# Development of Microsatellite in Monitoring Initial Harmful Algal Bloom (HAB)



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APEX™

# Algal Bloom is not something NEW!

*"Harmful algal blooms, or HABs, occur when colonies of algae — simple plants that live in the sea and freshwater — grow out of control and produce toxic or harmful effects on people, fish, shellfish, marine mammals and birds. The human illnesses caused by HABs, though rare, can be debilitating or even fatal."*

*a) Produces Toxins*

*b) Causes economic losses*

*c) Contaminates drinking water*

*d) Depletes oxygen…*

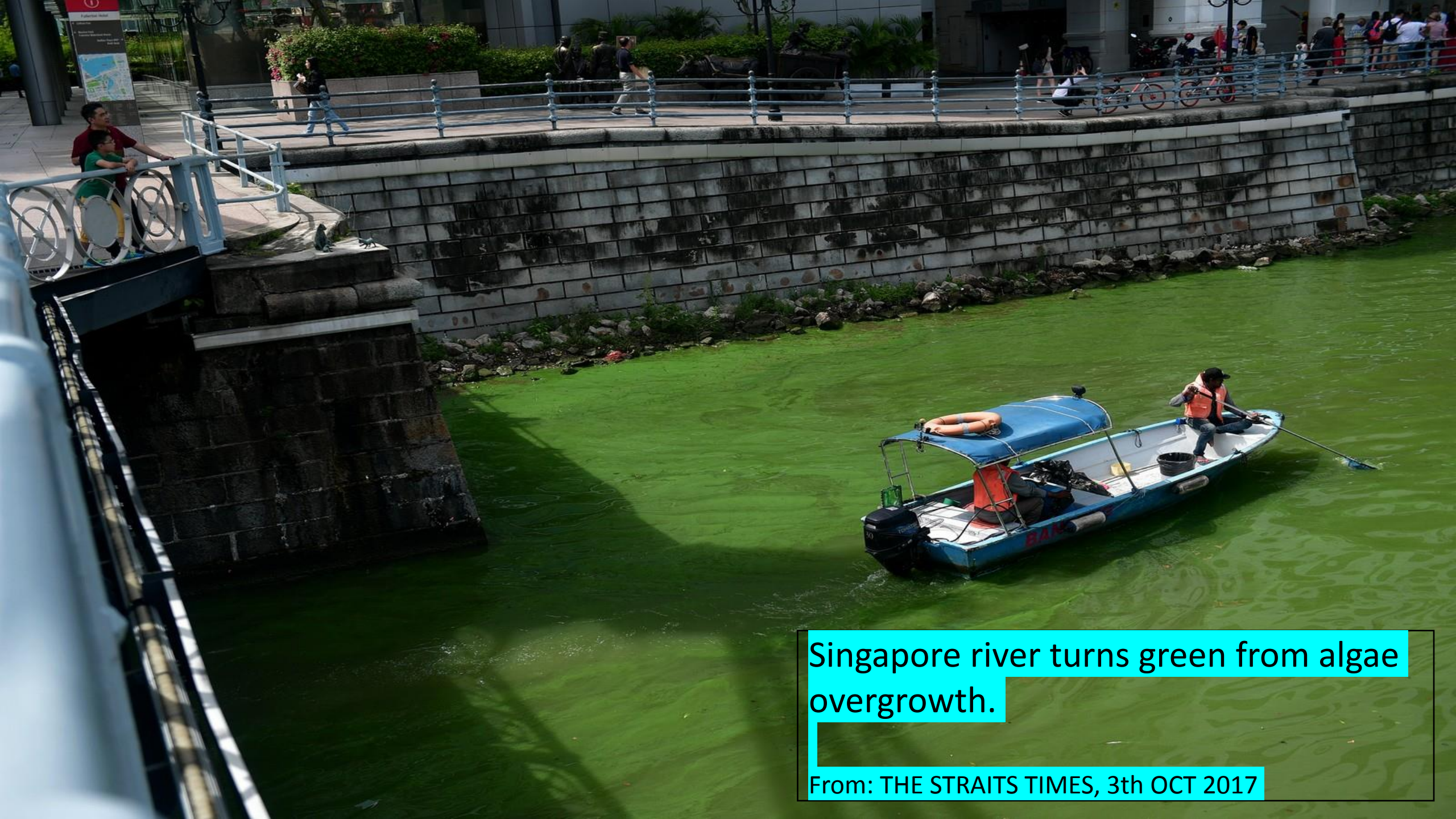
Causes by: Nutrient pollution, warm water condition, changes of water flow…

Reference from: NASA Applied Remote Sensing Training Program

# What kind of algae involves?

| Cyanophyta (Cyanobacteria / Blue-Green Algae) | Characteristic | Chlorophyta (Green Algae) |
|---|---|---|
| Typically 0.2 - 2.0 mm diameter | Cell Size | Typically 10-100 mm diameter |
| Many Toxic Species | Toxins | None |
| Many produce Geosmin & MIB | Taste & Odor | Some produce Geosmin & MIB |
| Binary fission (no meiosis) | Reproduction | Mitosis (meiosis involved) |
| Surface Blooms with many species | Blooms (Buoyancy) | Absent |
| Many Are | Nitrogen Fixers | No |

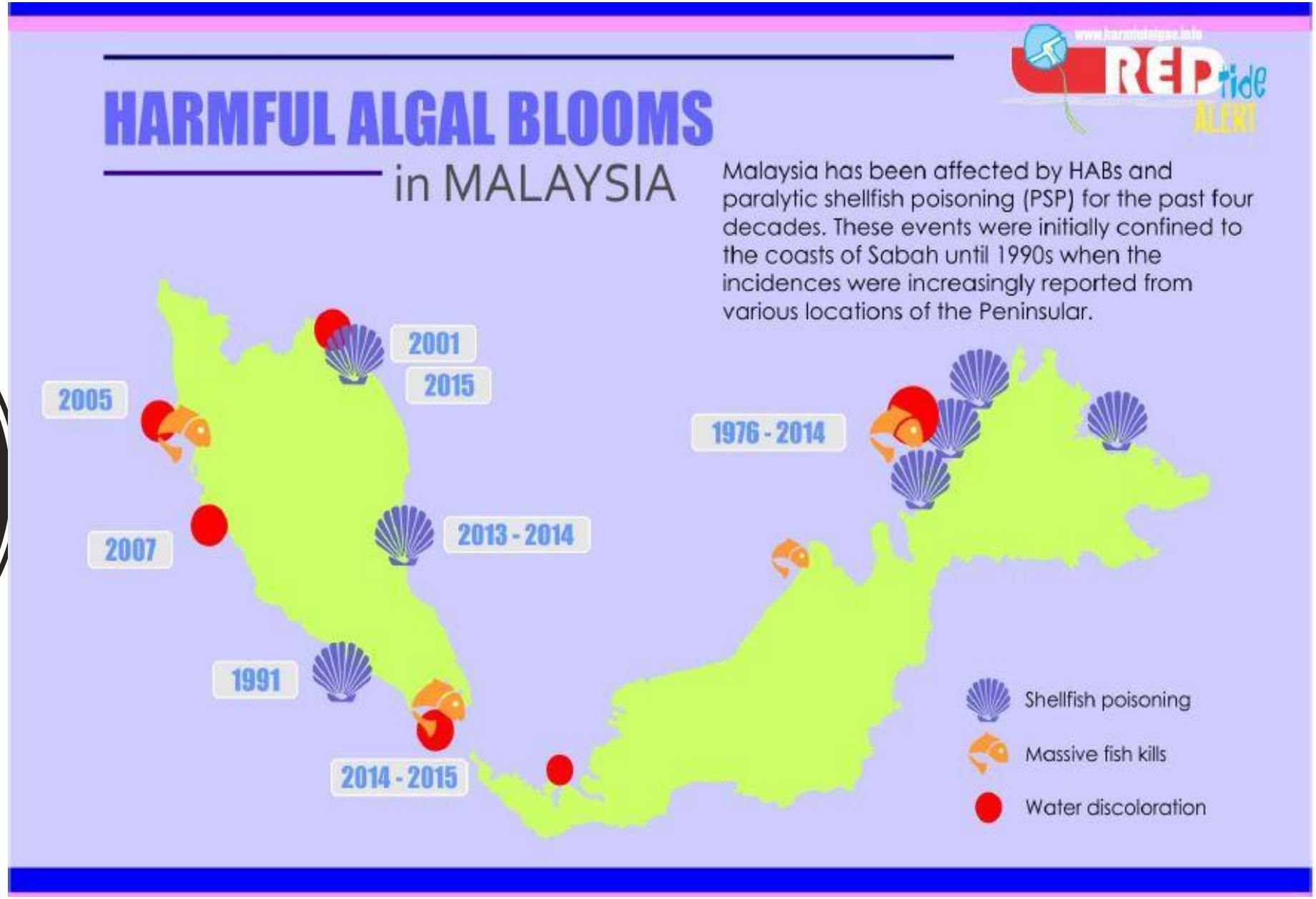
Reference from: Peroxygen Solutions, Nuisance Algae?



Singapore river turns green from algae overgrowth.

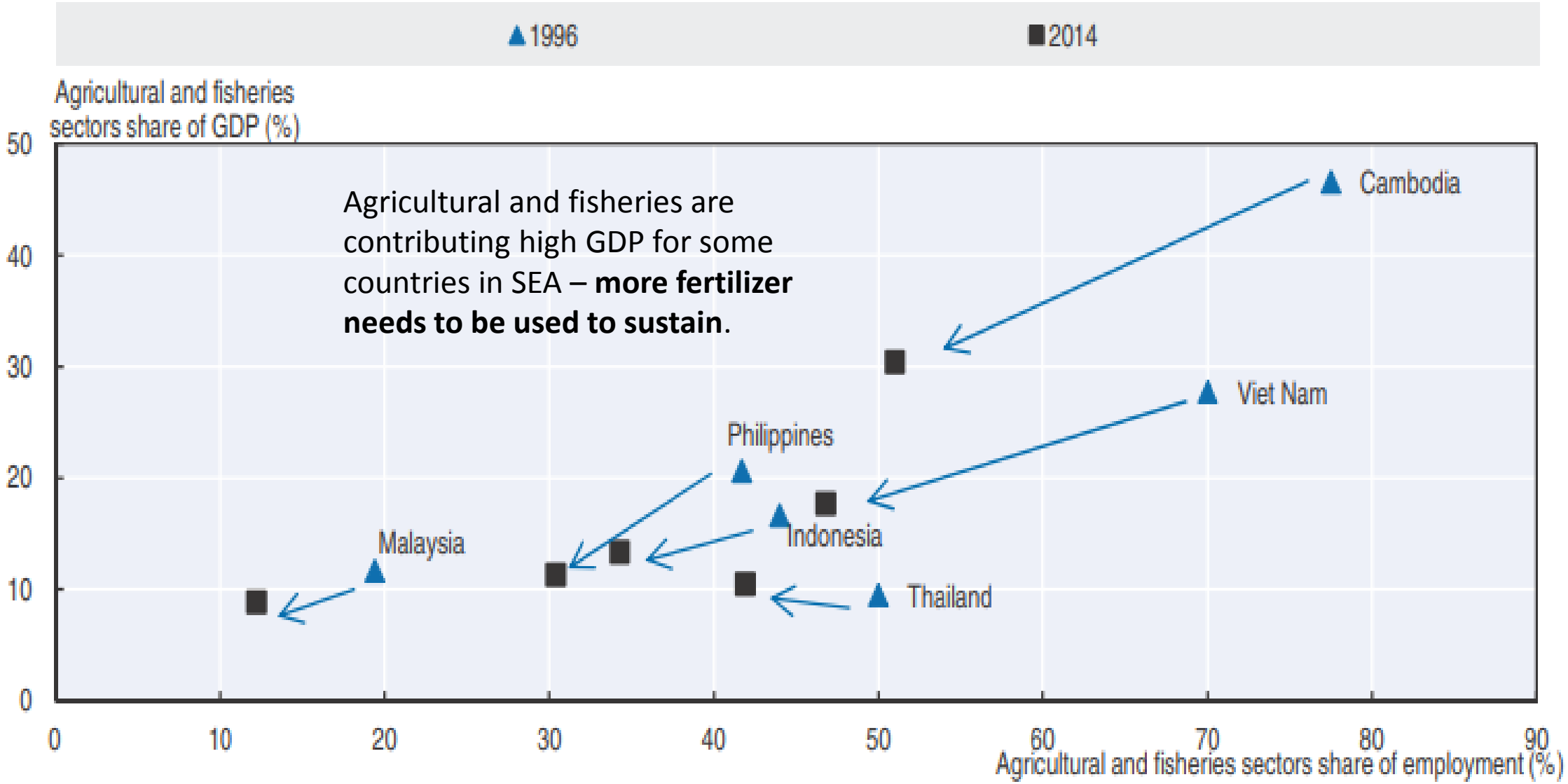
From: THE STRAITS TIMES, 3th OCT 2017

# Malaysia Algal Bloom Occurences:




Reference from: Major recorded HAB-related events in Malaysia: 2014-2016

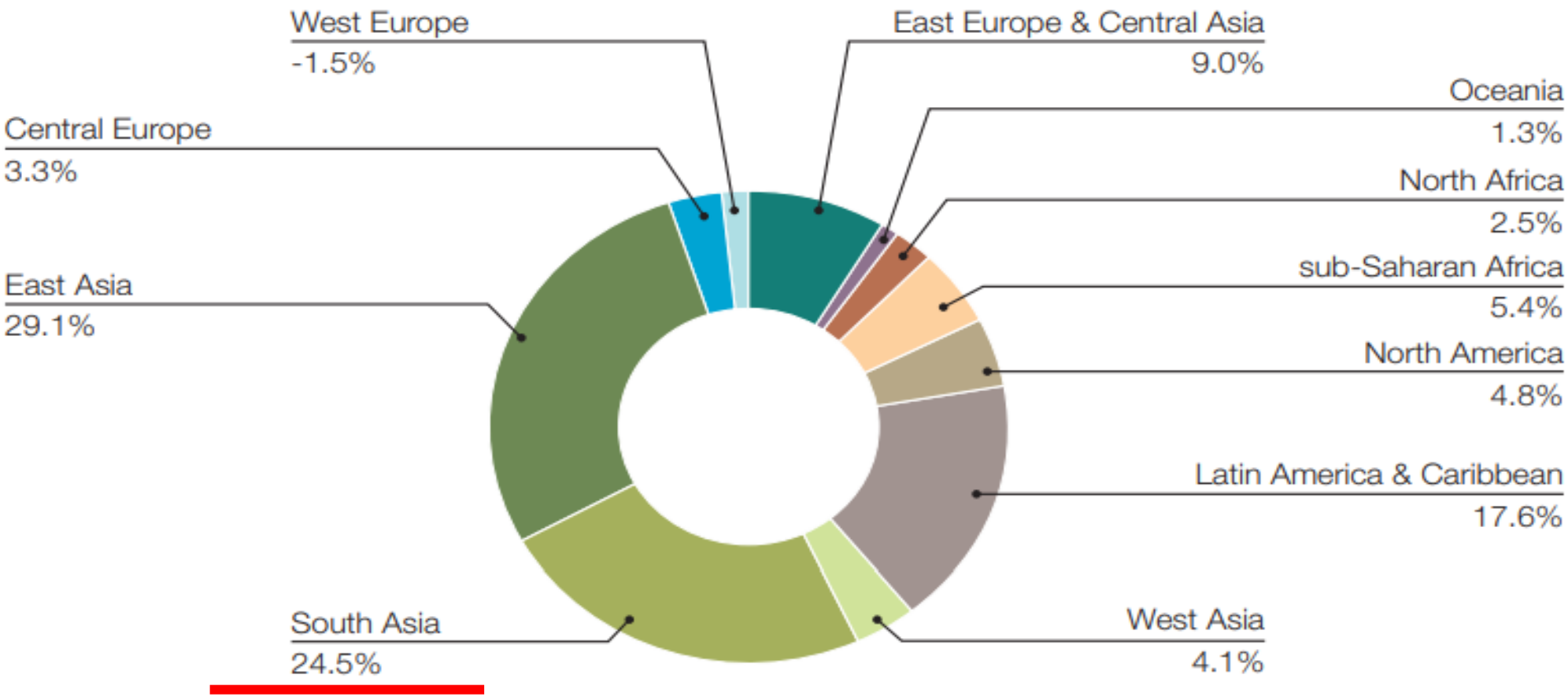
# Agricultural and fisheries sectors share of employment and GDP 1996 and 2014




Reference from: World Bank (2017), World Development Indicators

# Nitrogen Fertilizer Around the World

Figure 3. Regional and subregional share of world increase/decrease in nitrogen fertilizer consumption, 2014-2018




Reference from: FAO REGIONAL CONFERENCE FOR ASIA AND THE PACIFIC (2018)

# Huge Impact? Think of it carefully!

How many people are using fertilizers in their agriculture?

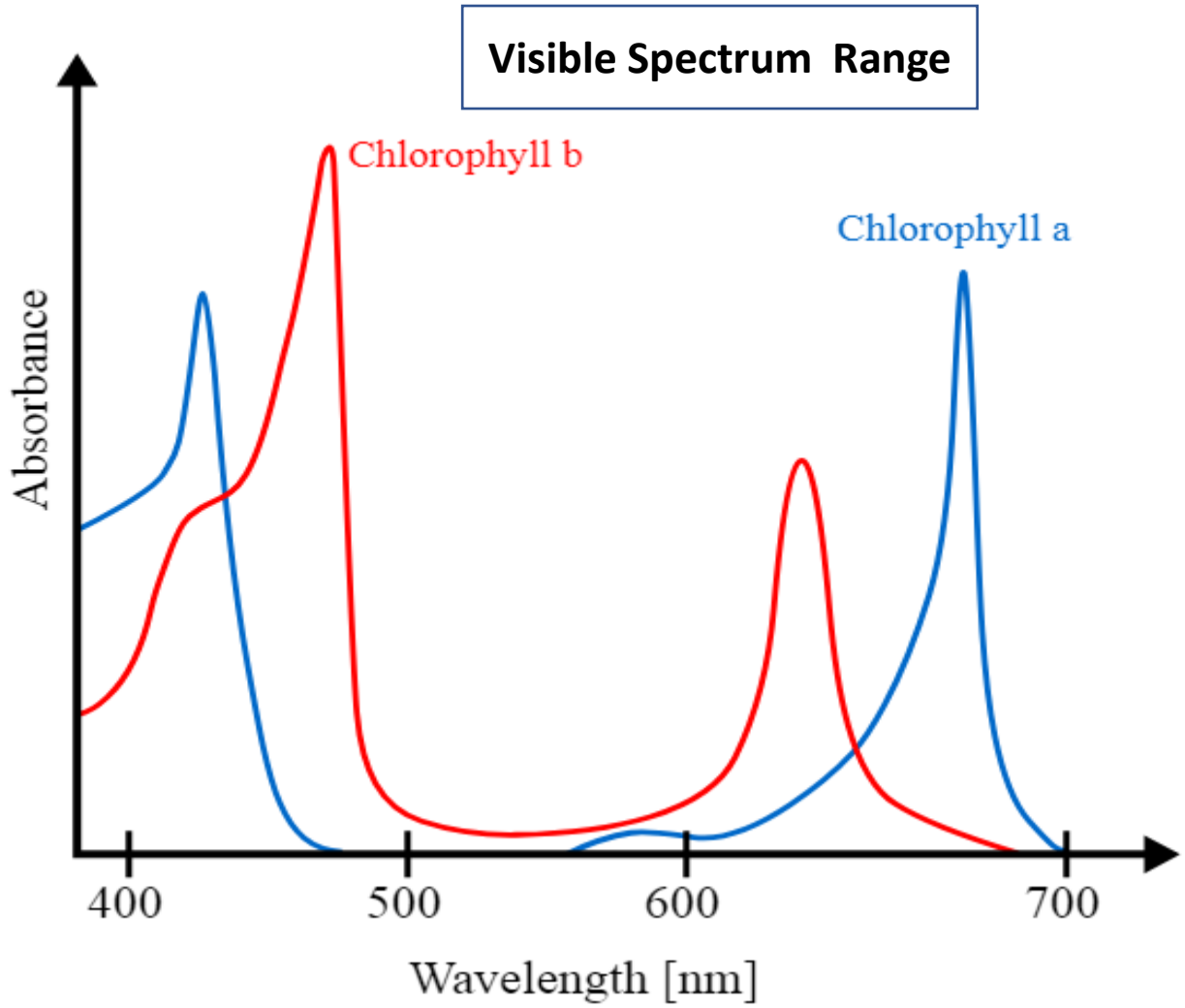
How many rivers and lakes in South East Asia and South Asia?

How many people and animals are living and consuming these contaminated water?

How their lives is going to be after consuming those polluted water?

# How do we know there is a HAB?

- Using Hyperspectral Imaging to capture the Chl-A and Chl-B concentration anomalies
- Evaluate the water surface temperature (WST)
- Decolouration of water (Bio-optical Properties)



# Objectives:

## Primary Objectives:

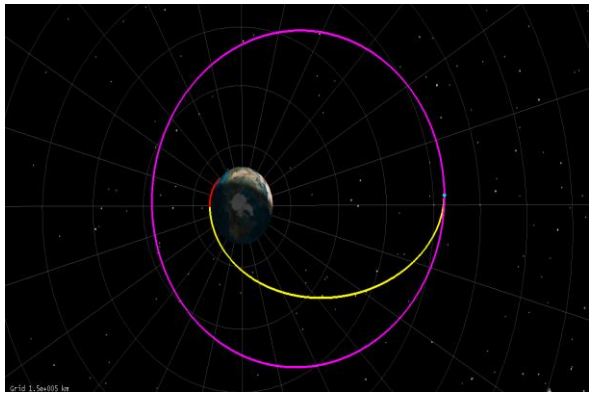
To establish a HABs monitoring and detecting system that provides early warning to authorities on Initial Harmful Algal Bloom in South East Asia (SEA).

## Secondary Objectives:

a) *To provide imaging services for other parties in assisting in the research of environmental issues as well as atmospheric and sea current conditions.*

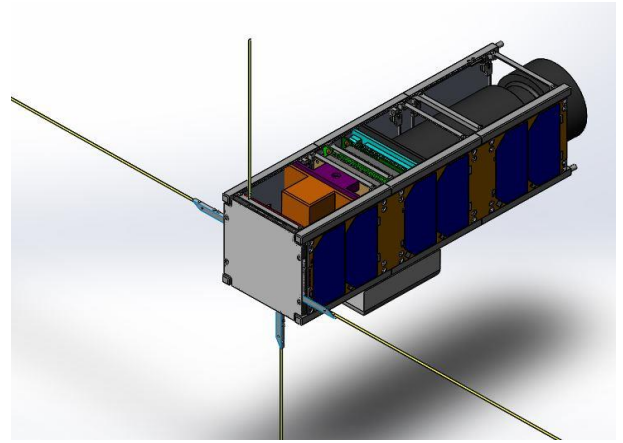
b) *To monitor the effects of prevention and control methods that applied to HABs and other environmental issues.*

# Concept of Operations:



Orbit Insertion

Nanosatellite Constellation Deployment:
3 satellites release consecutively at RAAN 60° , 120 ° and 180 °

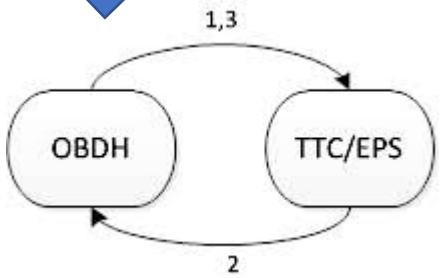


Subsystems, payload activations.
Antenna deployment

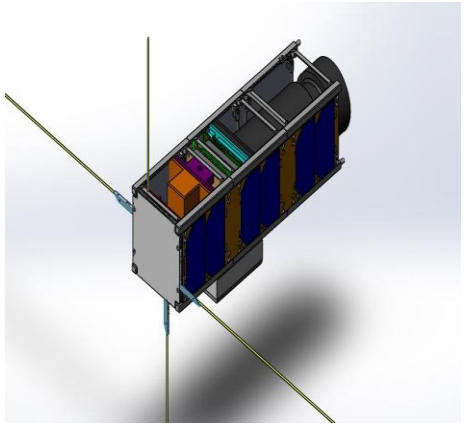
Deorbit and Mission Ended

Launch

Onboard operation, spectrum data storage, transmission to ground stations



# Mission Concept of Operation:



Satellite Constellation with 3 units of 3U CubeSat at different RAAN at NeqO

Ground Station Cluster in SEA

VNIR Hyperspectral Imaging
- Able to differentiate vegetations
- High NIR but low visible reflectance

**Data Management Agency** runs by Universities
- Matching with HSI Data Bank

**Initial HABs**

Point of Interest by Customers & Stakeholders

Customers & Stakeholders

Research Agencies

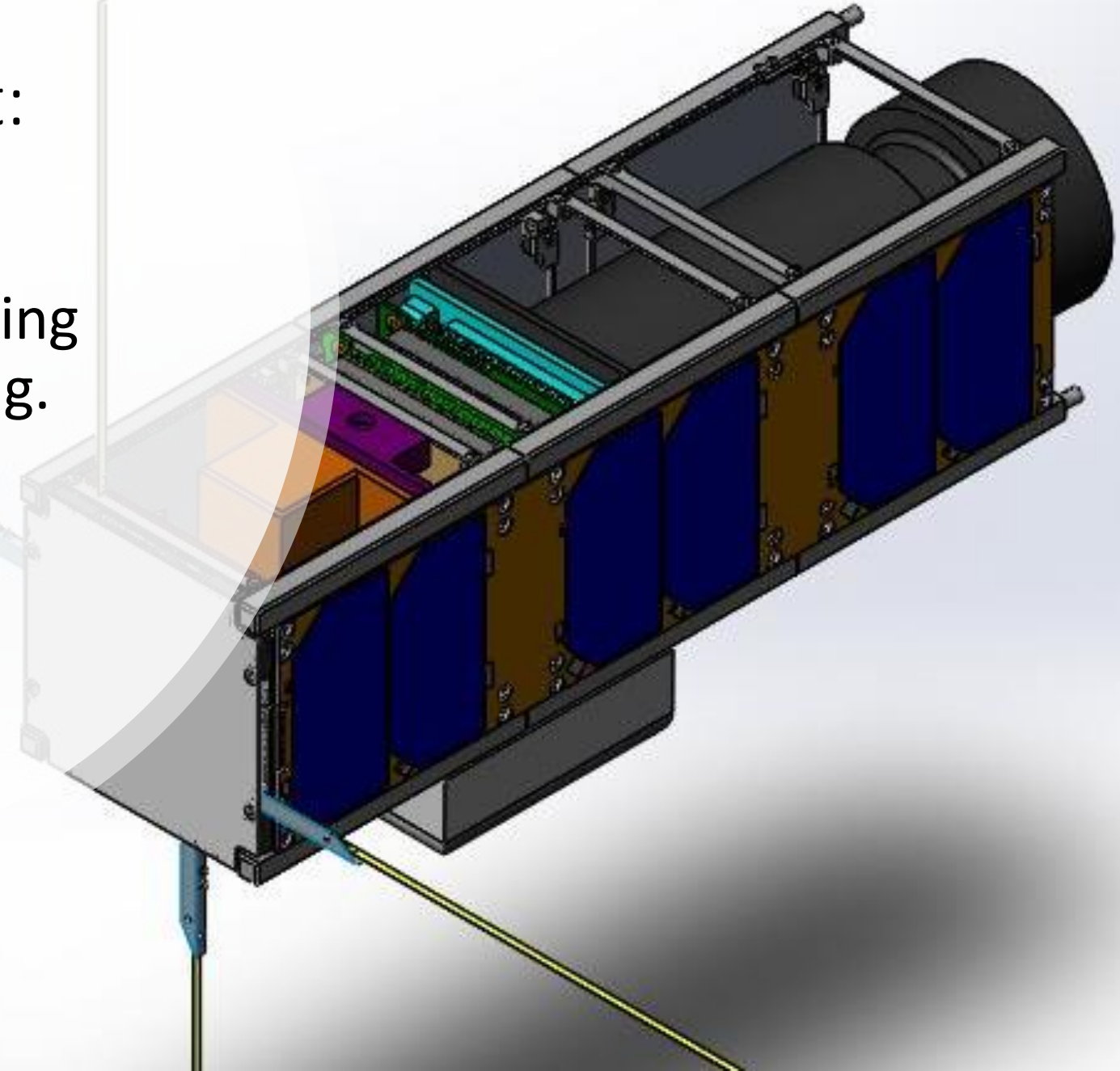
Government Environmental Segment – **water treatment department**

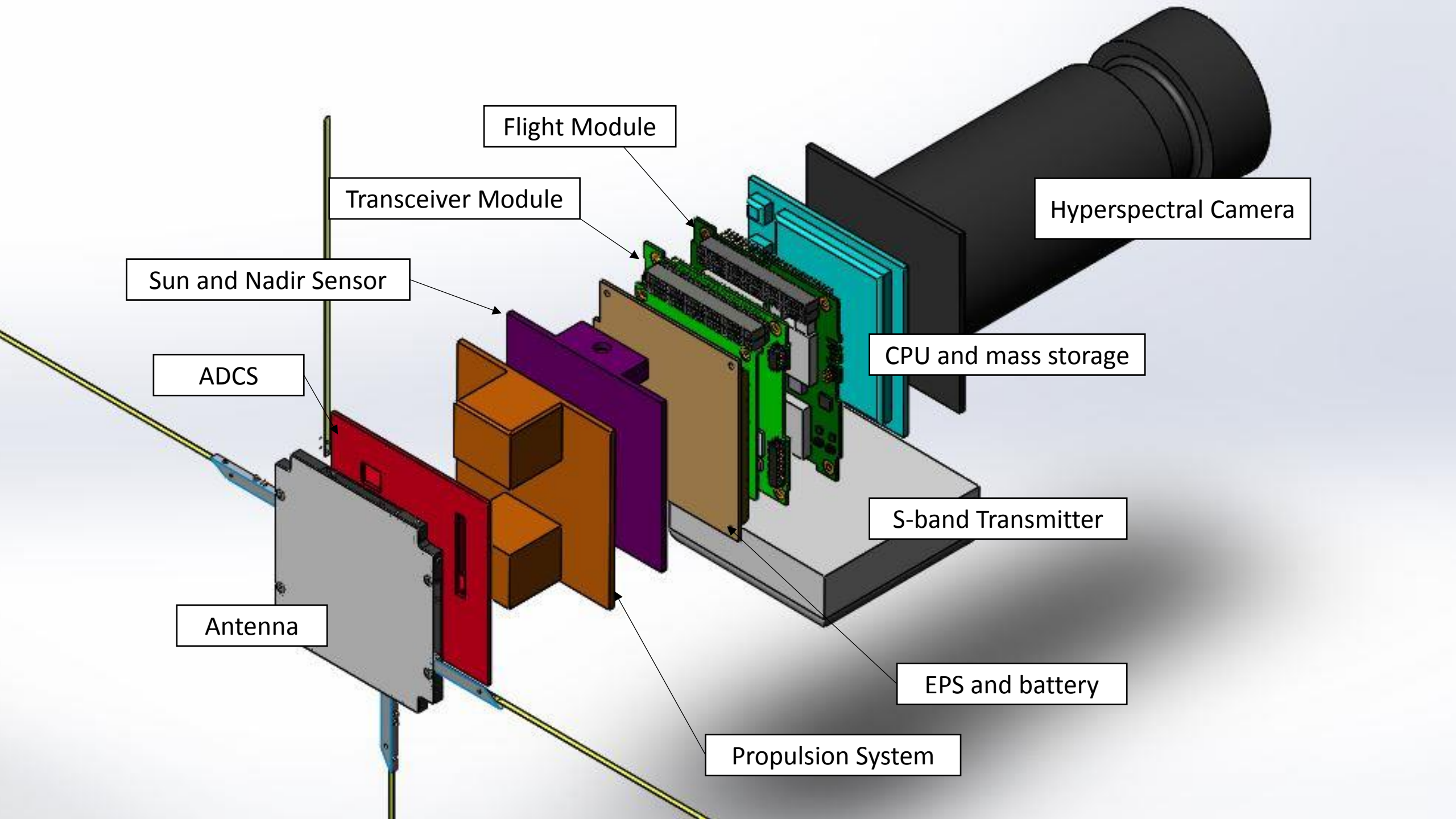

S-band antenna is required and using existing equipment

# Ground Segment: Ground Stations Involved

# Space Segment:

3U CubeSat with Hyperspectral Imaging (HSI) remote sensing.




Flight Module
Transceiver Module
Sun and Nadir Sensor
ADCS
Antenna
Hyperspectral Camera
CPU and mass storage
S-band Transmitter
EPS and battery
Propulsion System

# Key Performance Parameters:

1) Remote Sensing Spatial Resolution

Considerations:

- Spatial Resolution must be less than 30m
- The hyperspectral data must include VNIR (Visible Near Infrared) spectrum range
- Cloud penetration capability at equator regions (Hot, humid and cloudy weather)

Why?

- More details for countries or customers who need the data
- Business Lead Magnet for bands of VNIR and SWIR (mining, topography mapping, red tides …)
- To reduce pixels overlap (small water body)

# Imaging Payload Considerations (VNIR)

- **Vegetation** has a unique spectral signature which enables it to be distinguished readily from other types of land cover in an optical/near-infrared image.
- Algae and other vegetations can be identify by measuring the reflectance of Visible to Near Infrared spectrum data emitted by them.
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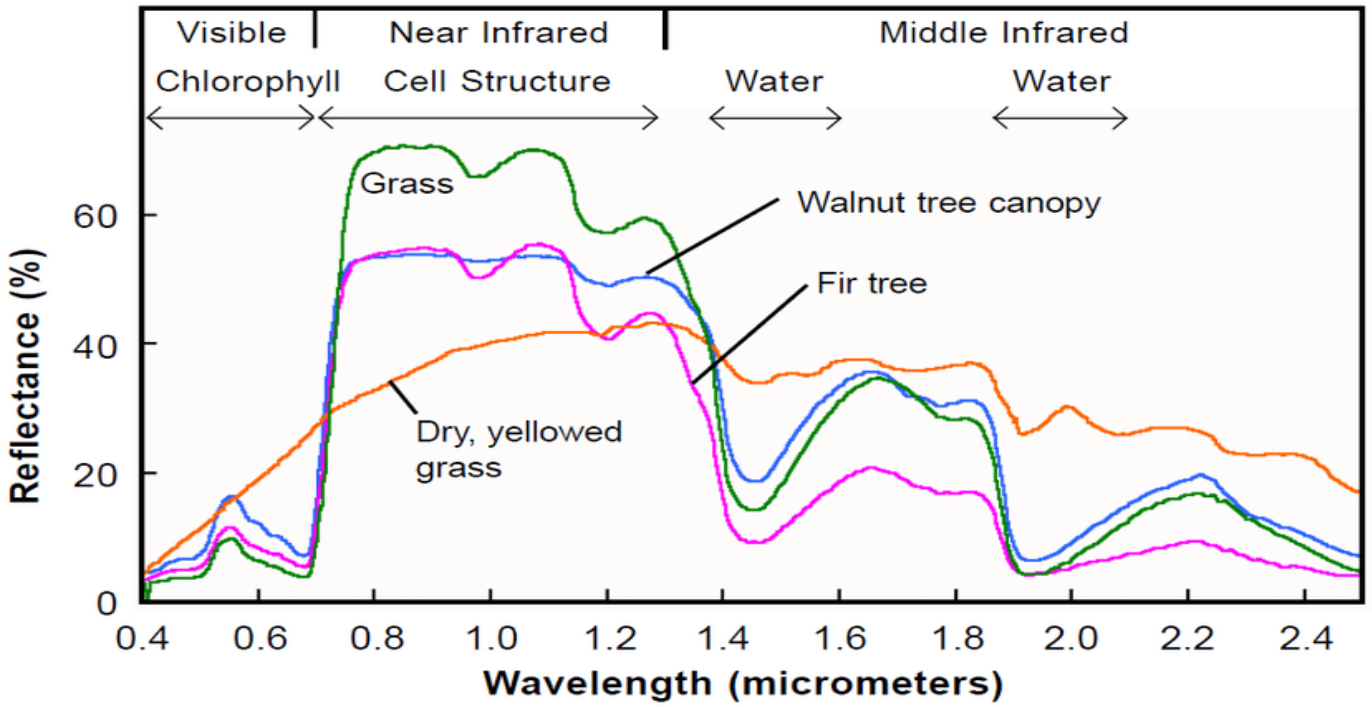



Reference from: Xavier Hadoux, Dimension Reduction by Orthogonal Projection for Discrimination (2015)

# Chameleon Imager – HSI applications

| CHAMELEON IMAGER | |
|---|---|
| Spatial resolution (GSD) @ 500 km | 9.6 m PAN; 19 m MS; 29m HS |
| Swath @ 500 km | up to 32 km |
| Spectral bands | Bayer RGB<br>or PAN + 8 Multispectral bands<br>or 150 band Hyperspectral |
| Signal-to-Noise Ratio | >200 PAN, >120 MS, >150 HS |
| Data format | 10-bit or 12-bit |
| Integrated mass data storage† | Up to 160 Gigabytes |
| Compression | Raw, lossless and lossy |
| Data interfaces† | LVDS, SPI, I2C, CAN-bus |
| LVDS output rate | 1 - 240 Mbps |
| Dimensions of imager | 2U (200 mm x 94 mm x 94 mm) |
| CubeSat standard | Compatible with 3U and larger |
| Power Usage | < 3.5 W (imaging mode)<br>< 2.5 W (readout mode)<br>5V or 28V* power supply |
| Mass (incl. electronics) | 1.35 kg |
| Operating temperature | +10°C to +30°C |
| Survival temperature | -20°C to +70°C |
| Radiation tolerance (TID) | Tested to 20 krad |

† Depends on chosen configuration.
* Requires optional add-on daughterboard


Brochure from: Chameleon Imager, SPACE Advisory Company

# Key Performance Parameters:

## 2) Coverage

Considerations:

- Rapid revisit at least 3 times per day (orbit selection)
- Limited to latitude North 22 degrees to South 22 degrees
- "NeqO" orbit (Near Equatorial Orbit)

Why?

- Faster data transmission from satellite to ground stations
- Faster warning and verification for authorities
- Prevent data overloads to the microsatellite
- Business Lead Magnet (countries in that region)

# Summary of the Microsatellite:

Attitude Determination and Control System(ADCS):

- 3 units of Small CubeWheels

Propulsion:

- 2 units of Vacco Micro Propulsion System (0.3U)

OBDH:

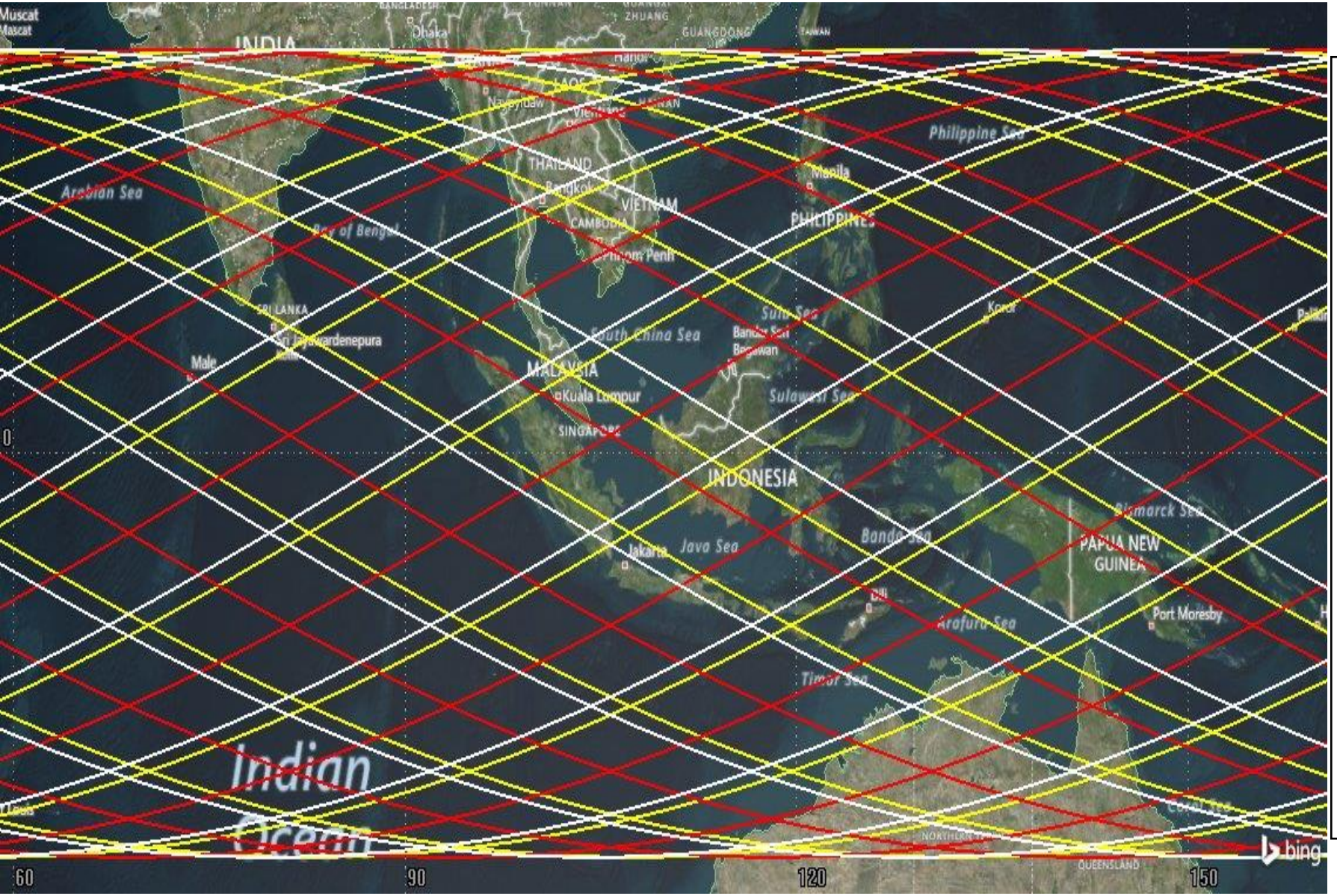
- CubeComputer & Mass storage
- Flight module (CubeSat Kit FM430)
- S – band transmitter (3.4 Mbps downlink)
- Transceiver (9600 bps for uplink and downlink)
- Deployable Antenna

Power:

- 4 units ISIS 3U fixed solar panels (generating 27.6 W)
- Imaging operation (used 6.60 W)
- Date transmission/ Receive (12.10W)
- Target Pointing (23.60W)

Parts Data from: cubesatshop.com

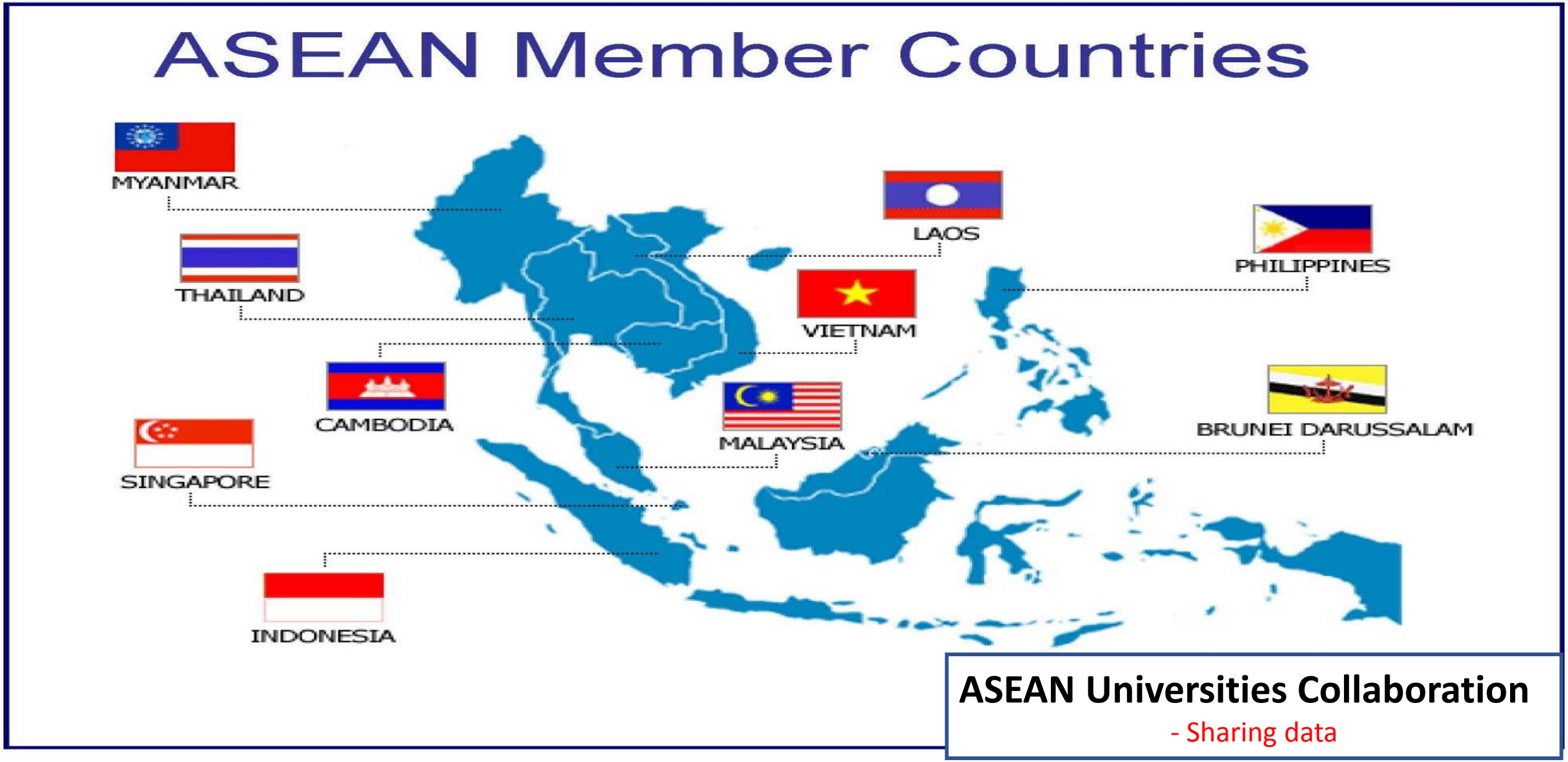
# Mission Description: New Implementation in SEA




**Near Equatorial Orbit (NeqO)**

- Alititude: 600 km
- Inclination: 22 degrees
- Orbital Period: 5801.6 s/ 96.7 mins
- Orbital cycle: 14.89/day
- Constellation: 3 satellites constellation
- RAAN: 60°, 120°, 180°
- 3 - 5 years mission

# Implementation:




**ASEAN Universities Collaboration**

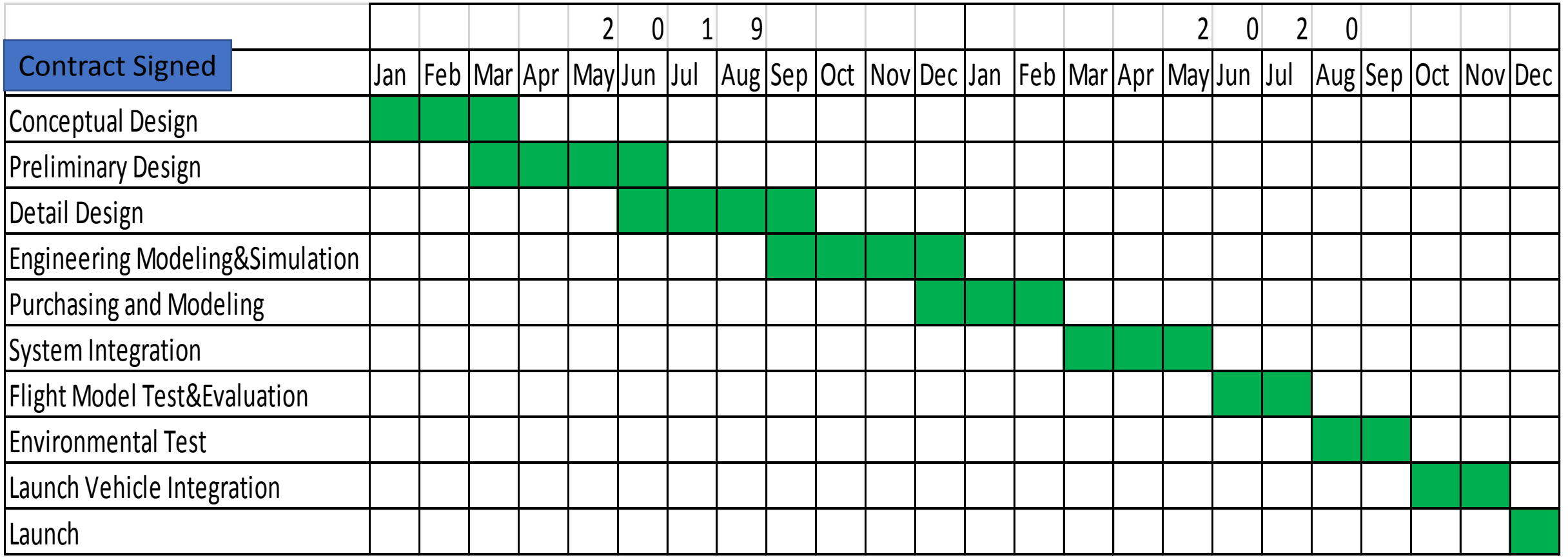
- Sharing data

# Budget Required

| Operation | Cost (USD) | Total Cost for 5 years (USD) |
|---|---|---|
| HAB-M 3U CubeSat Module | $ 254,700.00 | $ 764,100.00 |
| Integration, Testing and Launching | $ 300,000.00 | $ 300,000.00 |
| Ground Operations | | |
| Ground Stations Equipments set-up | $ 200,000.00 | $ 200,000.00 |
| Project Manager Salary /year | $ 30,000.00 | $ 150,000.00 |
| Scientist & Engineers (2 person)/year | $ 48,000.00 | $ 240,000.00 |
| Miscellaneous/year | $ 20,000.00 | $ 100,000.00 |
| | Total Cost | $ 1,754,100.00 |

1 year operational cost = USD 350,820.00

# Mission Preparation Timeline




Mission Planning Reference: Spaceflight - Schedule and Pricing

Let’s us protect the land and fresh water and together we live healthy life!