Mission Requirements and Analysis of Indonesia's Second Generation Satellite to Support Food Security Program

S. Hardhienata, G. Prabowo, and F. Fitrianingsih

Abstract One of the main priority middle term programs of the Indonesian government is to provide food security to the country's population. Considering the Indonesian geographical condition and its position as a government institution, the Indonesian National Institute of Aeronautics and Space (LAPAN) decides to develop a second generation satellite to help the government achieving its food security program goals. This paper describes the mission requirements and analysis of Indonesia's second generation satellite (a remote sensing satellite) to support the food security program.

1 Introduction

Indonesia's geographical condition, namely consisting of thousands of Islands covering a fast area, is very suitable for adopting satellite technology to help the country solve several of its national goals. Among these goals is to succeed the food security program. Food security is a foundation for a nation's development; therefore it becomes one of the top research priorities for the country's research institutions. Based on the Government National Middle Term Plan (RPJM) 2004–2009, the research activities focuses on six priority sectors, namely food security, health care and medicine technology, new and renewable energy resource, transportation technology and management, information and communication technology, as well as defense and security.

As a government institution, the Indonesian National Institute of Aeronautics and Space (LAPAN) has the responsibility to support the government in meeting its national goals. With the successful launch and operation of the LAPAN-TUBSat

S. Hardhienata
National Institute of Aeronautics and Space (LAPAN) – Republic of Indonesia
e-mail: s-hardh@indo.net.id

G. Prabowo
National Institute of Aeronautics and Space (LAPAN) – Republic of Indonesia

F. Fitrianingsih
National Institute of Aeronautics and Space (LAPAN) – Republic of Indonesia

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Surveillance Micro satellite in January 2007, LAPAN confidently moves to the next step namely developing a second generation satellite (a remote sensing satellite) whose mission direction is to support the national food security program. Its primary objective is to monitor the crop and harvest area as well as identify the plant growth phase.

2 Mission Requirements and User Needs

To fulfill the mission, goal criteria's has to be described clearly as mission objectives which describes what the satellites must do in order to achieve its objective. The satellite mission objective can be obtained through the user need's analysis by considering its technical limitations. After the mission objectives are defined, the next step is to define the mission requirements and the mission limitations. The mission requirements will be applied as a reference in the satellite design. Fig. 1 presents the mission definition.

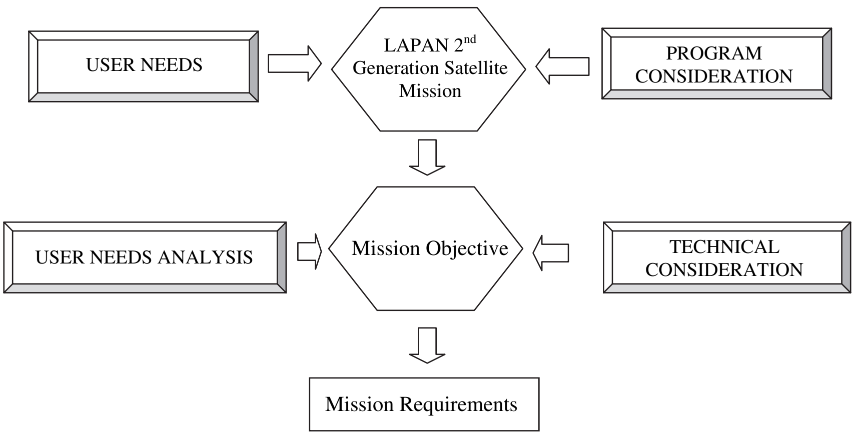


Fig. 1 Diagram of mission definition process

To obtain sufficient information about the user needs on remote sensing data, preparation has been made through seminars, workshops, and road shows. During the preparation process several government institutions have provided useful inputs namely the Agricultural Department, Marine and Fishery Department, and the Forestry Department. A significant input is the information that remote sensing satellite has been applied in Indonesia for a wide range of application ranging from agriculture, forestry, marine, disaster mitigation, and others. Table 1 describes the user needs in remote sensing satellite.

It can be seen from the table that the urgency and economical value of applying remote sensing satellite is very high. In the forestry sector, monitoring of fire points and fumes, which accounts for the destruction of hectares of forest area in Indonesia, can save the government more than $ 9 Billion, whereas in the Marine and Fishery

Table 1 Government department user demand for remote sensing satellite

No	Department	Utility	Urgency and Economical value
1.	Agriculture	1. Delineation in the land utilization change 2. Crop growth monitoring 3. Identification of the River Current Water Damage 4. Identification of the field destruction due to tsunami disaster 5. Delineation of the agro climate zone 6. Delineation of the flood potential and drought zone	Revitalization of 15 million agricultural fields as well as flood disaster mitigation and its economical impact
2.	Forestry	1. Monitoring of fire point/forest burning 2. Monitoring of fog/cloud (fumes) 3. Detection of forest burning	Prevent loss due to forest destruction can reach $ 9.7 billion.
3.	Marine and Fishery	1. Management and monitoring of the coastline space arrangement, conservation area determination, marine tourism planning. 2. Utilization of the coastline resources: fish cultivation, coral reef inventory, mangrove forest identification, ecotourism development. 3. Sea mapping, Exclusive Economical Zone and international border. 4. Fish potential zone identification. 5. Vessel Monitoring System. Environment monitoring program.	Support on the inventory and management of the natural resources with an economical value reaching $ 6 billion.

sector the utility implementation can support the natural resource inventory process which according to estimation has an economical value reaching $ 6 Billion a year.

3 Remote Sensing Application in Food Security

According to the World Food Summit in 1996 Food Security occurs when "all people at all times have physical economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for an active health life". This statement is not too different than the definition of food security stated in the Indonesian Law No 7 Year 1996, namely a condition where food needs are acquired for every household as indicated by the sufficient availability of food, both its quantity and quality, safety, prevalent, and affordable.

The availability of primary food such as rice is an important indicator that describes whether food security has been met or not. The government strategy in meeting the food security is based on the availability of five primary food types for the community. To ensure community access on their primary food source accurate information and analysis on food demand and availability is necessary if the government wants to decide the best strategy. The food availability depends on the food production, stock, and import. Meanwhile, the food demand is affected by the amount of population and their consumption rate. After both information are available food security analysis can be formulated to decide the best strategy. This process is presented in Fig. 2.

The application of satellite image to support food security in Indonesia has already been performed, such as the ASTI experimental project between the Agricultural Department and the Technology Application and Assessments Agency (BPPT) to predict rice harvest as well as cooperation between LAPAN and NASDA to apply remote sensing satellite from Japan, namely JERS-1, ADEAOS, and ALOS to map the rice crop field, monitor their growth phase, estimate rice harvest, and detect crop diseases.

Besides experimental project, the Agricultural Department has also applied remote sensing satellite for agricultural field area estimation in national levels, such as NOAA, Landsat TM, JERS, and SPOT. However not all of these satellites are suitable for high spatial resolution image remote sensing in the province level crop area estimation. In this case, Landsat TM can be applied.

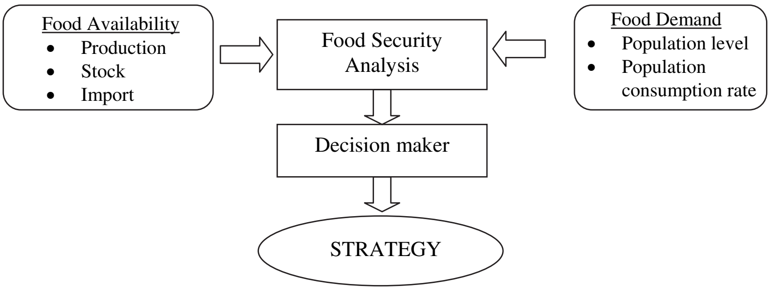


Fig. 2 Diagram of the food security analysis

Principally, all remote sensing devices can be used for crop monitoring. The choice depends on the desired specific application. Hyper spectral image satellites such as MODIS and TERRA-ASTER Satellites are optimal to identify the crop condition and discrimination, whereas the multi spectral image satellites (medium to high resolution) are optimal for crop area estimation, crop growth stage identification, and crop productivity. Ideally, hyper spectral image is applied to distinguish the food commodity because the hyper spectral sensor has more canals, thus the sensor sensitivity to distinguish color differences is better and therefore easier in detecting different food commodity. Less canal sensor requires multiple data if used for crop identification (called multi spectral sensors).

Compared to a conventional satellite, remote sensing satellites have the advantages in covering local and global areas with periodic and continuous observation, providing objective information, and has independent inputs for field verification, whereas conventional satellites are able provide more accurate information for crop identification. The disadvantages of the remote sensing satellite is the need for higher resolution due to higher accuracy however this statement is used for early estimation and needs further verification. The conventional satellite has the disadvantage that it covers only small areas and thus takes longer time for global analysis.

4 Users Tendency in Remote Sensing Data

Although all remote sensing satellite are applicable for crop monitoring, the users tend to choose one or two satellite type because more satellite types requires different methods thus consumes more time and energy. Many users also prefer medium resolution for economical reason because higher resolution satellites are more expensive than the lower one.

Table 2 provides remote sensing data and the type of information provided by these satellites, whereas Table 3 displays the satellite image price. It can easily be seen that better spatial resolution result in an increased cost per square kilometer (compare the cost per km^2 of IKONOS and SPOT).

The user needs analyses for the development of LAPAN's second generation satellite comprises the demanded image resolution, time delivery, and crop data. The image resolution should be good enough to analyze province level images, which means it is able to provide images with a 1:25,000 to 1:100,000 ratios, thus provides detailed information for each regency. The time data delivery should range from 14 to 30 days for plant identification (especially rice) whereas the demanded

Table 2 Remote sensing data and type of information

Satellite	Spatial Resolution	Equivalent with map scale	Type of Information
NOAA-AVHRR	1.1 km	1,000,000–2,500,000	Diagram
MODIS	210 m	500,000–1,000,000	Exploration
Landsat TM	30 m	100,000–250,000	Observation
SPOT 4	10–20 m	50,000–100,000	Deep Observation
SPOT 5	3–10 m	25,000–50,000	Semi detail
IKONOS	1–4 m	2,500–10,000	Detail

Source: Agriculture Department, 1999

Table 3 Satellite Image Price

Type of Data	Spatial Resolution	Scene size	Unit cost	Cost per km2
NOAA- AVHRR	1,1 Km	2300 × 2300km	USD 25	Free data
Resours-O	210 m	500 × 500km	–	–
Modis	250	1000 × 1000km	–	–
Landsat TM	30 m	180 × 180Km	USD 850	USD 0,3/km
SPOT	10–20 m	60 × 60km	17.000 FFr	USD 1,0/km
RADARSAT	10–20 m	40 × 40km	USD. 2000	
IKONOS	1–4 m	Min 10 × 10km	–	USD 34–44/km

Source: Deputy for Remote Sensing LAPAN, 2002 type of information consists of the estimation of crop planting and harvesting area, growth stage identification, productivity, discrimination, and condition/plant stress.

The plant condition can be estimated using the reflectance spectral, whereas the plant stress level can be detected through infra red canal. A hyper spectral imager such as MODIS is more sensitive in detecting different wavelengths, thus can better detect plant stress. The full information regarding a plant condition can be obtained by combining hyper and multi spectral images. Table 4 provides the principal application of various spectral ranges:

Table 4 Application of Spectral Bands

Spectral range (mm)	Principal application
0.45–0.52	Sensitivity to chlorophyll, coastal water mapping, soil/vegetation discrimination, forest type mapping
0.52–0.60	Green reflectance for vegetation discrimination and vigor assessment
0.63–0.69	Sensitivity to chlorophyll, plant species identification, water type discrimination
0.76–0.90	Vegetation type, vigor, biomass determination, water body delineation, soil boundary and geological boundary mapping
1.55–1.75	Sensitivity to amount of water in plants, useful for drought studies and plant vigor studies
2.08–2.35	Sensitivity to hydroxyl ion in minerals, useful in discrimination of rock types, Effective in identifying zones of hydrothermal alteration in rocks.
10.4–12.5	Surface temperature mapping

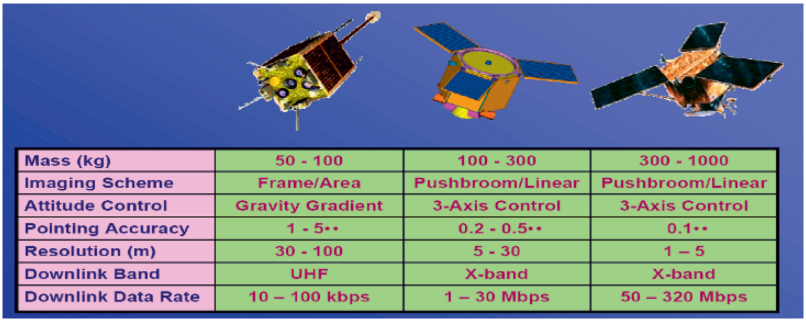
Source: An Introduction to Geographical Information System, Heywood, Cornelius & Carver

5 Technical Aspects and Constrains

As a remote sensing satellite with food security as its mission, LAPAN's second generation satellite should be able to meet the user requirements with its current technical achievements. This consideration should also match with LAPAN's satellite development program phases.

Besides achieving the mission objectives, the program also aims to increase the human resource capability and independence in satellite technology. To meet both objectives, an optimum point has to be searched. The result is a satellite with a weight between 50–300 kg and a performance like those given by Fig. 3.

The technical constrains can be classified into four points, namely the limitation of skill and experience, facility, manpower, and micro satellite constrains. The design of the satellite must be as simple as possible. The spatial resolution value of the satellite which consists of 3–4 canals will have a range between 10 and 30 or 3 and 10 m because these resolution are assumed to be sufficient for producing detailed regency level map with a scale between 1:50,000 to 1:100,000. This resolution is based on technical consideration, available human resources, demand level,



Mass (kg)	50 - 100	100 - 300	300 - 1000
Imaging Scheme	Frame/Area	Pushbroom/Linear	Pushbroom/Linear
Attitude Control	Gravity Gradient	3-Axis Control	3-Axis Control
Pointing Accuracy	1 - 5••	0.2 - 0.5••	0.1••
Resolution (m)	30 - 100	5 - 30	1 – 5
Downlink Band	UHF	X-band	X-band
Downlink Data Rate	10 – 100 kbps	1 – 30 Mbps	50 – 320 Mbps

Fig. 3 Typical performance of several satellite model based on its weight (SATREC*i*)

and acceptable. Higher spatial resolution means more complex satellite system. The temporal resolution is between 2 weeks to one month. It is estimated that the satellite will be launched in 2010 using piggy back with a lifetime of about 3 to 5 years.

6 Conclusion

Food security becomes one of the main government programs in Indonesia and LAPAN as a government institution has the responsibility to support the success of the program by developing a second generation remote sensing satellite. Its primary objective is to monitor crop and harvest area as well as to identify plant growth phase in Indonesia. The satellite's mission requirements are obtained after considering the mission objectives which are obtained after analyzing the user needs, program considerations and user needs analysis as well as technical consideration. The technical constrains can be classified into four points, namely the limitation of skill and experience, facility, manpower, and micro satellite constrains. In addition, the design of the satellite must be as simple as possible.

References

1. Department of Agriculture, *"Annual Report of Pilot Project on the Use of Japanese Satellite Data in Indonesia",* Jakarta – Indonesia, 2002.
2. Fitrianingsih, E., et al., *"Mission Design of Indonesian Second Generation Satellite",* Proceedings of Small Satellite System and Services – 4s Symposium, Cagliari Sardinia – Italy, September 2006.
3. Hardhienata, S., *"The Strategy of Indonesia Satellite Technology Development*", Proceedings of ISNET International Seminar on Space Technology & Applications, Islamabad – Pakistan, September 2006.
4. Hardhienata, S., *"Space Science and Technology Applications in Indonesia",* Proceedings of Technology Summit and Technology Platform, New Delhi – India, November 2006.
5. Hardhienata, S., Kadri. T. M., Briess, K., "*Remote Sensing Satellite to Support Food Sustainability Program in Indonesia*", Proceedings SIPTEKGAN X-2006, ISBN: 979-8554-91-4, Jakarta – Indonesia, November 2006.
6. Heywood, I., Cornelius, S., and Carver, S., *"An Introduction to Geographical Information Systems"*, Prentice Hall, 3rd edition , 2006.