurable FPGA, supports high-bandwidth interfaces, parallel processing.

Texas Instruments TMS320C6678 DSP

- Processor: Eight-core DSP, each at 1.25 GHz.
- Operating Conditions: Voltage: 0.9V to 1.1V; Temp: -40°C to +100°C.
- Key Features: High-performance, real-time signal processing, extensive peripheral support

3. Integration Strategy

NXP i.MX 8M Mini

- Processor: Quad-core ARM Cortex-A53, up to 1.8 GHz.
- Operating Conditions: Voltage: 0.9V to 1.3V; Temp: -40°C to +105°C.
- Key Features: Power-efficient, supports PCIe, I2C, SPI, UART, GPIO. Central control unit for system management.

Communication Interfaces & Power Management:

- High-Speed Interfaces: PCIe for fast data transfer; SPI/I2C/UART for low-latency communication.

Temperature Control:
Heat Dissipation: Heat sinks, thermal pads, and potential water cooling for FPGA and DSP.

Combines the strengths of NXP, Xilinx, and Texas Instruments processors.
Ensures robust, energy-efficient, and reliable operation at extreme depths.

FAIL SAFE

Multiple Thrusters: Equip the bot with redundant thrusters to maintain control and surface safely if one fails.

Mechanical ballast release system can drop weights, making the bot buoyant to float to the surface in case of power loss or malfunction.

Sealed Compartments Use watertight compartments with independent sensors and shut-off valves to isolate leaks and prevent flooding

Safety Systems: Monitor pressure and temperature to trigger surface return or compartment sealing if needed and manage overheating with cooling or shutdowns

Power Management: The bot can shut down non-essential systems in emergencies, with the nuclear reactor providing virtually limitless power.

Robust Tether System: Use a Kevlar-reinforced tether for durability and manual recovery, and continuously monitor it for wear or tension with protocols for safe retrieval.

Acoustic Pinger and Tracking: Equip the bot with an acoustic pinger for location tracking if lost or disabled, and use GPS on the surface and dead reckoning underwater

Automatic Data Backup: Transmit data to the surface in real time and regularly back up mission data to secure onboard storage for retrieval if the bot is lost.

Thank You