National Institute of Aeronautics and Space – LAPAN
Indonesia

Developing an Equatorial Earth Observation Satellite System

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Use of the Equatorial Orbit for Space Science and Applications:
Challenges and Opportunities

12-23 February 2007

Developing an Equatorial Earth Observation Satellite System

Introduction: Equatorial and Near-Equatorial Orbit Earth Observation satellites.

- Equatorial orbit having a zero degree inclination in the earth's equatorial plane;
- According to altitude above earth surface, satellite orbits are distinguished between Low Earth Orbit (LEO, 200-1,200 km), Medium Earth Orbit (MEO, 1,000-3,600 km) and Highly Eliptical Orbit (HEO, 50,000-400,000 km);
- Focusing on the use of equatorial MEO and near-equatorial LEO satellites;
- Technical requirements and considerations of equatorial and near-equatorial Earth Observation (EO) satellites;
- Utilization and application of equatorial and near-equatorial orbiting EO satellites;
- Challenges and opportunities on development of equatorial and near-equatorial orbiting EO satellites.

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Need of space applications in Indonesia:

Extensive and diverse geography of Indonesia;

Growing need of space technology utilization and application for national development:

- **Telecommunication (first domestic satellite telecommunication system in operation in 1976);**
- **Earth observation (natural resources, rural and infrastructure development, land use, environment, weather, climate and others);**
- **Navigation;**
- **Disaster mitigation and relief;**
- **Health;**
- **Education;**
- **Others;**

Requirement on utilization of progressive space technology and application for sustainable development;

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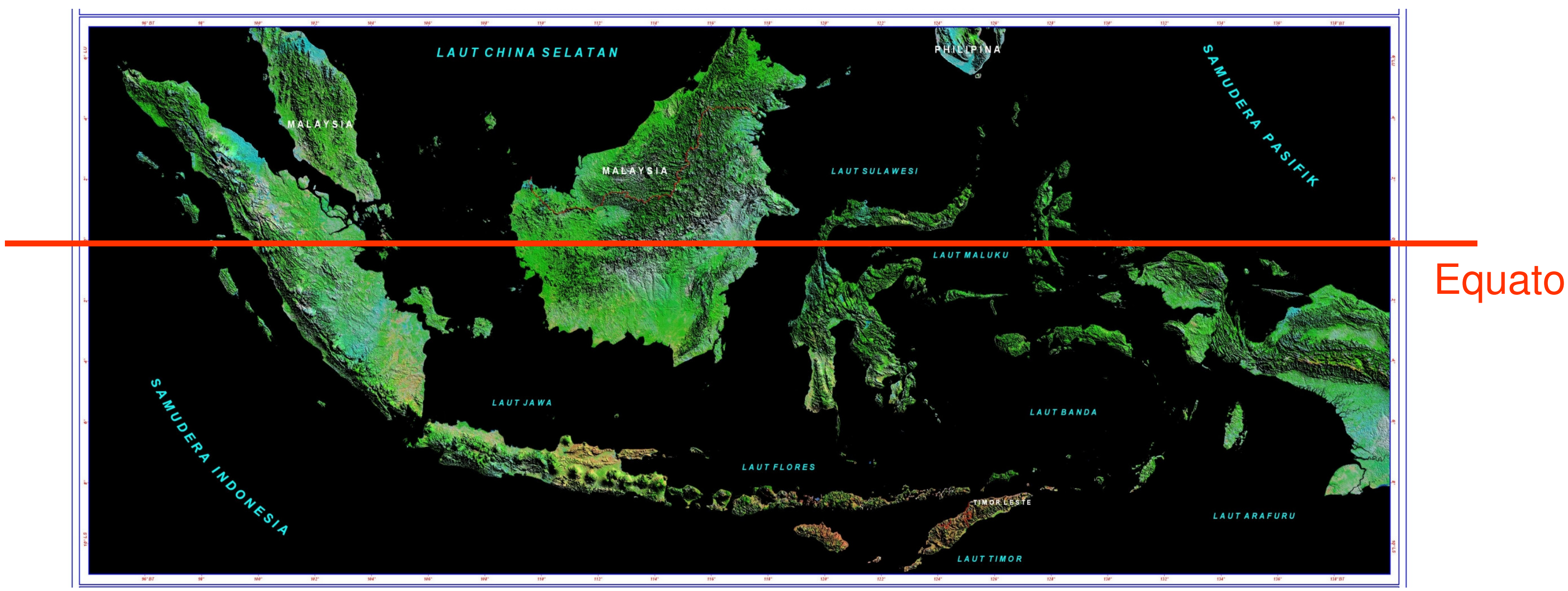
Importance of equatorial satellite orbit for Indonesia:

Indonesia is located roughly 5,150 km along the length of the equator (or about 1/8 th of the length) , and the widest breadth is roughly 1,750 km.



The unique equatorial location of maritime continent Indonesia (marine, coastal and land environment) provide geographical advantages for utilization of satellites in the equatorial and near-equatorial inclination orbits, e.g. earth observation, communication, disaster management and others.

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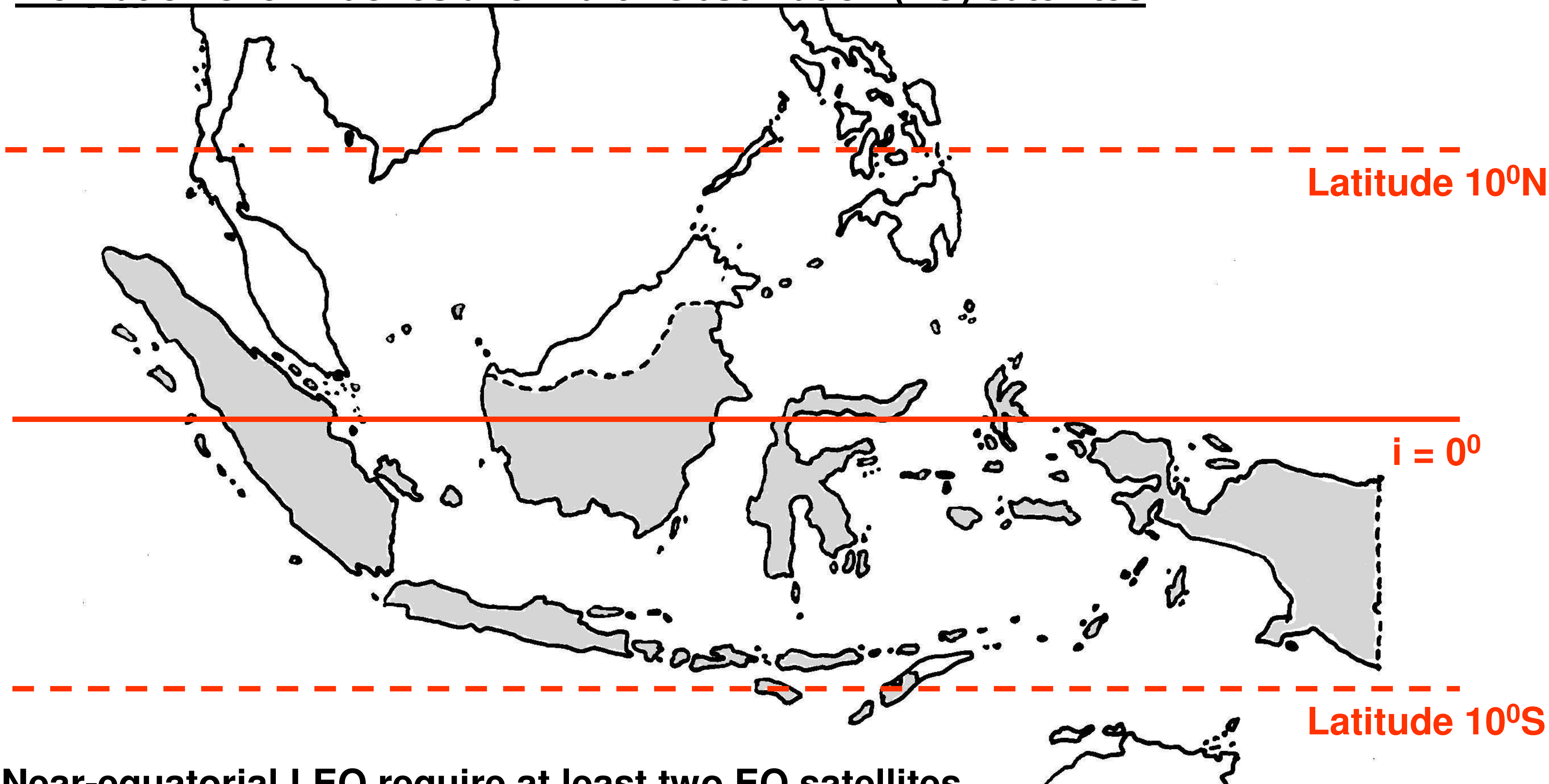
Approximate optimum coverage of equatorial and near equatorial satellite orbit inclination over Indonesia for Earth Observation (EO) satellites.



Near-equatorial LEO require at least two EO satellites at 10^0 orbit inclination.

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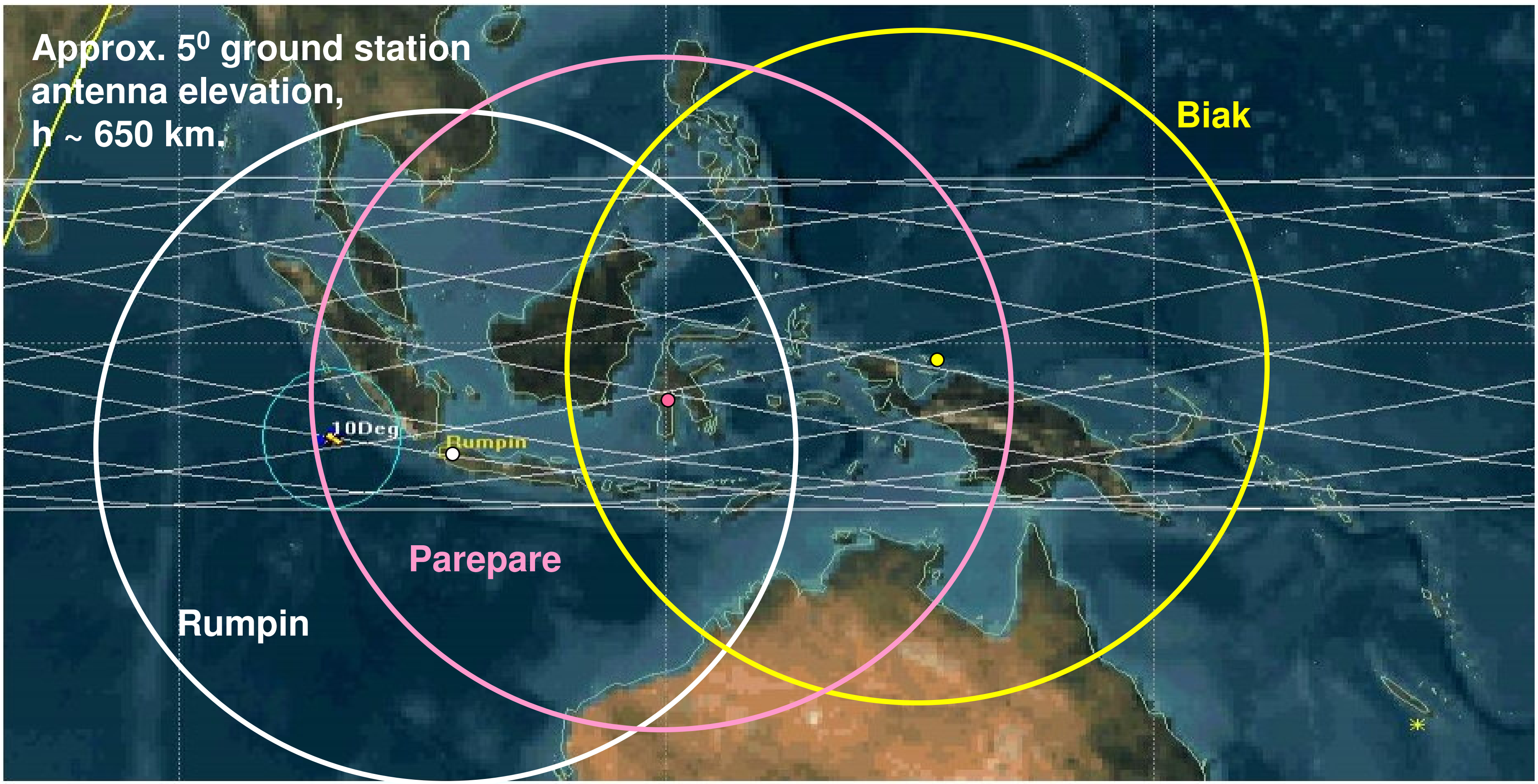
Coverage of one satellite in near-equatorial LEO at 10^0 inclination over Indonesia.



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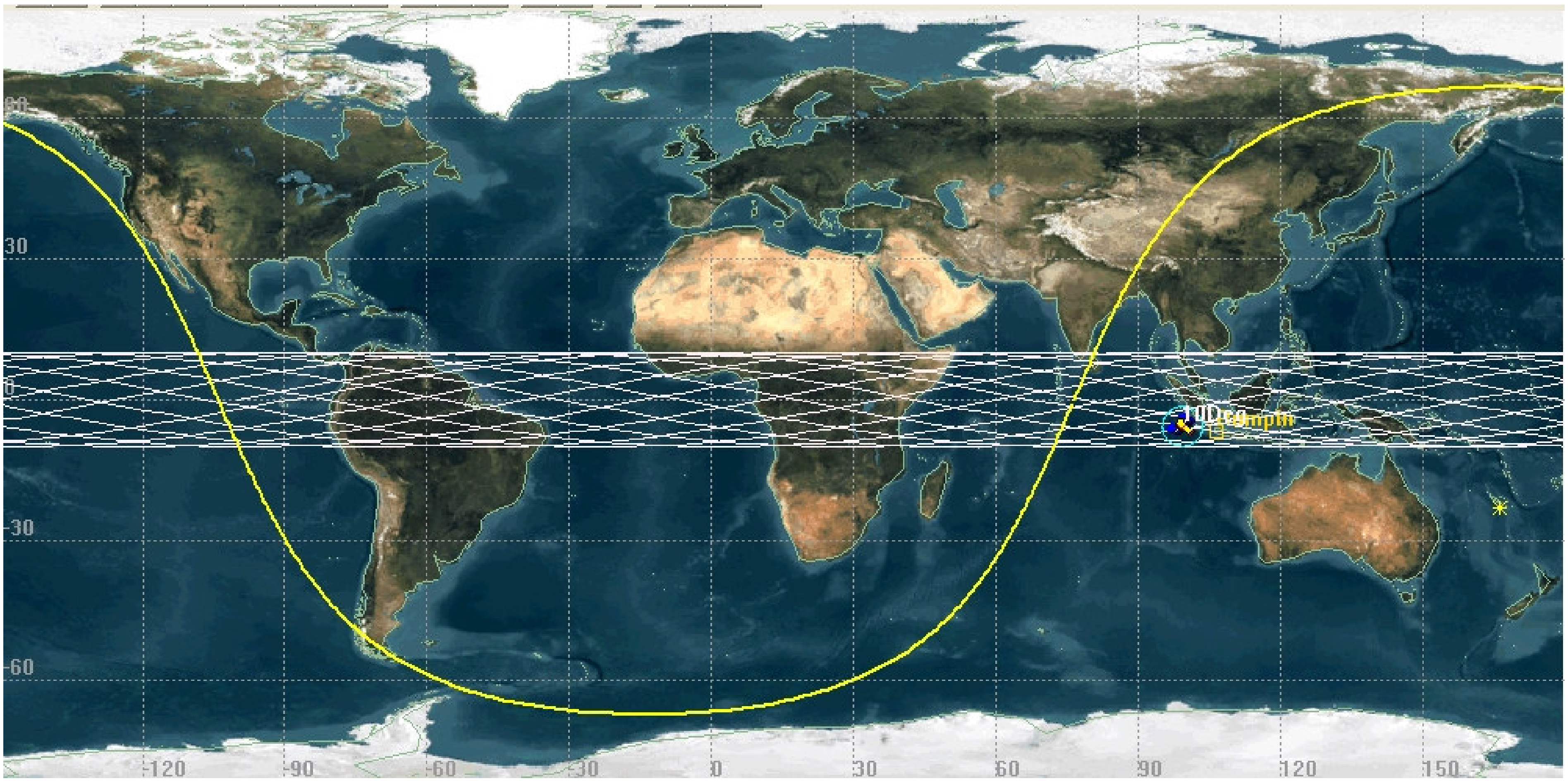
World coverage of one satellite in near-equatorial LEO at 10^0 inclination, h ~ 650 km.



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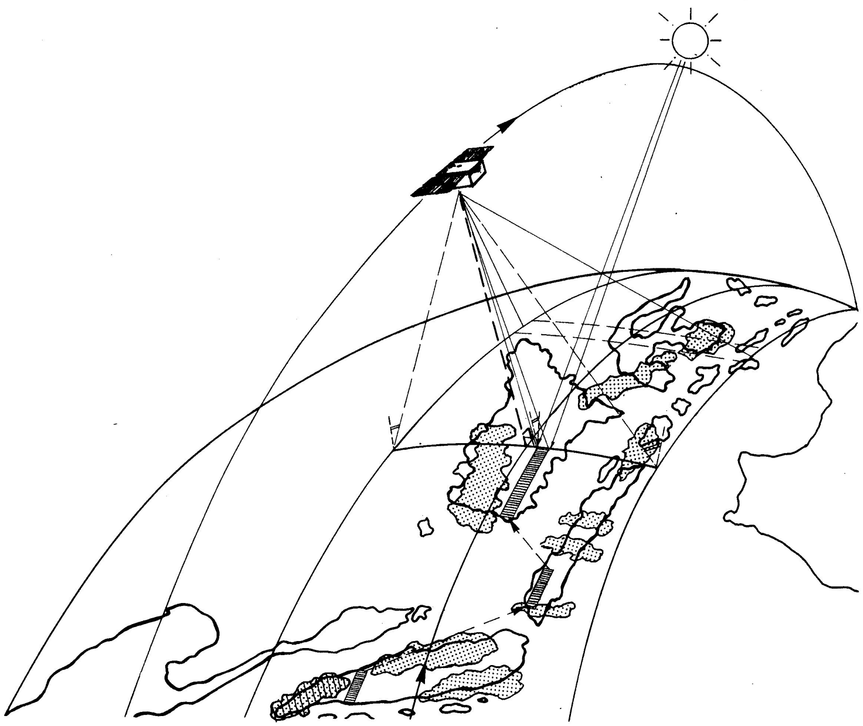
Topical Earth Resources Satellite - TERS Study.



Joint study by Nederlands Institut Voor Vliegtuigontwikkeling En Ruimtevaart – NIVR and LAPAN during 1979 to 1986.

With respect to orbit coverage repetition cycles preference is for one equatorial 0^0 inclination MEO satellite at 1,680 km altitude. Off-nadir pointing coverage over orbit path between 10^0N and 10^0S. True equatorial orbit provide 11 orbit passes per day, with available 4 passes in daylight between 07:30 and 16:30 used for data acquisition. Spacecraft mass is about 950 kg.

Selective remote sensing of primary sensor off-nadir viewing is assisted by the forward viewing cloud sensor.

An alternative is two identical satellites at 847 km altitude LEO in complementing 10^0 - 15^0 near-equatorial inclination. Off-nadir pointing capability is used.

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Tropical Earth Resources Satellite - TERS Study.

Value added processed Landsat-7 ETM map, acquired and processed by Pusdata, LAPAN. Shrimp farming, Lampung Province, Indonesia

Mission requirement is compared to existing and future LEO (polar orbit) remote sensing satellite systems of that period.

Imaging spectral characteristics:
TERS 1: 490 - 590 nm
TERS 2: 610 - 685 nm
TERS 3: 750 - 835 nm
TERS PAN: 490 - 685 nm
Ground resolution 16x16 m multispectral and 8x8 m panchromatic. Swath is 60 km.

Fields of (higher repetition) application:
- **Resource base mapping;**
- **Agriculture and forestry;**
- **Transmigration;**
- **Rural and urban survey;**
- **Public works;**
- **Environment protection;**
- **Oceanography.**

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Satellite technology opportunity:
Micro-Satellites < 100 kg.

Indonesian engineers with LAPAN-TUBSAT micro-satellite developed by LAPAN in cooperation with Technische Universität Berlin, Germany, and launched as auxilliary payload on Indian Space Research Organization (ISRO) PSLV-C7 Cartosat-2 and SRE mission on 10 January 2007.

Use of current advanced technology;

Opportunities for international cooperation;

Access to knowledge, skill and experience;

Carry experimental and demonstration mission payloads;

Ease of satellite development:
- **+ Simplified production and test facility;**
- **+ Shorter development time;**
- **+ Lower costs;**

Possible launch to orbit as an auxilliary payload on launch vehicle;

Used by governments, private companies and universities for experimental application and technology demonstration satellites.

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LAPAN-TUBSAT micro-satellite.

Transfer of knowledge, skill and experience on micro-satellite technology development from Technische Universität Berlin, Germany to LAPAN.

Dimension approx 45 cm (l) x 45 cm (w) x 27 cm (h)
Weight 54.7 kg.

Interactive 3-axis attitude control;
Star Sensor for satellite attitude determination;

CCD color video camera on 1,000 mm Cassegrain lens provide 5 m ground resolution and 3.5 km swath;
CCD color video camera on 50 mm lens provide 81 km swath and 200 m resolution;
Provide space borne EO surveillance for, e.g. natural resources, environment and disaster management;

Polar LEO orbit at 630 km altitude, inclination at $97,6^{0}$.
Launched as auxilliary payload on ISRO PSLV-C7 Cartosat-2 and SRE mission at SDSC SHAR, India, on 10 January 2007.

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LAPAN investigation of satellite EO mission requirement (imaging and surveillance):

Food security application, e.g.
- **Crop yield estimation;**
- **Crop growth cycle;**
- **Marine food resource;**
- **Agriculture land use and estates;**
- **Estimation of planting season;**
- **Soil and agroclimate, and others.**

Land application, e.g.
- **Disaster management, e.g. land slide, volcano, tsunami, floods, forest fires;**
- **Natural resources management;**
- **Forest management and inventory;**
- **Land use and land cover monitoring;**
- **Environment monitoring, draught and change detection;**
- **Water catchment areas and hydrology;**
- **Geology, and others.**

Marine application, e.g.
- **Coastal marine resources;**
- **Potential fishing ground;**
- **Coastal zone and environment;**
- **Marine pollution;**
- **Marine vehicle monitoring;**
- **River estuaries and discharge, and others.**

Technical requirements:
LAPAN carry out study on technical requirements of micro-satellites for Indonesia in consultation with German Aerospace Center (DLR).

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Immediate detection and successive monitoring:

Ulee Lhee, Banda Aceh, effects of Tsunami, Ikonos data.

Disaster management:

- **Early warning;**
- **Distress information;**
- **Detection and assessment of disaster areas;**
- **Mitigation and relief;**
- **Rehabilitation.**

Recurring disasters:

- **Earthquake;**
- **Tsunami;**
- **Volcanic eruption;**
- **Floods and flash floods;**
- **Land slides;**
- **Draught and climate anomalies;**
- **Forest fires.**

Equatorial and near equatorial orbit EO and data relay communication satellites are potential to provide immediate disaster relief information and repetitive monitoring (multi-mission satellite).

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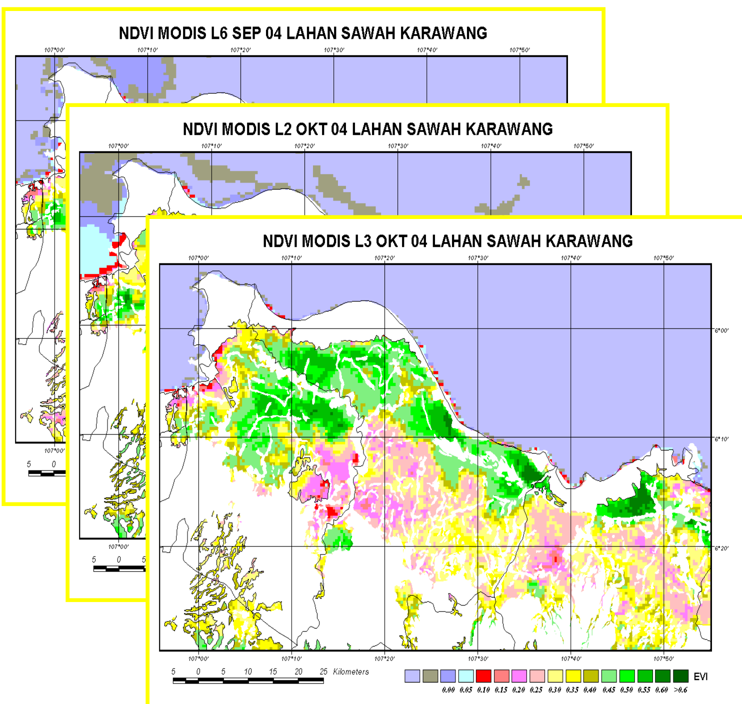
High spatial and temporal resolution environment change detection and monitoring:



Vegetation Index map of rice fields in Karawang, West Java from MODIS data.

- **Agriculture (food production estimation, disease, pests, irrigation, agroclimate, perennial crop area);**
- **Coastal and marine resources;**
- **Potential marine fishing ground;**
- **Forestry (logging, illegal cutting, settlements, shifting cultivation, forest fire, land degradation, reforestation);**
- **Urban development and land use change;**
- **Marine pollution;**
- **Coastal zone land use;**
- **Mangrove inventory;**
- **Coral reef assessment;**
- **Coastline change and erosion;**
- **Shipping traffic and sea passage;**
- **Water resources, and others.**

Equatorial and near equatorial EO satellites with high temporal resolution provide better access of detailed earth feature change monitoring.

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Opportunities for equatorial and near-equatorial EO satellites:

Equatorial and near-equatorial EO satellite using selective off-nadir optical viewing assisted with cloud sensor provide opportunity as following:

- **High temporal resolution data acquisition of equatorial EO satellite (e.g. possible of up to 4 daylight passes for one TERS at 1,680 km MEO to cover 10^0N and 10^0S latitude);**
- **Optimized data acquisition of satellite passes to better serve user requirement;**
- **Possible access of high spatial resolution data acquisition immediately required the same day and successive observation for disaster monitoring, as well as other urgent special detection and dynamic temporal monitoring purpose;**
- **Possible programming and selection of areas to be observed with acceptable cloud cover before and during satellite data acquisition;**
- **Better access of data acquisition for precise timely programmed monitoring of earth resource process and environment process, e.g. crop yield estimation;**
- **Multi-instrument payload increase the usefulness of equatorial and near-equatorial EO satellite, e.g. data relay, space science and others, e.g. multi-mission satellite;**
- **Extended and systematic high resolution EO data archiving of the equator region;**
- **Interpretation of equatorial and near-equatorial EO satellite data with variable illumination and sun angle could provide new detection and application methods;**
- **More benefit of near-equatorial orbit satellites for EO using imaging radar (SAR);**
- **Data utilization and benefit by countries located in the equator region.**

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Challenges for equatorial and near-equatorial EO satellites:

- **Effort to effectively use micro-satellites for near-equatorial EO experiments, e.g. with optical or thermal imagers, cloud cover sensor, off-nadir viewing, orbit maintenance;**
- **Data acquisition at different time of daylight with varied illumination, sun angle and atmosphere scattering may be difficult for consistent interpretation methods, e.g. to achieve standard image quality for interpretation, as well as image data overlays;**
- **Equator MEO EO satellites, e.g. TERS at 1,680 km and 0^0 inclination orbit is exposed to higher radiation in space limiting effective operational lifetime. Radiation shielding will increase satellite weight;**
- **Equator and near-equator EO satellites will encounter more earth curvature and atmosphere scattering at distant off-nadir viewing, i.e. limiting pointing angles;**
- **Use of LEO require a small constellation of near-equatorial orbit inclination EO satellites to achieve expected temporal resolution data acquisition of areas covering 10^0N and 10^0S latitude pointing angles due to earth curvature and atmosphere effects. This increase ground receiving stations operation, as well as incoming data volume;**
- **Near-equator LEO EO satellites have complex arrangement for image registration;**
- **Higher revisit data acquisition require more operation of ground segment, user services, data processing, data archiving, cataloging and acquisition priority setting;**
- **More study is needed for new image data utilization and application of equatorial and near equatorial orbit EO satellites, and to overcome its technical obstacles.**

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Conclusion.

- **Indonesia shall potentially benefit from the use of equatorial and near-equatorial orbit EO satellite utilization. Similar potential benefit could also be expected by other countries in the equatorial region;**
- **High repetitive visit capability of equatorial and near-equatorial orbit satellites, is potential for near real-time high resolution (possible daily) data acquisition and dynamic temporal monitoring, e.g. for disaster management and others;**
- **Forward viewing cloud sensor and off-nadir main sensor payload viewing optimize the potential use of equatorial and near-quatorial orbit EO satellites;**
- **More study is needed to address mission requirement, data processing, data utilization, system operation and technical design requirement;**
- **Micro-satellites are potential experimental EO satellites in the near-equator inclined orbit, a.o. also to explore additional advantages and challenges;**
- **TERS Study shall be a significant baseline for work on equatorial and near-equatorial orbit EO satellites in Indonesia;**
- **LAPAN have consideration on the potential use of equatorial and near-equatorial orbit EO satellites for Indonesia;**
- **International cooperation is significant to elaborate and utilize the optimum potential of equatorial and near-equatorial EO systems, in particular countries to benefit from equatorial and near-equatorial EO satellite orbit.**

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