Development of Space-based Magnetic Activities Measurement Mission in LAPAN's Micro-Satellites

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Abstract

LAPAN has been observing space weather data using ground-based sensor, among others magnetometer. With the develoment of micro-satellite technology in LAPAN, it become possible for LAPAN to have space-based magnetometer. The paper elaborate the mission concept of the payload, and the development progress that has been done to achieve the mission objectives. The learning process done on the satellite-based magnetometer data handling at the Center of Satellite Technology and Center for Space Science was started with the data handling of magnetometer in attitude control system of LAPAN-A2 micro-satellite. With such knowledge, the specification and the test procedures of magnetometer that will be on-board of LAPAN-A3 and LAPAN-A4 micro-satellite was defined. The paper also discuss further planning that was drawn for the development of more scientific class geomagnetic measurement mission in LAPAN-A4 micro-satellite.

Keywords : micro-satellite, science mission, geomagnet

1. Introduction

Space weather is the condition in the sun, solar wind, magnetosfer, ionosfer and thermosfer, may influence the capacity of space-based technology, such as telecomunication and navigation satellites. Sun phenomenon that may effect space weather the most are flare, coronal mass ejection (CME), and coronal holes (CH). One of their effect is magnetic storm. Magnetic storm occur when particles from Sun the came toward the Earth and meet its magnetosfer. Here, the indication of the storm may be read from the change in geomagnet data.

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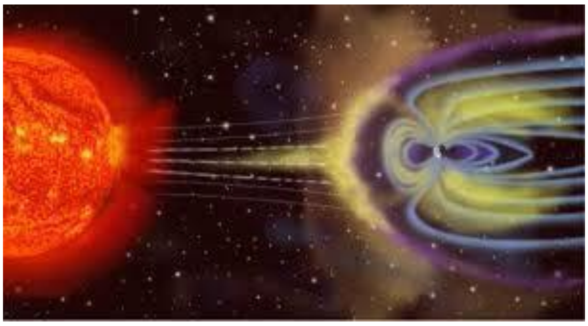

Fig 1. Solar wind interaction with Earth magnetic field [ref 1]

1.1. Geomagnet research at Center for Space Science LAPAN

The geomagnet data observation can be done using ground-based and space-based sensor. In Indonesia at the moment, there are 11 sensor locations, that use fluxgate magnetometer and magdas, which belongs to Center for Space Science, National Institute of Aeronautics and Space (LAPAN). The sensors are also used in international collaboration research, among other, between LAPAN and SERC (Space Environment Research Center), Kyushu University [Ref 2]

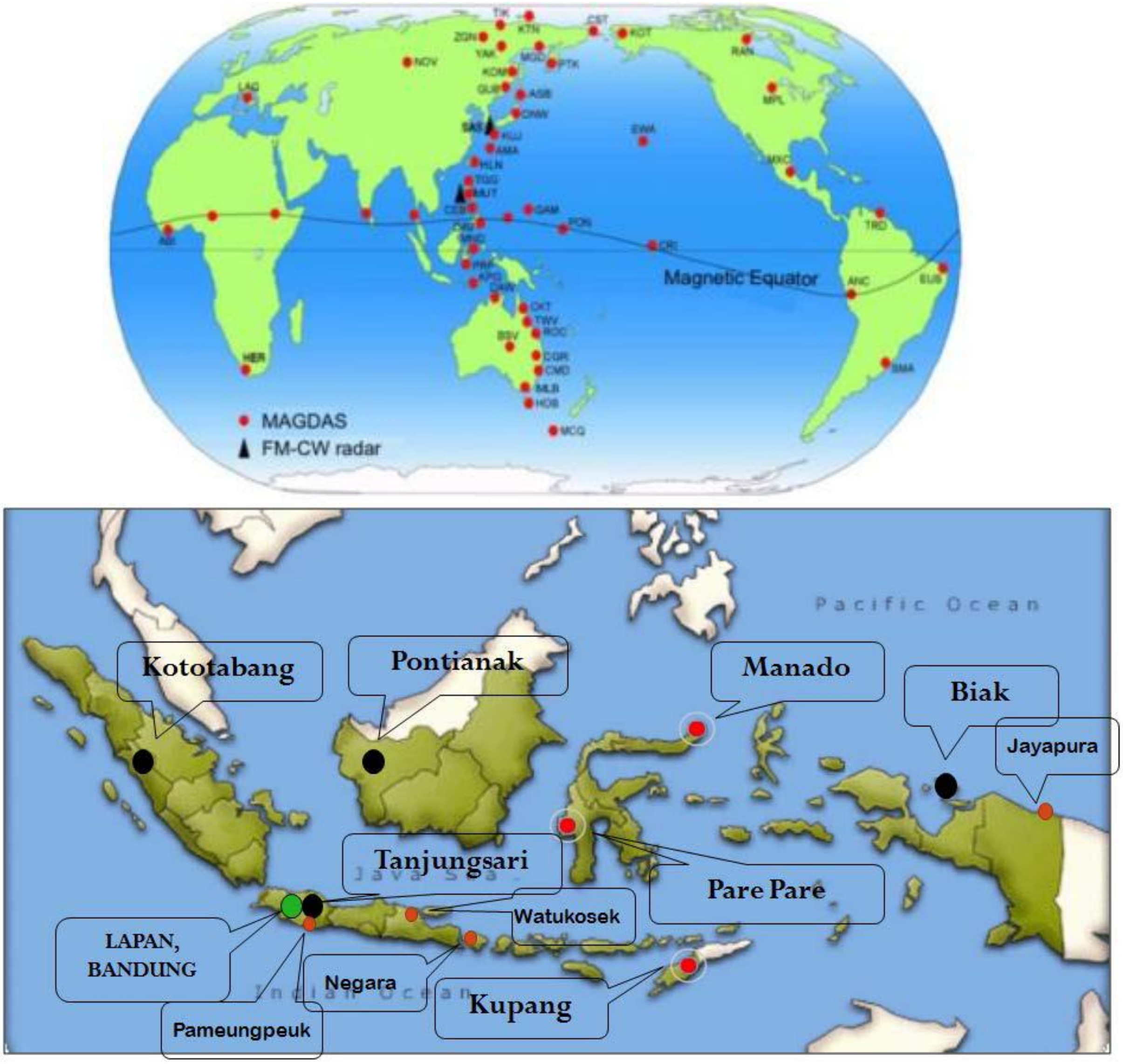

Fig 2. Geomagnet sensor location in Indonesia, and their international network [ref 2]

1.2. Microsatellite development at Center for Satellite Technology LAPAN

The development of micro-satellite at Center for Satellite Technology of LAPAN has made it possible for LAPAN to have space-based sensors. The microsatellite program was started with LAPAN-A1/TUBSAT. The project received funding aproval in 2003, where the satellite development was done in Berlin, Germany, and launched in 2007 as auxilary payload on Indian PSLV-C7 rocket [ref Hardhienata]. Its 2nd and 3rd satellite, LAPAN-A2/ORARI and LAPAN-A3/IPB received their approval from in 2008, which the satellite development is to be done in Bogor, Indonesia. With the establishment of microsatellite integration and test facilities in Indonesia (Fig 3A) and the completion of LAPAN-A2 integration in 2012, the planning was drafted for further satellite tecnology development in Indonesia as illustrated in Fig 3B [ref 3].

For mission realiability, subsystem technology heritage is implemented in the development plan, i.e. LAPAN-A2 will cary the same analog video camera payload as LAPAN-A1, in addition to a newly developed of digital camera payload that has better resolution and swath. LAPAN-A2 will also cary space-borne ship monitoring system (AIS) and employ better automation in satellite attitude control [ref Triharjanto, 2012].

LAPAN-A3 will carry the same digital camera payload as LAPAN-A2, and newly developed 4-band multispectral imager payload. The major improvement in the satellite is its data transmition system, which are 16 times faster than its predecesor [ref Hasbi, 2013].

In LAPAN-A4, in addition to the 2nd flight of multispectral imager, the satellite will cary thermal camera based on coolingless bolometer technology, and a scientific magnetometer payload from Center for Space Sience of LAPAN.

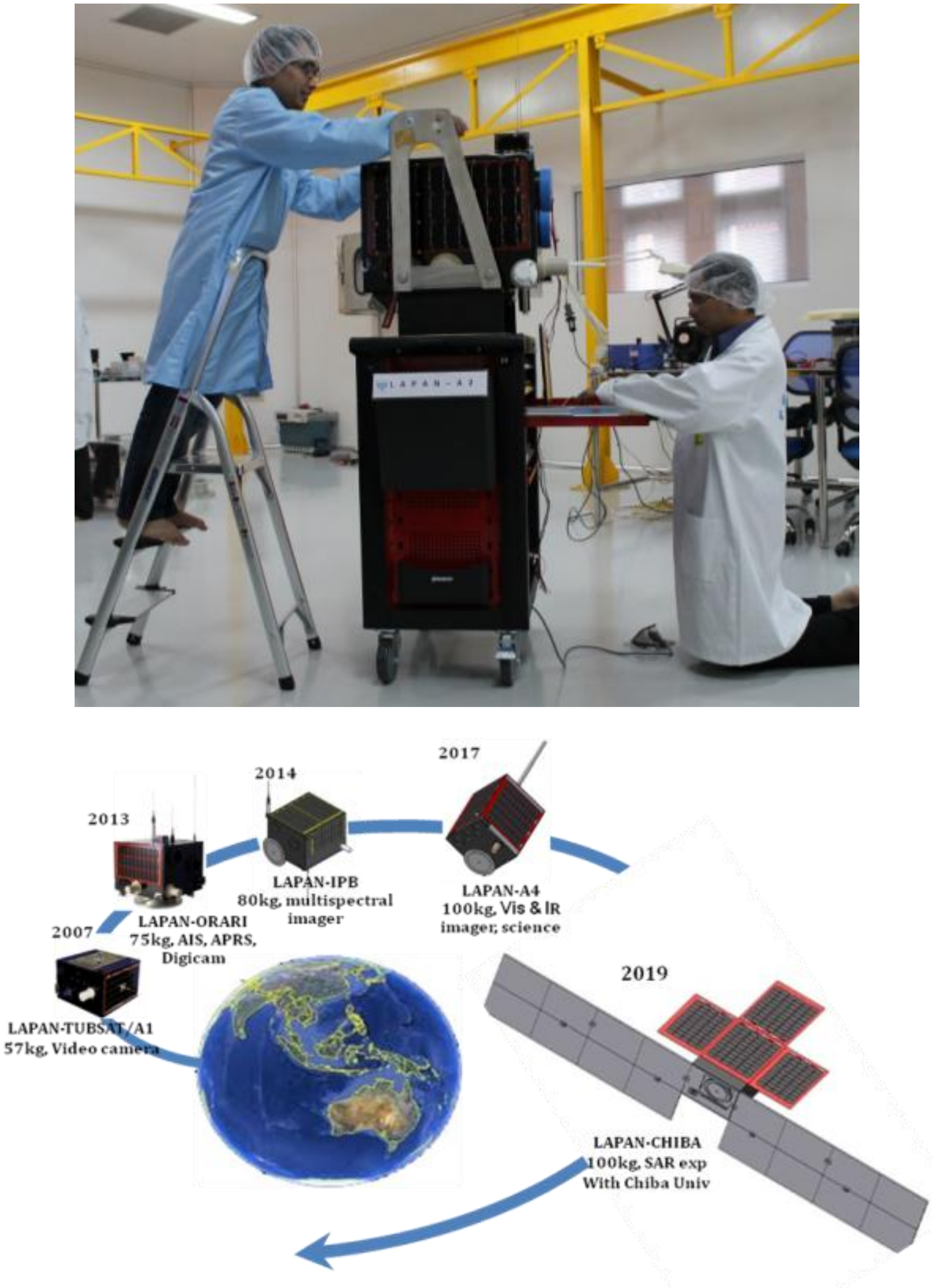

Fig 3. (A) LAPAN's microsatellite integration facility (B) LAPAN's microsatellite roadmap

2. The Magnetometer Payload Definition

Center for Space Science and Center for Satellite Technology so far has studied 2 scientific microsatellites that carry magnetometer payload, i.e. Australian Fedsat, and Brazilian SACI-1. Fedsat is a 58 kg, 50x50x50 cm microsatellite dedicated for several scientific missions, while SACI-1 is a 60 kg, 57x44x44 cm microsatellite also dedicated for several scientific missions.

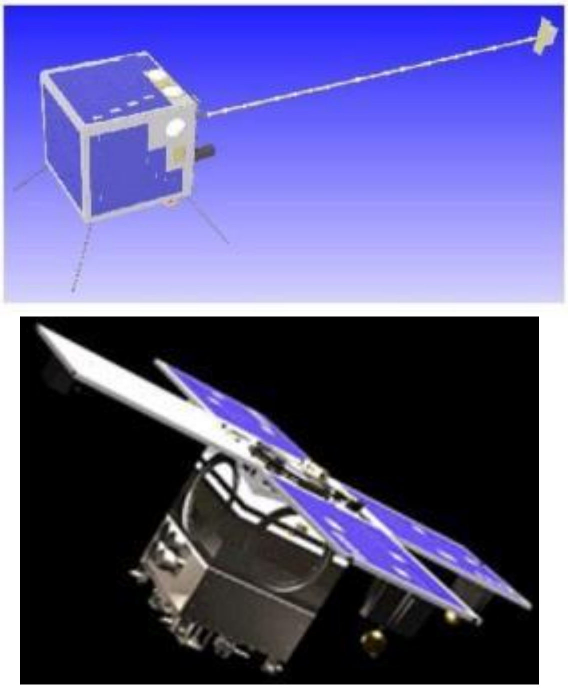

Fig 4. Fedsat & SACI-1 [ref http://space.skyrocket.de/]

The geomagnet mission of Fedsat is to contribute to the monitoring and mapping of the geomagnetic field in the Australian region. The satellite payload is high precision triaxial fluxgate magnetometer with a reading range of ± 65.000 nT. Since the satellite orbit altitude is at about 800 km, the magnetometer needs to be sensitive enough to measure the magnetic perturbations of the order of 10 nT. In such orbit, to measure field-aligned current structures, the payload has a sample rate of 10 vector samples per second (vs/s) so that 1 km structures can be identified.

Fedsat magnetometer is built by Institute of Geophysics and Planetary Physics, UCLA, which already has space heritage. The sensor dimension is 11,4 x 5,4 x 6,1 cm, with mass of 1,62 kg (sensor 420 g, electronics 1,2 kg), and power consumption of 3,5 W. To ensure magnetic cleanliness from other satellite's subsystems, the sensor was placed on 2,5 m boom, which also serve to give gravity gradient stabilization for the satellite. [ref Fraser]

SACI-1 magnetic sensor, which is also from UCLA, is mounted at the tip of one of the four solar panel arms. Therefore, the sensor is 50 cm away from the main body of the satellite for the reason of magnetic cleanliness. The sensor assembly is covered with a thermal blanket in order to protect the sensors from large temperature variations. The magnetometer is capable of measuring geomagnetic field intensity in the range of ± 65.000 nT with reading resolution of ± 1 nT. In SACI-1, the magnetometer data will be sampled at 10 samples per second. [ref Trivedi]

From the data of the two satellites it is known that micro-satellites that has magnetometer mission employ space-proven sensor with reading range of ± 60.000 nT, and the reading resolution no less 10 nT, in which, such specification will become the base of LAPAN's magnetometer payload design.

Off-the-shelf option for magnetometer payload with above specification are the space-proven German magnetometer of Magson and space-proven US made magnetometer of TFM65. Magson magnetometer has weight of 280 g, and dimension of 3,5 x 5 x 5 cm, reading acuracy 100 pT and reading range of ±60.000 nT. Its power consumption is about 1 W. TFM65 magnetometer payload has weight of 117 g, dimension of 3,5 x 3,2 x 8,2 cm, reading range of ±60.000 nT, and reading resolution of 35 pT. [ref 9]

3. LAPAN Satellite's Magnetic Noise

In LAPAN-A2, the magnetometer used in its attitude control system (ACS) is fluxgate VMFS-51, wich has reading resolution of 200 nT. Such magnetometer is designed for navigation purposes of satellite and not mean for scientific measurement. However, since the sensor has been integrated in the satellite, it can be used to learn about the magnetic noise LAPAN's satellite platform generate and about the sensor's data handling system.

The study about the satellite magnetic noise was done by the Center for Space Science, by reading the emision from LAPAN-A2 satellite using its ground-based magnetometer, a Magson type. The reading range of the sensor is ±60.000 nT and its accuracy is 10 pT. The experiment set-up is shown in Fig 4, where the magnetometer is placed at about 20 cm from the satellite body. The magnetic noise emited by the satellite during its operation mode is then read.

Fig 5. Satellite's magnetic noise test set up [ref 8]

The study shows that LAPAN's satellite AIT facilities in Rancabungur, Bogor, is not suitable to calibrate scientific class magnetometer. The personel activities, which may cary electromagnetic devices, as well as other devices arround the laboratory (including car park nearby) disturb the reading. The differential magnetic field reading shows that the magnetic noise from satellite subsystem is less than the noise coming from the environment. Therefore, the reading is repeated at LAPAN facilities at Pameungpeuk, Garut. Knowing that the magnetic feld from the air coil can be predicted, and therefore can be filetered in the reading software, the test the focus on the magnetic noise that come from reaction wheels. The test in Pameungpeuk use the engineering model of the satellite that contain the flight model reaction wheels (platform wheel in Fig 5).

4. LAPAN-A3 and LAPAN-A4 Magnetometer Configuration

The magnetometer chosen to be used in LAPAN-A3 is Hybrid Fluxgate Magnetometer (HFGM) type, which are are commonly used for scientific space mission. The HFGM is using a vector compensated ringcore sensor and the electronics for the digital signal processing. The soft-magnetic material of the ringcores is driven into saturation by an AC excitation current. The external magnetic field distorts the symmetry of the magnetic flux in the core, which generates a signal at even harmonics of the excitation frequency. Sensor and electronics are designed for the selective measurement of the second harmonics of the excitation frequency. A feedback current is generated to compensate the external field at the ringcore position by a Helmholtz coil system. The component values of the external field are calculated by the settings of field proportional feedback current and the remaining field at the core position. [ref 9]

In LAPAN-A3, the magnetometer will be used for attitude control system. However, since investigation is to be done to prepare the dedicated scientific mission in LAPAN-A4. Therefore, high accuracy fluxgate magnetometer will be used. To minimize magnetic noise from other the satellite components, the sensor will be placed outside the satellite body (Fig 6). In LAPAN-A4, its is planned that the sensor is placed on deployable boom at length of more than 1 m from the satellite body.

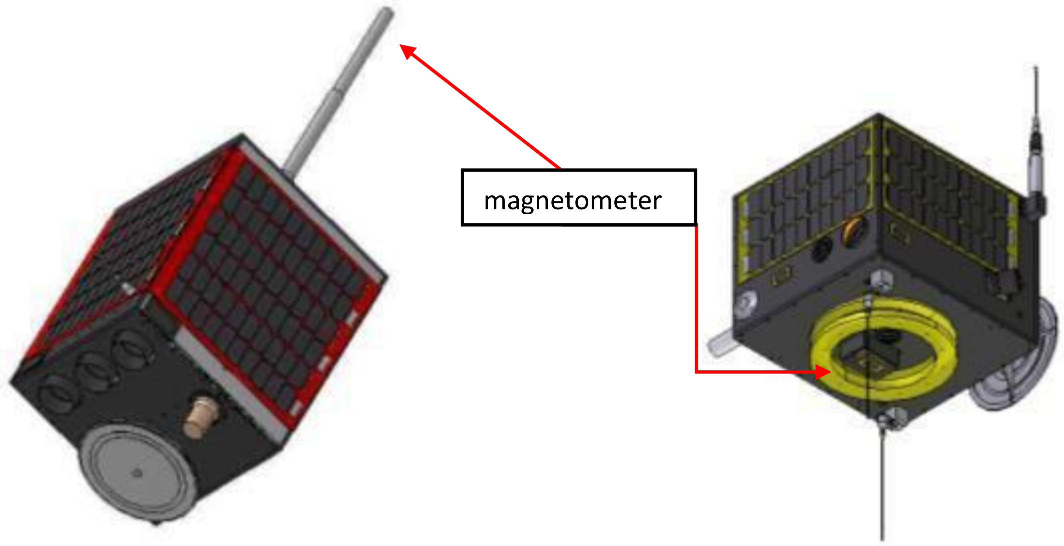

Figure 6. LAPAN-A4 and LAPAN-A3 showing their posible magnetometer position

The magnetometer of LAPAN-A3 will be operated continuously and take data with sampling rate of 1 Hz. A 2,4 Mb memory space is reserved on the satellite main computer for the magnetometer data, which will be downloaded via TTC link over Spitzberg and Indonesia. The reding will be synchronized with the satellite's clock so that the location of the reading can be identified.

For the calibration of the sensor, the Center for Space Science is currently procuring Triaxial Helmholtz Coil with dimension of no less than 1 x 1 x 1 m. The coils will be used to callibrate all the center's magnetic sensors, and to performed functional and calibration test on LAPAN-A4's magnetometer payload.

Kalibrator magnetometer merupakan suatu sistem peralatan yang digunakan untuk mengkalibrasi peralatan pengamat geomagnet (magnetometer). Magnetometer lama ataupun yang baru dibangun perlu dikalibrasi untuk mengetahui/menjaga akurasinya. Kalibrator ini mengukur sekaligus tiga komponen magnet (sumbu X komponen horizontal Utara-Selatan, sumbu Y komponen horizontal Timur-Barat dan sumbu Z komponen Vertikal).

5. Summary and Further Plan

The development progress of geomagnet measurement mission in LAPAN's micro-satellites is :

1. Has finished defining specification for scientific class magnetometer payload
2. Has performed study on the magnetic noise emmited by LAPAN's micro-satellite components
3. Based on the study, has made preliminary design on the payload placement, and payload operation scenario
4. Has prepared scenario on the payload functional test, as subsystem and system, as well its necesary facilities

Further research to be done is the study the effect of boom on the attitude control of satellite. The study is important since the other payload of LAPAN-A4 is an imager, which require good attitude stability.

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