Title: Development of Microsatellite to Detect Illegal Fishing "MS-SAT"

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(v) **We apply for Student Prize.**

Need

As a large country in which most of its territory is sea, and an economy which heavily depends on maritime activity, Indonesia needs an observation system to protect its maritime resources from activities such as illegal fishing or disasters like oil spill. The requirement to address this problem is to detect it as early as possible to minimize the negative effect. Currently there is no effective solution to fulfill this requirement because Indonesia's sea is very large in size and there is no system that can detect the problem timely enough to get a fast response from the authority, therefore the development of this system is necessary.

Mission Objectives

Primary Objective

1. Detect and locate potentially illegal fishing ship using satellite image, AIS data, and external sources.

Secondary Objective

2. Monitor maritime environment and provide early warning for environmental disasters such as oil spillage.
3. Monitor maritime traffic and detect any ship illegally trespassing territorial water.
4. Provide intelligence of sea-based crime such as ship hijacking and piracy.

Concept of Operations

The MS-SAT operation consists of ground segment, space segment, user segment, and launch segment.

The space segment consists of a satellite in near-equatorial low earth orbit. This satellite will have a high resolution camera to detect ships in a particular area, an Automatic Identification System receiver (AIS, a system used by ships to automatically report its position and other data) to receive signal from ships in the area, a GNSS receiver to locate the satellite's position, and a transceiver. Other than an observation tool, the satellite has a secondary function as a repeater to receive and transmit data from ground station to user segment

Ground segment consist of multiple ground station in Indonesia, mostly operated by LAPAN (Indonesian National Institute of Aeronautics and Space) and some smaller ground station operated by universities such as ITB. The function is to receive the data sent by the satellite (images and its information, AIS data, etc.), and process the data while receiving other external input such as marine radar data, weather satellite data, and data from other satellite which can be used in conjunction with MS-SAT (such as LAPAN-A2 and LAPAN-TUBSAT). That

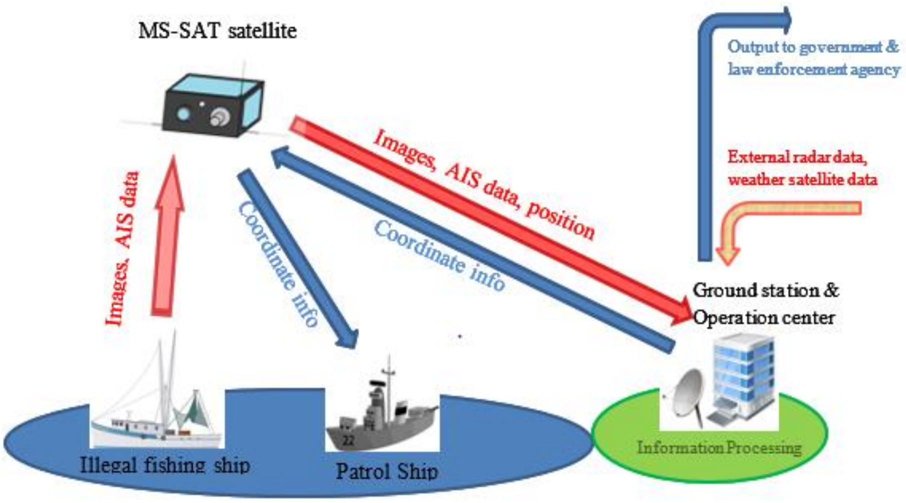

Figure 1: Illustration on MS-SAT concept of operation

information will be combined and further processed to make an output which consist of coordinates and images of potential illegal fishing ship (usually illegal fishing ships deactivate their AIS to avoid detection). The output will be sent to user segment via ground to ground radio, marine VHF radio, satellite repeater, or internet. Ground station also control the space segment and its subsystem such as modes of operation, and send command to take photo at a specific time of a specific area. The architecture of this system is such that the control and processing is done in the ground segment as much as possible to reduce the complexity and cost of the space segment, and to make future upgrade of the system easier.

The user segment consists of the Navy, patrolling ship, and government agency that has the authority such as Ministry of Marine and Fisheries. It uses commercially available computer laptop with specialized software connected to VHF/UHF receiver combined with demodulator and/or internet to receive the data sent by ground station.

In the launch segment, the satellite will be launched as piggyback payload to a larger satellite with the same near-equatorial orbit. After reaching orbit, the satellite will be ejected from the main payload via spring loaded mechanism. After that, the satellite will deploy the antenna and start receiving command from the ground station to turn on all the subsystem for a test run to calibrate the system and to check whether the system is functioning properly. Afterward, the mission can be started.

Key Performance Parameters

The key performance parameters to assure mission accomplishment are

- Spartial resolution. The camera must have a spartial resolution of at least 4 m to detect ships and other object of interest.
- Target pointing. The satellite must be able to point a target with less than $0{,}5^0$ of accuracy and maintain a stable position to take good images.
- AIS receiver coverage. The satellite AIS receiver must have a coverage radius of at least 400 km from the satellite nadir.
- Data link bitrate. The satellite must be able to transmit all the data it has gathered within

one single pass of a ground station.

Space Segment Description

The space segment consists of three satellites orbiting in near-equatorial orbit with altitude of around 500 km above sea level. The delta-V required to reach this orbit is around 7.153 km/s (already considering the rotation of earth, assuming satellite orbit direction is the same with earth rotation)

Structure. The main structure consists of box shaped housing made from Aluminium 7075-T6 with semi-monocoque construction to ensure lightness and strength. The dimensions are 480 mm x 400 mm x 240 mm.

Attitude determination and control system. The ADCS consist of reaction wheels and gyros, one for each axis (X, Y, Z). It also has a CMOS star sensor to sense its orientation. Power from the solar panel also used as sun sensor to determine satellite's relative orientation to the sun.

Payload. The payload consists of primary high resolution camera, secondary camera as a target area locator, and an AIS antenna and receiver. The cameras are located in Z+ side of the satellite, normally pointing towards nadir. AIS antenna located in Y+ side.

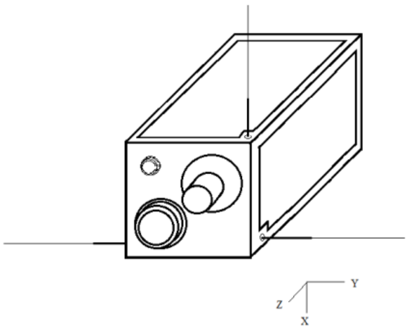

Figure 2: Simple drawing of the satellite

Power control and data handling. The PCDH system is the central device which control satellite's activity. It consists of processor, RAM, SSD, internal clock, power control and distribution unit, fuses, and input cable from sensors.

Communication system. The communication system includes UHF transceiver and antenna to communicate with ground station, VHF transceiver and antenna to relay information between user segment to ground station, and a S band transmitter and antenna to send images and data at high bitrate.

Power system. The power system consists of battery unit and solar panels. The battery has several cells with total voltage output of 14 Volts. There are 4 solar panels located in X+, X-, Y+, and Y- position. The solar panels are placed in the side panel of the satellite and are non-deployable type to reduce its complexity, cost, and weight.

Component	Mass (gr)	Component	Mass (gr)
Structure	12500	**PCDH**	1950
ADCS	8090	PCDH Module	1050
Gyro X,Y,Z	420	Harness and connectors	900
Reaction Wheel X,Y,Z	4100	**Communication**	2162
Damper X,Y,Z	950	S Band Transmitter	292
Coil X,Y,Z	1200	S Band Antenna	160
CMOS Star Sensor	1420	UHF Antenna (2)	360
Payload	9120	VHF Antenna	200
Primary camera & lens	7500	TTC (3)	1150
Secondary camera & lens	420	**Power System**	6800
AIS Receiver	900	Battery Unit	5000
AIS Antenna	300	Solar panel (4)	1800
		Total	40622

Figure 3: Mass of MS-SAT Components

Component	Mean Power (W)
PCDH	0.85
TTC (3)	7.5
Reaction Wheels (3)	10.7
Gyros (3)	3.8
CMOS Star Sensor	0.5
Coils	1.5
S band transmitter	14.15
Primary Camera	5.8
Secondary Camera	1.2
Focus Motor	0.72
AIS Receiver	1.8
Total	48.52

Figure 4: Power Budget of the subsystem

Orbit/Constellation Description

The orbit type that we create to support our mission objectives is near-equatorial orbit. It is determined by the orbit parameter such as semi-major axis, RAAN, argument of pericenter, and the crucial parameter is inclination angle.

Besides, we use three satellites constellation which is designed with RAAN difference is 120^0 to each other and the altitude is approximately 500 km from the earth surface. Here, we also attach the table for orbit parameter of three satellite below

	a (km)	e	i (deg)	ω (deg)	Ω (deg)	true anomaly (deg)	propagator
1st satellite	6871.14	0.000025	5.5199	25	120	360	two body
2nd satellite	6871.3	0.000025	5	25	0	360	two body
3rd satellite	6871.14	0.000025	5.5	25	240	360	two body

Figure 5: Orbital parameter of the satellite

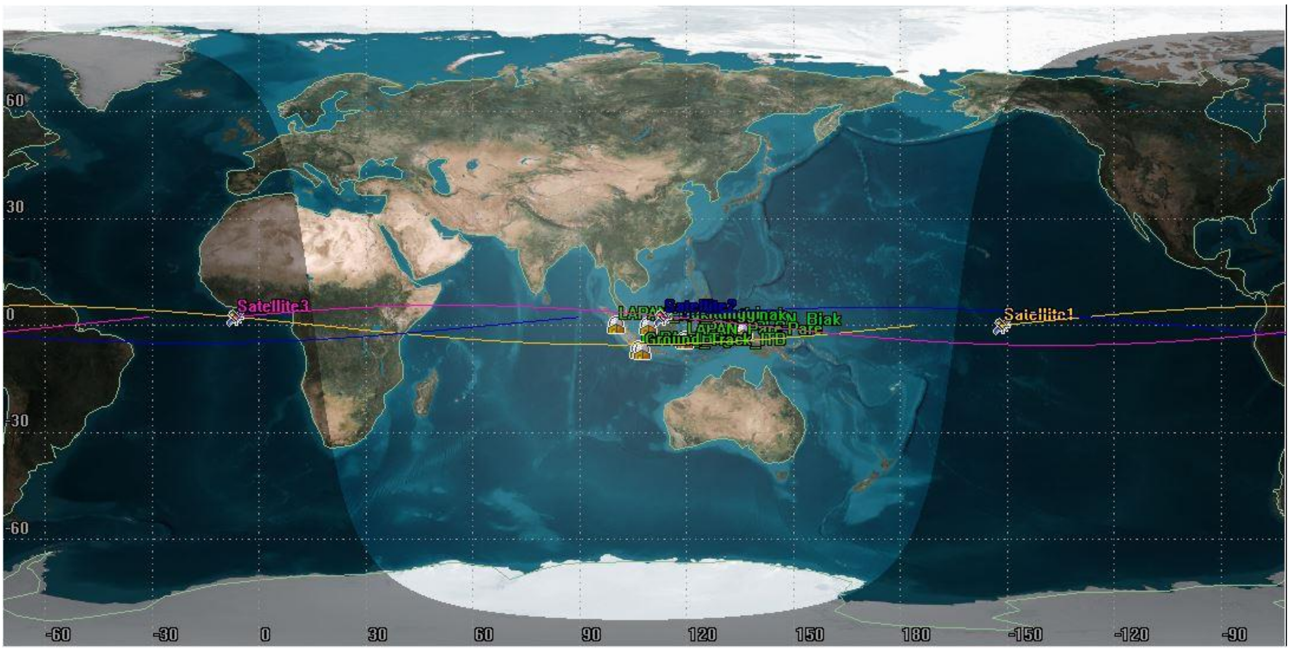

Figure 6: Ground track of the 3-satellite constellation

Implementation Plan

The MS-SAT system is designed with modular design using off the shelf component as cost is one of our primary concern. The project will involve a number of government agencies, universities, law enforcement agency, and the Navy. Design stages will be done by universities in collaboration with LAPAN (Indonesian National Institute of Aeronautics and Space) while receiving inputs from government agency involved. Engineering model manufacturing and test will be done by LAPAN while receiving inputs from universities. Flight model manufacturing, system integration, flight model test & evaluation, environmental test, and launch vehicle integration will be done by LAPAN with active involvement from universities. Launch is done by other space agency as a piggyback to a larger satellite using similar orbit. After orbital deployment, the satellite will be operated by joint operation center involving LAPAN, government and law enforcement agency, the Navy, and universities. The operation center will have direct access to all ground station.

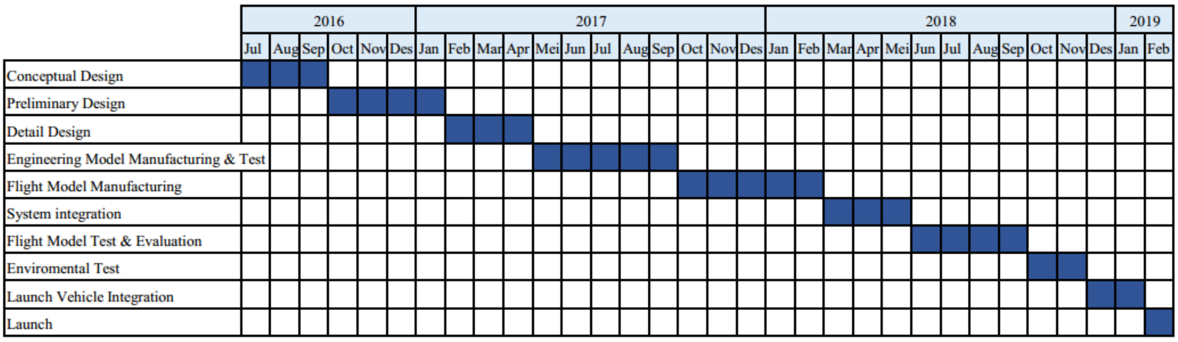

Figure 7: Timetable of the project, from design to launch

The top 5 project risks of MS-SAT mission are

1. Launch vehicle failure, as this will severely delay the project and led to budget overrun.
2. ADCS failure. This will render the satellite useless for taking images. Intensive test and evaluation can reduce this risk
3. Sensor failure. This will reduce the capability of the system or led to total failure of the space segment. This is an important risk to address because some of the subsystem is off the shelf component (not space-rated). Test and evaluation can reduce this risk
4. Battery failure. This will reduce the performance of the satellite, as it can only operate with direct sunlight and limited power. Using reliable battery and tests can reduce this risk.
5. Weather uncertainty. Bad weather and large clouds can hinder the ability of the camera to take a good image. It can also disturb the communication and AIS signal. Using weather satellite data can overcome these shortages by planning the satellite to take images in certain weather condition.

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