Title: Development of Microsatellite in Monitoring Initial Harmful Algae Bloom (HAB) – “HAB-M”

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(√) We apply for Student Prize.

[SDG14: Life below Water, SDG15: Life on Land]

Need

Harmful algae bloom (HAB) is a disaster that caused by the growth of colonies algae – a simple group of predominantly aquatic photosynthetic organisms – that grow out of control and produce adverse effects to health, environment, and ecosystem. HAB can be harmful because it produces toxins that kill living creatures in the water, causes economic losses, contaminate drinking water as well as depleting oxygen in the water. The world’s rapid developments in agriculture, industrialization, and urbanization, heavy nutrients loading such as nitrate and phosphorus have caused a severe deterioration in water quality, and this eventually reduces the amount of fresh water that can be safely consumed as well as more money needs to be spent to treat contaminated water. The satellite system available nowadays only estimate and predict the distribution of the HAB. Therefore, there is a need for the constellation that can continuously monitor and detect to early bloom of HAB for the authorities to take further actions to preserve the quality of water

Mission Objectives

Primary Objective:

1. To establish a HABs monitoring and detecting system that can continuously provide the algae growth distribution with high-resolution imaginary under specific time and latitude range to the fresh water sources and seas in the world.

Secondary Objective:

2. To provide imaging service for other parties in the research of environmental issues as well as atmospheric conditions.
3. To monitor the effects of prevention and control methods that deal with HABs and other environmental issues.

Concept of Operations

Space Segment:

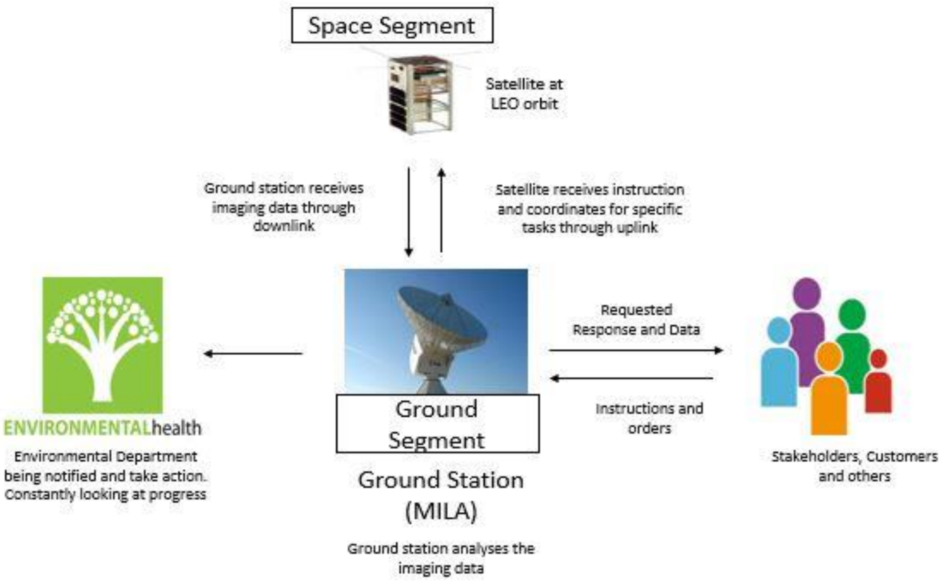
The 3U CubeSat will be placed in the Polar Sun-synchronous orbit (PSSO) where a nearly polar orbir that passes the equator at the same local solar time on every pass. This orbit provides strategic place for the image-taking satellite since shadows will be the same on every pass. Images and inspection to the ground will only be taken in the region of latitude 66° North to latitude 66° South which is about 74% the orbit time where the CubeSat will pass by. The CubeSat will also observe the initial algal bloom by detecting Chlorophyll-a concentration(Chl-a) anomalies and freshwater surface temperature and others supporting sensing data to predict and monitor the environmental factors that contribute to the HABs by using multispectral remote sensing devices. Upon crossing the assigned ground station, all the compressed data will be sent batch by batch to the ground station and will be interpreted there. The CubeSat will transmit data through a S-band transmitter that is able to provide a downlink data rate of **3.4 Mbps.**

Ground Segment: Downlink and Analysis:

The data obtained will be transmitted to the **International Ground Station (IGS) Network** which alike Landsat 7. Since Landsat 7 has around 12 ground stations to receive data, hence, HAB-M will use similar ground stations. The data from downlink will be interpreted and send to the desired stakeholders or ground stations that near to the initial HABs occurrence. The ground station will analyse and inform the environmental departments about the occurrence so that preventive methods can be applied to reduce the destruction of HABs to the environments and health. The acquisition aid antenna is to provide a specific frequency of S-band to reduce the congestion due to massive data transmission. S-band transmitter is used to send data back to Earth with a frequency range of **2200-2290MHz** (EESS/SRS/SOS allocations)

<u>Ground Segment: Uplink</u>

Stakeholders and researchers allow to request the CubeSat to investigate the desired location within the satellite surveillance regions for topography and scientific researches. The coordinates and commands are to be uplinked to the CubeSat when it passed by the assigned ground station. Every request for remote sensing service is well defined and simplified to allow the CubeSat to function at its maximum capacities.



Key Performance Parameters

The key performance of the 3U CubeSat is highly dependent on the available marketed products. In this mission, remote sensing is the primary functions.

- <u>Spatial resolution</u>: Since this mission is not a real-time tracking unit, hence the spatial resolution that can be supplied by the best remote sensing device in the current market will be taken as guidelines. Hence, the spatial resolution will be 9.6m.
- <u>Accuracy</u>: The accuracy and clarity of the images are highly dependent on the ADCS system on-board which contain feedback system that can continuously adjust to obtain the best graphic quality. Reaction wheel based ADCS is used to improve it accuracy up to 0.5°.
- <u>Service Coverage</u>: The 3U CubeSat will be placed at an altitude of 550 km which allows the microsatellite to have 15 orbits per day. Most of the time, the microsatellite will start to take in information upon reaching latitude 66° North to 66° South where those regions have the highest occurrence of HABs. However, the region outside can be requested based on customer needs.

Space Segment Description

Components	Part Description/Source	mass/unit (kg)	Mass(kg)	COTS/Custom
General				
3U CubeSat Structure	ISIS	0.304	0.304	COTS
ADCS	CubeWheel Small (3)	0.060	0.180	COTS
Solar Panels	EXA Deployable Solar Panels DS/1A (3)	0.087 /0.070	0.244	COTS
Cables and Misc.	Misc.	0.150	0.150	COTS
Propulsion	Vacco Micro Propulsion Satellite	0.542	0.542	COTS
Power Supply	Baox High Energy Density Battery Array (Irvin Class)	0.115	0.115	COTS
OBDH				
CPU Board &Mass Storage	CubeComputer	0.070	0.070	COTS
Transmitter	ISIS High Data Rate S-band Transmitter	0.250	0.250	COTS
Transceiver	UHF Downlink/VHF Uplink Full Duplex Transceiver	0.075	0.075	COTS
Antenna	ISIS Deployable Antenna System	0.085	0.085	COTS
Flight Module	CubeSat Kit FM430	0.090	0.090	COTS
Imaging Payload				
Sensors	CubeSense	0.080	0.080	COTS
Lens and camera	SAC Chameleon Imager	1.350	1.350	COTS
		Total mass:	3.535	kg

The Chameleon is an extensive CubeSat imager that is used and integrated into a 3U CubeSat. It provides high-resolution Multispectral or Hyperspectral line scan that able to capture images with a range of electromagnetic wavelength. Chameleon Imager is good enough to provide sufficient multispectral data required for analysis because Chlorophyll-a Concentration that is carried by HABs tend to absorb certain wavelengths. With Chameleon Imager selection, the prediction of HABs out bloom can be made. Next, it has high frame RGB Bayer-pattern imaging and high integrated high-speed data storage that allows it to cooperate with Cube Computer to process and compressed data into smaller bits. The built-in storage is up to 160 GB which is mass storage with relatively low power consumption.

General: ADCS

Three CubeWheels will be installed into the 3U CubeSat at different axes (X, Y, Z). The CubeSense which is an integrated sun and nadir sensor for attitude sensing which reduces the need to buy different parts. CubeSense makes use of two CMOS cameras which are dedicated to sun sensing and horizontal sensing. Both camera have wide FOV optics with the outputs that able to calculate the sun and nadir relative to the camera boresights.

Solar Panels & Power Storage

The peak power usage is estimated around 23.86W therefore the selection of solar panels and battery must be able to supply this amount of power. The solar panels selection is once again selected from the available product. In this mission, it is planned that there will be 2 pairs of deployable solar panel from EXA which each pair of them contains two pieces 1U w/low cost solar cell with one 1U w/high power solar cell. Both types of solar panels do not have NAMEA shielding. These two pairs of solar panels arrangements will give a 25.4W of power supply.

Structure:

ISIS 3U standard structure with high modulus primary and secondary structures. This structure is a highly modular design and providing detachable side panels that allow many other systems to be placed inside. Multiple PCB sizes supported with dual kill-switch mechanism. The outside envelope is 100mm x 100mm x 340.5mm while the inside envelope is 98.4mm x 98.4mm x 295.2mm.

Communication System:

High data rate S-band transmitter with ISIS Deployable Antenna System work together to transmit the imaging data to the ground stations. The uplink frequency range for HF is **136MHz to 470MHz** where this frequency only be used for updates and instruction to CubeSat. The instruction and updates are sent by using UHF Downlink/VHF Uplink Full Duplex Transceiver while the imaging data is sent by using the S-band transmitter with a downlink rate higher than transceiver.

OBDH:

Instructions and coordinates are uploaded to the satellite when it passed by the ground station. When the satellite approaching the target location, the direction of camera pointing will be adjusted by ADCS with the coordinates input. The images will be processed and stored in the imaging payload or the memory storage of the CPU before the next connection with the ground station.

Power:

Table 1:Estimated Power Usage of 3U CubeSat

Component/s	ADCS	Propulsion	OBDH	Payload	Total
Average Power(W)	0.64	0.25	2.74	2.5	6.13
Peak Power (W)	2.16	10.0	8.2	3.5	23.86

The average power required is 6.13W whereas the peak power usage is 23.86W where the highest portion of the peak power is due to full thrust by the propulsion system which is 10W.

Orbit/Constellation Description

The altitude set in this mission is 550 km from Earth's surface. The satellite will follow the polar Sun-synchronous orbit (PSSO) track and fly from North pole to south pole with an inclination about 90°. The calculated orbital period is 95.64 mins which means the satellite will travel 15 times across the orbit.

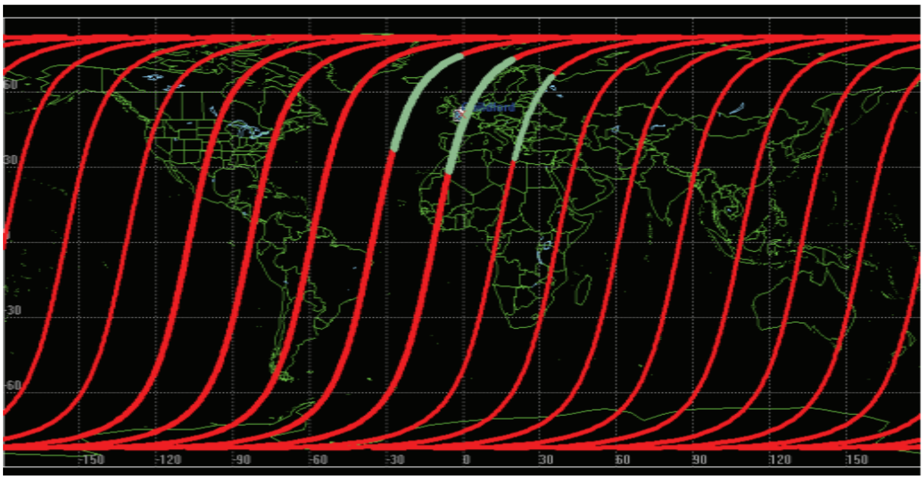


Figure 1: Satellite Footprint

The presence of disturbance such as gravity gradient, solar pressure, atmospheric drag and magnetic field will cause orbital decay to the satellite. Assume that the rate of orbital decay is 2km/months, after 5 years of service it will be 60 months. Hence, the altitude of the satellite will be 430 km with an orbital period of 93.17 mins which is lower than the initial period.

Implementation Plan

There are 5 phases of designing a mission which are design phase, development phase, integration and assembly phase, testing and launching. Each phase required cost to run and integrate. However, most of the parts can be bought and customized by worldwide manufacturer. Hence, the cost for integration and testing will be the focus. All the parts required to build a 3U CubeSat will sum up a total cost of 234,100 USD. Integration and assembly will take up 90,000 USD, testing will take up to 220,000 USD and last the cost required to launch is around 2,000,000 USD. Hence, this will make up a total cost of **2,556,600 USD.**

Table 2: Estimated Budget of the HAB-M

Procedure	Unit Budget	Integration &assembly	Testing	Launching
Approximate cost (USD)	246,600	90,000	220,000	2,000,000

The mission is a 5 years mission and each year this mission will spend **513,320 USD.** This project will involve number of governments, research centres and stakeholders.

Table 3: Timetable for Project Implementation

					2	0	1	9									2	0	2	0				
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Conceptual Design	■	■	■																					
Preliminary Design				■	■	■																		
Detail Design							■	■	■															
Engineering Modeling&Simulation										■	■	■												
Purchasing and Modeling													■	■										
System Integration															■	■	■							
Flight Model Test&Evaluation																		■	■					
Environmental Test																				■	■			
Launch Vehicle Integration																						■	■	
Launch																								■

The top 5 project risks in HAB-M mission are

1) Ground Communication Failure (unable to connect the satellite back to online)
2) Launch failure (money wasted)
3) Imaging payload failure (hitting by space debris and causing scratches to the lens)
4) ADCS and sensors unable to work well (affecting the stability of the satellite and blur images capture)
5) Power failure (battery unable to be charged or solar panels hit by space debris)

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