SENTINEL-Orb: SpacE operatioNs, moniToring, and mappINg ExpLorer: a smart Orb-system

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SENTINEL-Orb : Sentinel-orb is an ongoing project with an exploratory technology focused on developing a smart orb (small sphere) that will be able to fly, navigate and be capable of mapping. This project aims to be a service robot for assistance and cooperation, supporting the extravehicular activity (EVA) on the Moon, in outer space, and in spacewalks carried out by the astronauts. Therefore, the robot developed under this project's scope will ultimately be tested in a microgravity environment during several parabolic flights.

I. From Deep-Sea to Outer-Space

The SENTINEL-Orb is a conceptual project aimed to be built upon the underwater technology developed by the INESCTEC team as part of the UNEXUP initiative, specifically based on the UX1-NEO system.

- Main Objectives:

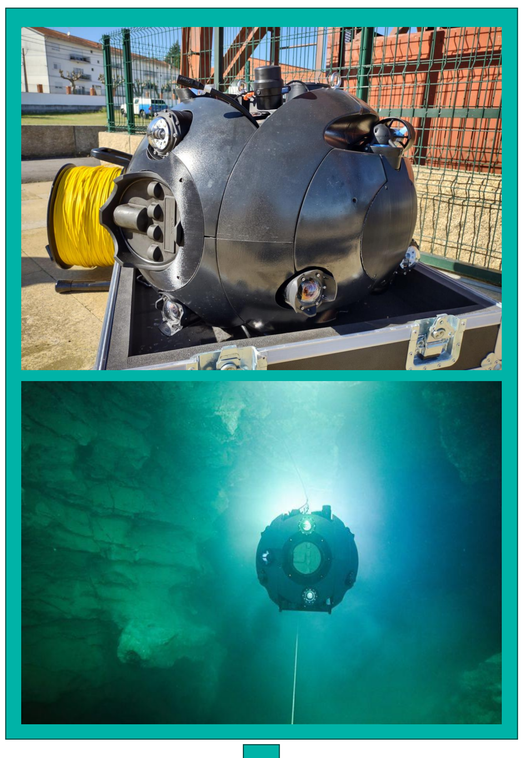
1. Miniaturize and develop a robotic system based on UX-1Neo for Space;
2. Integrate sensors and give the ability to fly and navigate;
3. Utilize visual-inertial odometry with a high-resolution camera;
4. Integrate algorithms for object detection and anomaly identification;
5. Test Space maneuvers in a microgravity environment.

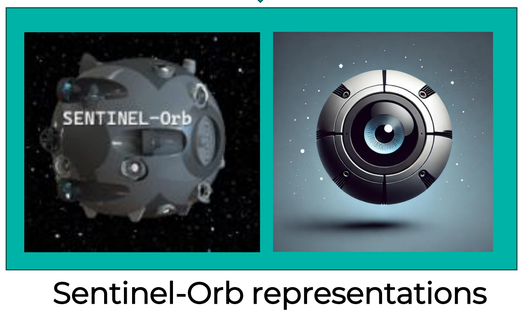
Water vs Space

Similarities:
- Neutral buoyancy achieved in water environments produces forces that are in similar magnitude to space and are smaller in comparison to the gravity force exerted in Earth.
- Both environments require UAVs to operate autonomously with energy efficiency and limited real-time communication.

Differences:
- UAV for underwater requires pressure-resistant and corrosion-proof materials, whereas in Space, needs lightweight materials that withstand radiation and temperature extremes.
- The environment underwater has high pressures, dense medium, and cold temperatures. In space. There is no “environment” due to vacuum so there isn’t any pressure to take into consideration.

UX1-NEO [underwater mission]



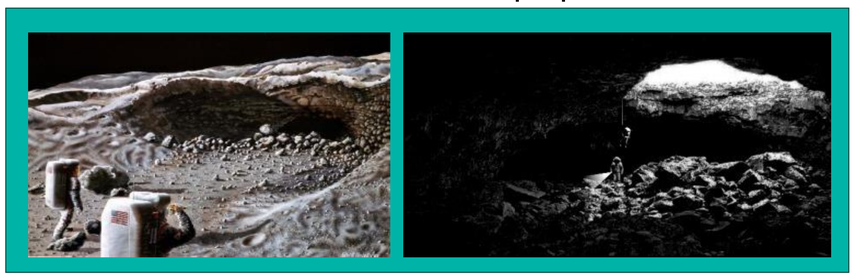


Sentinel-Orb representations

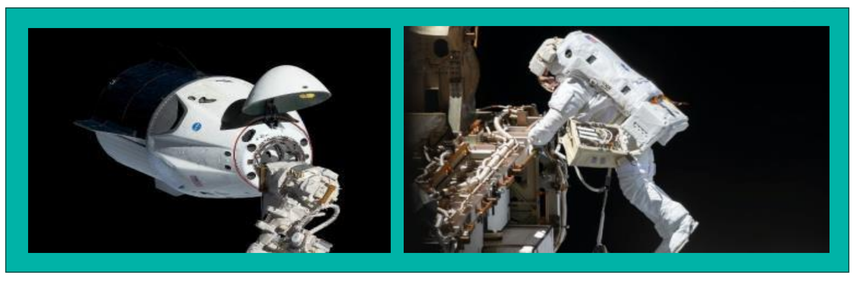
II. The Potential of the Sentinel-Orb

SENTINEL-Orb holds vast potential across various domains of space exploration and management, such as:

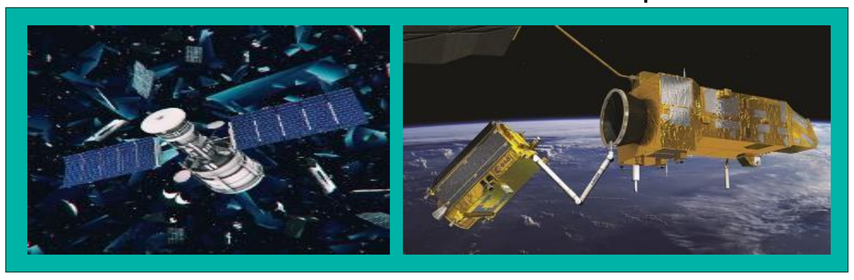
Deep Space – Scout Robot



Extravehicular Activities (EVA) Support



Near Space - Debris



III. Motion System

The Sentinel-Orb project cannot utilize propellers due to a lack of atmosphere in Space, so it will utilize air compressed thrusters instead. However, the configuration of the propellers developed in the UX1-NEO can be reproduced for the Sentinel-Orb, replacing the propellers with thrusters.

The system developed for UX1-NEO is represented below, composed of two sets of four thrusters placed, respectively, in a cross configuration at each side of the sphere, representing fully 5 Degrees of Freedom.

Motion	Thrusters Used
Surge	$T_1, -T_3, T_5, -T_7$
Sway	$T_1, T_2, T_3, T_4, -T_5, -T_6, -T_7, -T_8$
Heave	$T_2, -T_4, T_6, -T_8$
Roll	$-T_2, T_4, T_6, -T_8$
Pitch	/
Yaw	$T_1, -T_3, -T_5, T_7$

To adapt the system for the Sentinel-Orb, the configuration will be held the same, utilizing two manifolds of four air compressed thrusters each. It will be tested both air and CO2 for this project, preferrable CO2 for its lighter molar mass.

Additional thrusters can be added upon further investigation to assist in certain motions and provide better maneuverability.

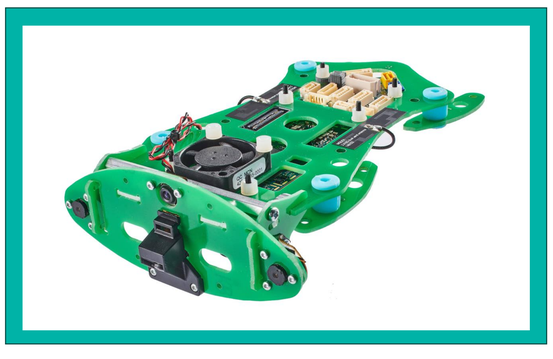
IV. Visual Inertial-Odometry (VIO)

This technology allows UAVs to estimate its position and motion by combining visual data from a camera with inertial data from sensors such as accelerometers and gyroscopes. The integration of a pre-built board to cooperate in this project is crucial due to time constraints.

VOXL 2 is ModalAI's flagship autonomous Blue UAS Framework AI Autopilot which is a powerful companion computer with integrated flight controller and is built around the Qualcomm Flight RB5 5G Platform using the QRB5165 processor. The developer kit has a fully assembled and calibrated flight kit. Pre-configured for GPS-denied navigation using VIO. It also integrates several sensors that would be required for the motion system, such as Inertial Measurement Units (IMU)

The camera captures images of the surroundings and by analyzing changes between consecutive frames, the system can estimate the movement of the UAV relative to objects in the environment.

In space, where GPS is unavailable, VIO allows autonomous navigation by referencing stars, planetary surfaces, or space station structures for visual data.



VOXL 2 Developer Kit

https://www.linkedin.com/company/sentinel-orb/

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