Title: Using constellations of nanosatellites to identify coral reef-cultivable areas on the seafloor.
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Need

Coral reefs, the rainforest of the sea, are the most diverse of all the marine ecosystems, as 25% of all marine species live in and around reefs, which contain only 1% of the marine environment [1]. Coral reefs are indeed connected to humanity in various ways and also have significant impacts on human life. First of all, Coral reefs serve as a significant indicator of climate change and are frequently employed to identify potential risks to ecosystems that possess greater resilience, owing to their heightened susceptibility to alterations. In addition, beaches serve as a protective barrier against storms, erosion, and flooding, as they effectively absorb the energy of incoming waves. The natural barrier provided by the rigid structure of corals effectively diminishes wave energy by as much as 97%, thereby mitigating the impact of Tsunamis and hurricanes on a global scale [2]. Reefs also affect the ocean's atmosphere through carbon dioxide exchange through the global carbon cycle as they take CO_2 and release O_2 during their feeding process [3]. So, coral reefs effects on climate are undeniable.
Secondly, coral reefs are of significant economic importance globally, contributing to various sectors such as tourism and marine recreation. Though occupying only 0.2% of the seabed (150,000km) from the coastline of more than 50 countries, it provides direct livelihood to 8% (More than 500 Million people) of the world's population, whose estimated annual net benefit is $375 billion USD [4,5]. Coral reefs support food security in developing island nations. Many coastal communities get their protein from reef fish and other marine organisms. Coral reefs supply oxygen and food for fish, which provide roughly 5% of the world's protein [6]. Coral reefs host many organisms, including sponges and soft corals, that produce bioactive compounds for medical development. Thus, coral reefs play a vital role in providing us with food, medicine, and security.
Finally, there are many threats to coral reefs, like warming oceans, sea level rise, wave patterns, ocean acidification, heat waves, and so on. Rapid climate change causes many of these events. According to scientific projections, there is a potential for a substantial decline of more than 90% in coral reef coverage by the year 2050 unless immediate and decisive measures are taken to mitigate greenhouse gas emissions. The current situation can be accurately described as a climate emergency [3]. To solve this problem, we came up with a solution, and the proposed approach involves utilizing a network of satellites to systematically observe and analyze coral reefs. The primary objective is to create detailed maps of the reef's habitat as well as the composition of the benthic and substrate elements. By employing a geomorphic zonation framework, the study aims to identify factors contributing to the decline and decay of coral reefs. Additionally, the research seeks to locate alternative areas within the seabed that may be more conducive to executing microcolony fusion, a technique aimed at enhancing coral cover and promoting the growth of reefs.

Mission Objectives

Primary Objective:

1. The first objective is to conduct tracking and monitoring activities on coral reefs in order to determine the geomorphic zonation of the habitat, identify the various species of reef organisms, and analyze the composition of the benthic and substrate components.
2. In the context of the reef habitat, the second study aims to investigate the identification of optimal environmental conditions as well as the factors contributing to the decline of this ecosystem.
3. The third objective is to explore alternative locations within the seabed that can serve as more favorable habitats for coral reefs, as well as identify the specific species of reefs that are likely to thrive in these areas.

Secondary Objective:

1. The implementation of microcolony fusion techniques within unoccupied seabed areas that are conducive to coral growth aims to enhance the size and rate of coral development.

Concept of Operations

Mission execution involves 3U cubesats, ground-based remote-sensing platforms, and ground stations, divided into space and ground segments based on location.

Space Segment: The Chameleon MS multispectral camera makes it possible to choose from seven different multispectral bands. Band 1 is coastal aerosol (0.43-0.45 nm), Band 2 is blue (0.45-0.51 nm), Band 3 is green (0.53-0.59 nm), Band 4 is red (0.64-0.67 nm), Band 5 is near infrared (NIR) (0.85-0.88 nm), Band 6 is short-wave infrared (2.11-2.29 nm), and Band 7 is thermal infrared (10.40-12.50 nm) and has a swath width of 40 km at 500 km altitude. With the aid of these bands, a thorough benthic ecosystem map of coral and its surrounding environment can be produced. Important factors must be taken into account during this mapping process, including thermal mapping using sea surface temperature (SST) measurements, sea level measurements using single beam echo sounder (situ) measurements, vegetation analysis using the normalized difference vegetation index (NDVI), water assessment using the normalized difference water index (NDWI), coastal and aerosol data analysis, ocean wave mapping, and evaluation of sea level soil conditions.

Ground Segment: By utilizing a constellation of satellites and a multispectral satellite sensor, a comprehensive collection of images of coral reefs will be obtained by three ground stations to facilitate object-based image analysis (OBIA). This analysis will enable the creation of geomorphological and thermal maps, which will incorporate data pertaining to the surrounding environments. Preprocessing is a necessary step prior to the utilization of sensor image data for object-based image analysis. Turbidity, clouds, and cloud shadows pose substantial challenges for satellite operations, albeit with potential mitigation strategies. The first step involves the application of the Function of Mask (Fmask) algorithm to conceal the region with cloud cover. Subsequently, by employing multi-temporal imagery, which encompasses various images obtained from either the same or different satellites within the constellation, we amalgamate them to generate a cloud-free perspective. Multi-temporal images are commonly acquired from various perspectives and locations, thereby requiring the application of both geometric and radiometric corrections to produce a more precise outcome. Various components, including clouds, land masses, deep sea areas, and boats, have the potential to be concealed in order to enhance the outcome. However, caution must be exercised when considering the coastal lands, as they fulfill a crucial environmental role through the presence of reefs. Given that the overall accuracy has attained a value of 73%, it is deemed appropriate to employ an object-based classification model utilizing the Support Vector Machine (SVM) machine learning algorithm for the purpose of delineating the coastal reefs [7]. The present study focuses on the application of object-based image analysis (OBIA) techniques for the analysis of coral reef ecosystems. The utilization of multiple classification algorithms for the purpose of mapping benthic habitat To generate a geomorphological map, it is necessary to include various factors related to water penetration, temperature, light density, and benthic heterogeneity during the preprocessing phase. The Water Column Correction technique aims to mitigate the influence of water penetration error, thereby enhancing the comprehension of spectral bands and elucidating the behavior of light. The water column can be measured in situ by employing a single-beam echo sounder, thereby obviating the necessity for ground-truth data. The maps will be generated through the integration of all of them using the Object-Based Image Analysis (OBIA) algorithm named Support Vector Machine (SVM). After that, we will be looking into unfamiliar seabed zones to find more suitable places for coral reefs with the trained model along with descriptive analysis.

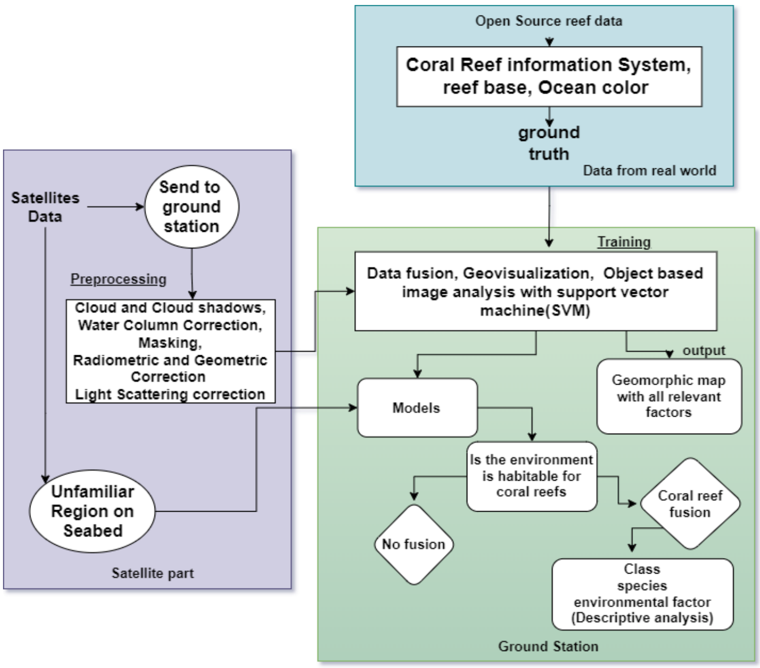


Fig: Ground Segment Operation

Key Performance Parameters

Key Parameters	Value	Key Parameters	Value
Spatial Resolution	10 m	Swath width	55 km
Camera Direction	Always look at earth	Mission Lifetime	5 years
Image size (each shutter)	5.5 km^2	Camera shutter	only in the coastal area

Space Segment Description

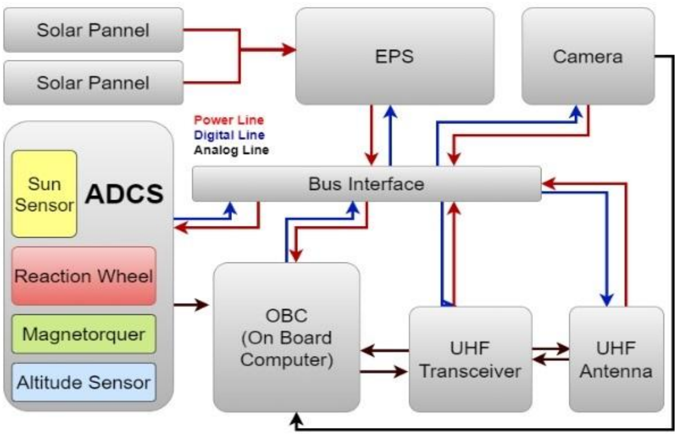


Fig: Space Segment design

The estimated mass of the 3U CubeSat is 3.364 kg, making it a custom build. The table shows how the CubeSat's four subsystems and two payloads are divided up in terms of mass and power. A transceiver, camera, and battery make up the scientific payloads. The many components are the Telemetry, Tracking, and Control (TT&C) Subsystem, the Altitude Determination and Control (ADCS) Subsystem, the Onboard Computer (OBC), and the Thermal Control (TC) Subsystem.

Calculations

Transceiver Specifications:
Transmit power (Pt): 1 W
Receive sensitivity (Pr): up to -121 dBm

Antenna Specifications:
Frequency range: 435 - 438 MHz or 400 - 403 MHz
Gain: Assumed to be 1.5 dBi

System Losses:
Cable losses: 0.5 dB
Connector losses: 0.3 dB
Atmospheric losses: 0 dB (assumed)

Free Space Loss (Lfs):
Lfs = 20 * log10(distance) + 20 * log10(frequency) - 147.55
Distance: 700 km (700,000 meters)
Frequency: Assumed to be the center frequency of the range (436.5 MHz)
Lfs = 20 * log10(700,000) + 20 * log10(436.5 * 10^6) - 147.55
= 156.53 dB

Swath Width Calculation:
Given, swath, s = 40 km at 500 km
s = 2 * h * tan(a)
h: Height
a: half scanning cone
a = 2.2906 deg
s = 2*700*tan(2.2906) = 55 km

Link Budget Calculation:
Link Budget = Pt + Gt + Gr - Lfs - Lm - Lp - Pr

Pt: Transmit power = 1 W
Gt: Transmitter antenna gain = Assumed to be 1.5 dBi
Gr: Receiver antenna gain = Assumed to be 1.5 dBi
Lfs: Free Space Loss = 156.53 dB (calculated above)
Lm: Miscellaneous losses (cable and connector losses) = 0.5 dB + 0.3 dB = 0.8 dB
Lp: Atmospheric losses = 0 dB (assumed)
Pr: Receiver sensitivity = -121 dBm

Link Budget = 10 * log10(1) + 1.5 + 1.5 - 156.53 - 0.8 - 0 - (-121)
= 137.17 dB

List of Sub-Systems:

Component	Mass	Volume	Peak (V)	Max power	Mass%	Power%
Structure	340 g	**100x100x340.5 mm**	0	0	10.11%	0%
Transceiver	94g	100 x 100 x 20 mm	3.3 OR 5 V	3.5w	2.79%	8.70%
OBC	130g	100 x 100 x 30 mm	3.3 V or 5 V	10w	3.86%	8.70%
EPS	360g	96 x 92 x 11.34 mm			10.70%	4.34%
Antenna	105g	Thickness: 2.2 mm ±150 µm	5V	3.5W	3.12%	15.21%
ADCS	435g	95 x 90 x 32 mm	15v	4500mW	12.93%	19.56%
Solar Panel	300g	Side:2.5 mm &top/ bottom: 1.8mm	1+3.3 + 5 V	45Wh	8.92%	0%
Camera	1.6 kg	10 cm × 10 cm × 21.5 cm	5V DC	10 W	47.56%	43.48%

Orbit, Constellation, and Description

The primary aim of our study is to conduct a thorough analysis of the coastal region with the intention of acquiring a comprehensive understanding of coral bathymetry. This necessitates a global scope of observation. The present study will employ object-based image analysis (OBIA),

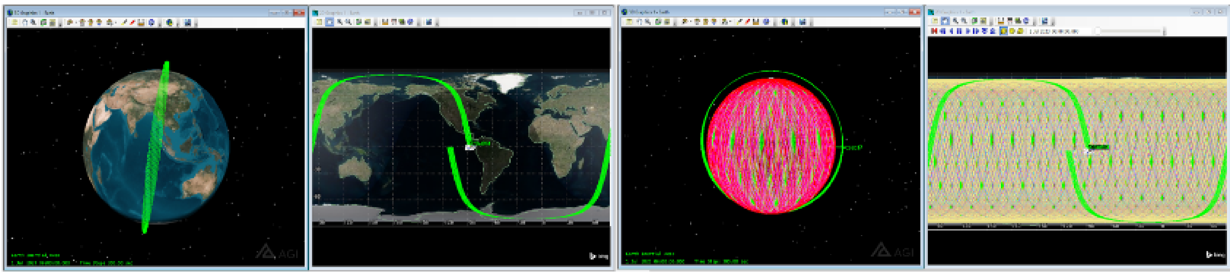


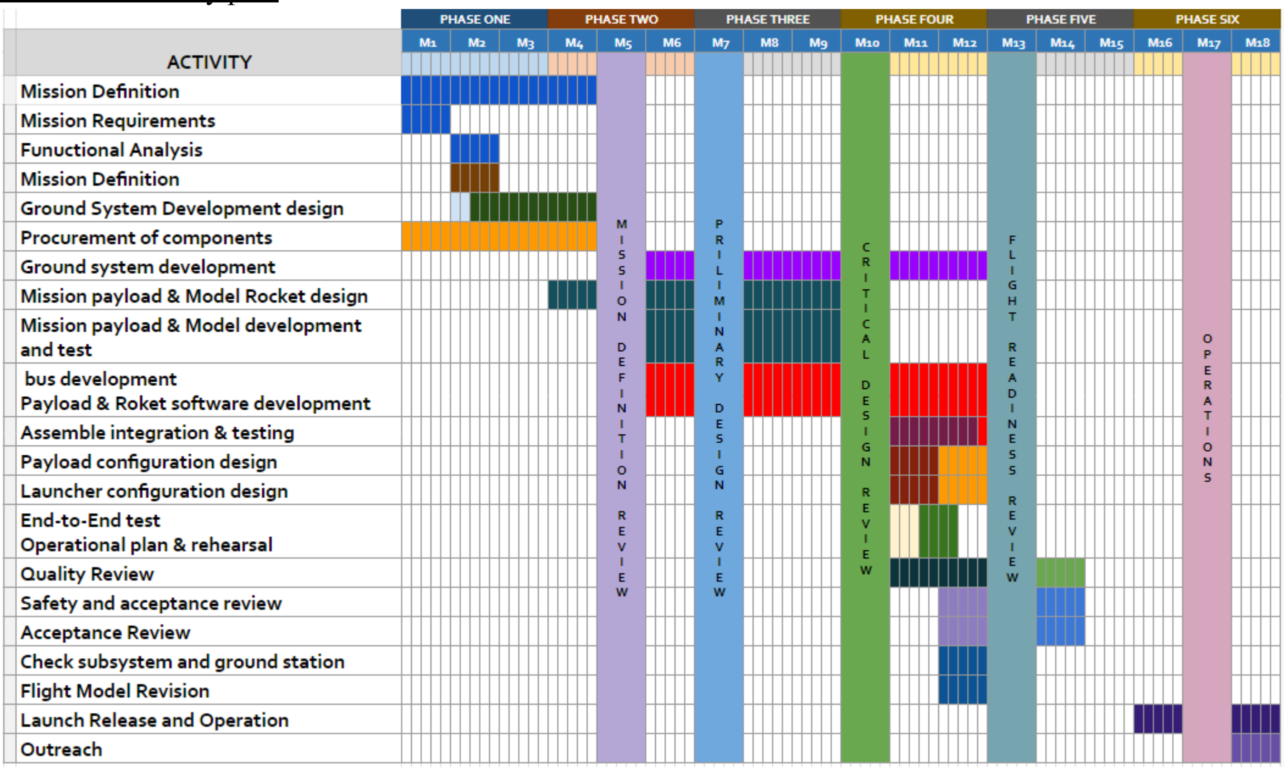
Fig: left image shows the path of constellations and right image shows the coverage at 5th day

a methodology that necessitates the acquisition of accurately captured images. Linear constellations are employed specifically for this objective. The investigation employed a swath width of 55 kilometers, and a total of 14 nanosatellites were chosen for the study. The parameter known as "Local Time of Ascending Node" exhibits variations of 2 minutes and 1 second among the different satellites. Furthermore, these satellites collectively capture images at a distance of 750–770 kilometers from the coastline. In a span of five days, this constellation offers a remarkably precise depiction of the entirety of the Earth.

Implementation Plan

We, BRACU and IUT students, are proposing launching a satellite specifically designed for conducting tracking and monitoring activities on coral reefs. The satellite will use remote sensing to track changes in coral reef health. Utilizing the satellite's data, it will be possible to determine the ideal environmental conditions for coral reefs, look into alternative locations for coral reef restoration, and use microcolony fusion techniques to promote coral growth. The project will benefit a variety of stakeholders, including the Global Coral Reef Monitoring Network (GCRMN), the Coral Reef Alliance (CORAL), Coral Guardian, the International Coral Reef Initiative (ICRI), the UN Development Programme (UNDP), and the UN Environment Programme (UNEP). The project will also help to achieve the United Nations Sustainable Development Goals (SDGs), specifically Goal 14: Life below water, Goal 15: Life on land, and Goal 17: Partnerships for the goals

<u>Here is the activity plan</u>:



Serial No	Risk	Risk Management
1	Delay of launch or license and problems with launch environment	After proper testing and validation, this is an unusual event
2	Solar Panel deployment	The solar panel design will be mitigated according to the orbit
3	Camera calibration for cloud and turbidity	Using the Fmask function and masking the specific disturbance for clouds
4	Gravitational Perturbations	Reaction wheel and magnetorquer for mitigating the situation
5	Corrupted images	Corrupted images can be generated and should be identified and discarded .

Table: Some risk factors and associated management

Procedure	Cost(USD)	Total
Engineering model(EM)	100K*1	100K
Unit Flight Model (FM)	120K*12	1440K
Space Launch System	1603K*1	1603K
Environment Testing	50K*1	50K
Ground Segment	50K*3	150K
Total		3343K

Table: approximate budget for corresponding events

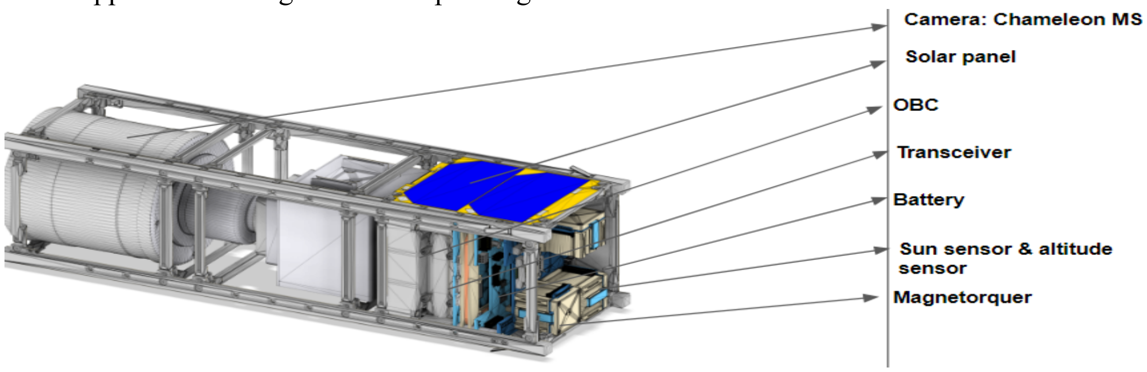


Fig: 3D model of the satellite and acquired components

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