Indonesian LAPAN-TUBSAT Micro-Satellite Development

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National Institute of Aeronautics and Space – LAPAN
Indonesia

Asia-Pacific Regional Space Agency Forum (APRSAF-14)
Main Theme: Space for Human Empowerment
21-23 November 2007
Bangalore, INDIA

Need of space applications in Indonesia:

Extensive and diverse maritime continent 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, urban and rural land use development, environment, weather, climate and others);**
- **+ Disaster management;**
- **+ Navigation;**
- **+ Search and Rescue;**
- **+ Health;**
- **+ Education;**
- **+ Others;**

Need on utilization of progressing space technology and application for sustainable development of prosperity for the people.

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Earth observation small/micro-satellite system

Satellite technology opportunity:
Micro-Satellites < 100 kg.

LAPAN-TUBSAT micro-satellite in preparation for launch as auxilliary payload on Indian Space Research Organization (ISRO) PSLV-C7 Cartosat-2 and SRE mission from Sriharikota, India 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 auxiliary payload on launch vehicle;

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

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Earth observation small/micro-satellite system

Extensive remote sensing mission application (mapping and surveillance)::

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

Spatial information to promote social and economic development of the people.

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

Consideration of developing small/micro-satellite program by developing country.

Case: Indonesia (LAPAN).

Satellite Program

Acquisition of Technology

Focus on knowledge, skill and experience on integration, test, launch and operation.

Development of Mission and Technology

Focus on application.

Design-to-cost EO satellite ⇨ **Ext. performance EO satellite** ⇨ **Known and proven EO mission** ⇨ **Dedicated and new EO mission**

→: Steps taken. Development according to empowerment of human resources.

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Micro-satellite development for earth observation.

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 nearly 57 kg.

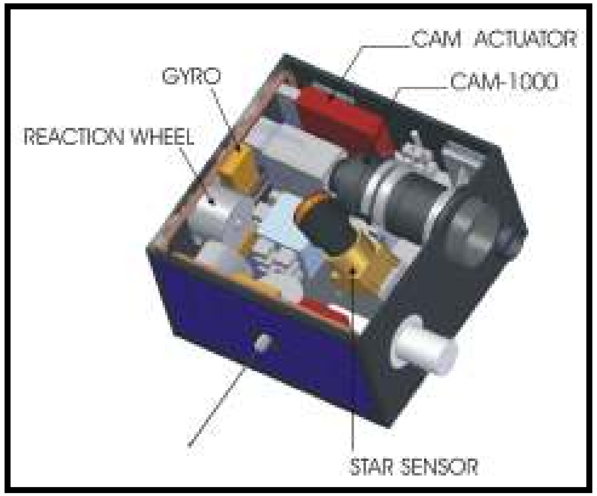
Interactive 3-axis attitude control;
Star Sensor for satellite attitude determination;

CCD color video camera on 1,000 mm cassegrain lens provide 5 m ground resolution and 3.5 km swath width.
CCD color video camera on 50 mm lens provide 81 km swath width and 200 m resolution. Application for earth observation surveillence, e.g. natural resources, urban land, environment and disaster management;

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

LAPAN-TUBSAT Micro-Satellite

SPECIFICATIONS



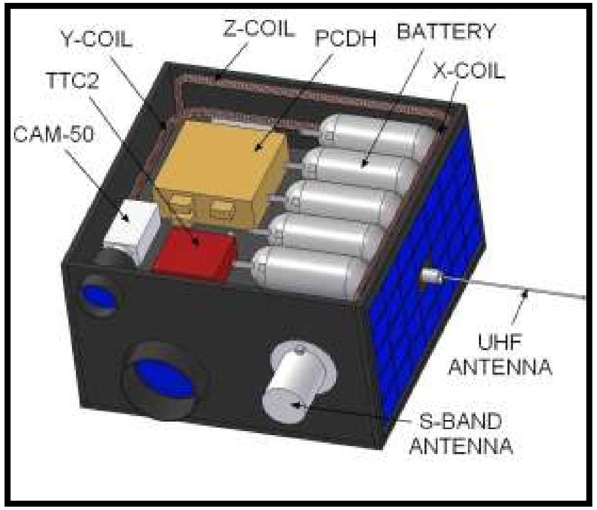
DIMENSION : Length : 450 mm, Width : 450 mm, Height : 270 mm

WEIGHT : 57 kg

POWER : 4 Solar Panels, 432x243 mm, 35 Cells in Series, Max 14W, 5 NiH2 Batteries, 12.5 V nominal voltages, 8 Ah

COMMUNICATIONS : 2 TTC's; Frequency 437,325 MHz, Modulation FFSK, 1200 bps, 3.5 W RF output

DATA HANDLING : OBDH with 524 kB external and 4 kB internal RAM, 524 kB EEPROM, 16 kB PROM, 38.4 kBps SCI speed

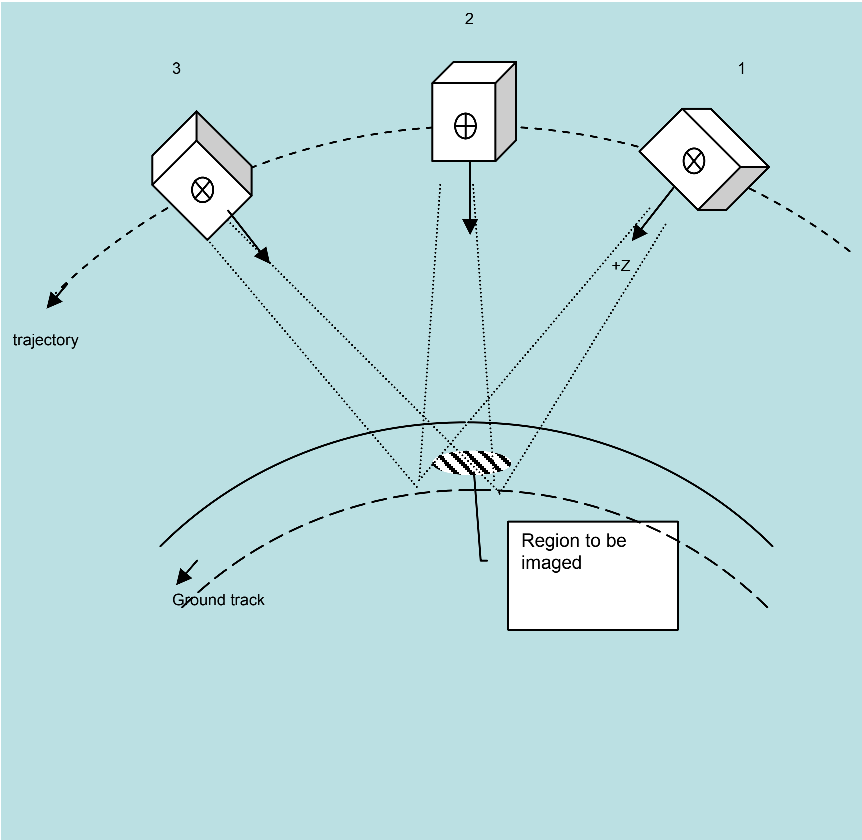


PAYLOADS : S-band Frequency 2220 MHz, FM Video Modulation, 5 W RF output, Camera 1 : CCD with color splitter prism, Effective Picture Element : 752x582, 1000 mm case grain lens, Swath 3.5 km, Ground Resolution 5 m (in 630 km LEO), Camera 2 : color CCD, Effective Picture Element : 752x562, 50 mm lens, swath 81 km, Ground Resolution 200 m (in 630 km LEO)

ATTITUDE CONTROL SYSTEM : 3 wheels fiber optic laser gyros in orthogonal axis, CMOS star sensor, 3 magnetic coils in orthogonal axis, Coarse sun sensor (solar cells) at 6 sides

LAPAN-TUBSAT Micro-Satellite

Attitude Control Strategy



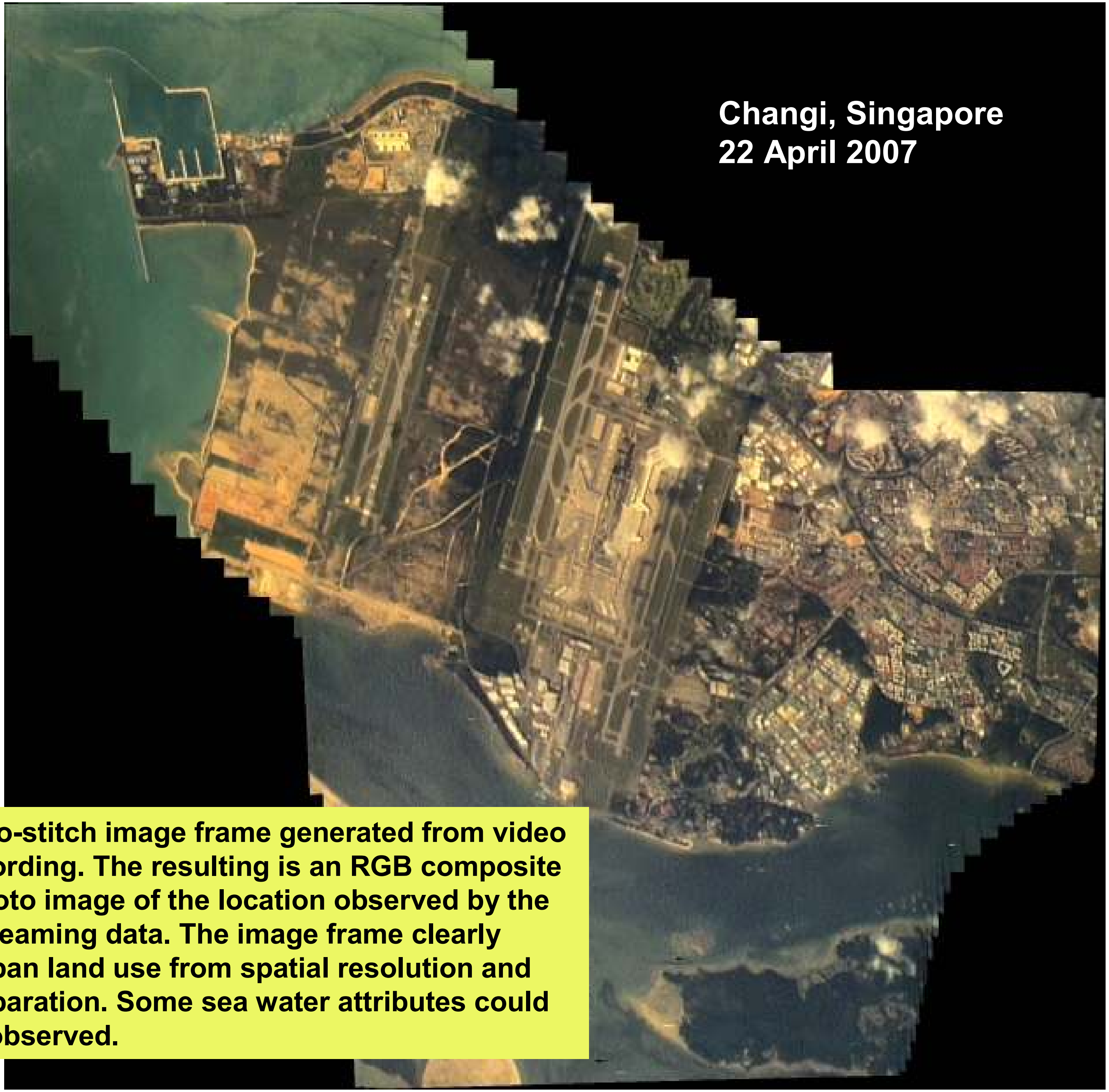
Target-locking Imaging

The left figure illustrates the scenario of the satellite keep its camera pointing to a certain region during its flight. Here the satellite initial pitch and pitch rate (wy) is managed so that +Z axis would be pointed to the designated point. Application of such picture mode is for example recording moving object in the area or producing stereographic images. The control of the pitch rate could be done interactively since the satellite uses video camera payload.

The operation of two cameras, the wide angle camera and the high resolution camera would enable the users to make the selection of the object to be captured interactively. The wide-angle camera would be used to determine and select the general location of the object by watching its coastline of specific terrain, and the high-resolution camera is used to zoom in to the area, to get better image of the boat, volcano, transportation infrastructure or any other objects.

LAPAN-TUBSAT also has a free tumbling option (deep sleep mode), in which all system is switch OFF except the OBDH and TTC (in the receiving mode). By doing so, the satellite would nutate naturally. Such mode would draw very minimal power from the satellite and the satellite still could be used for store and forward mission.

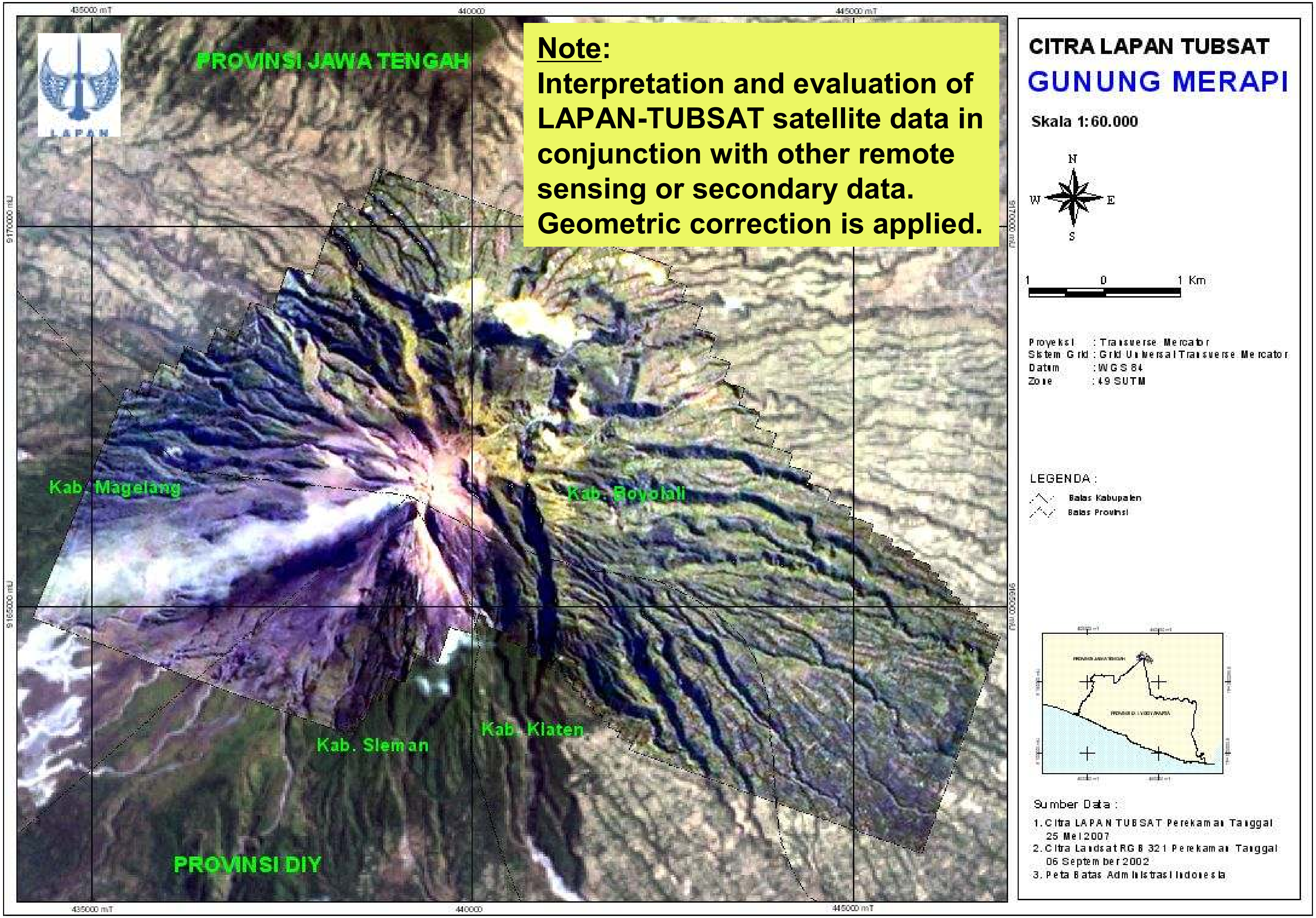
LAPAN-TUBSAT video image of Singapore, acquired 22 April 2007
Sony video camera on PAL European TV format with 390x584 pixel CCD sensor area.
(Click on black frame to run video recording)

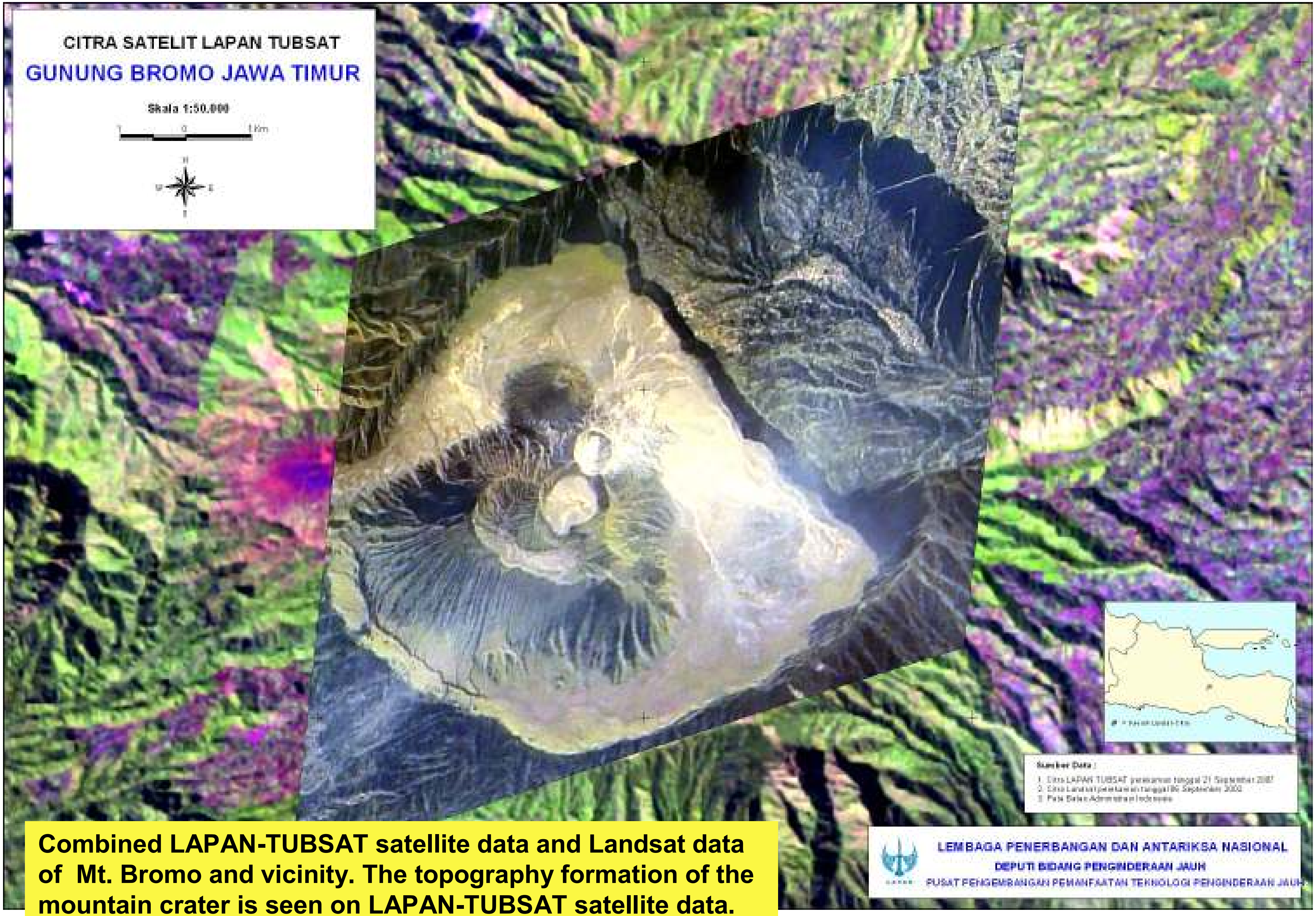


The video-stitch image frame generated from video data recording. The resulting is an RGB composite color photo image of the location observed by the video streaming data. The image frame clearly show urban land use from spatial resolution and color separation. Some sea water attributes could also be observed.

Mt. Semeru
Video stitch image,
LAPAN-TUBSAT
September 2007

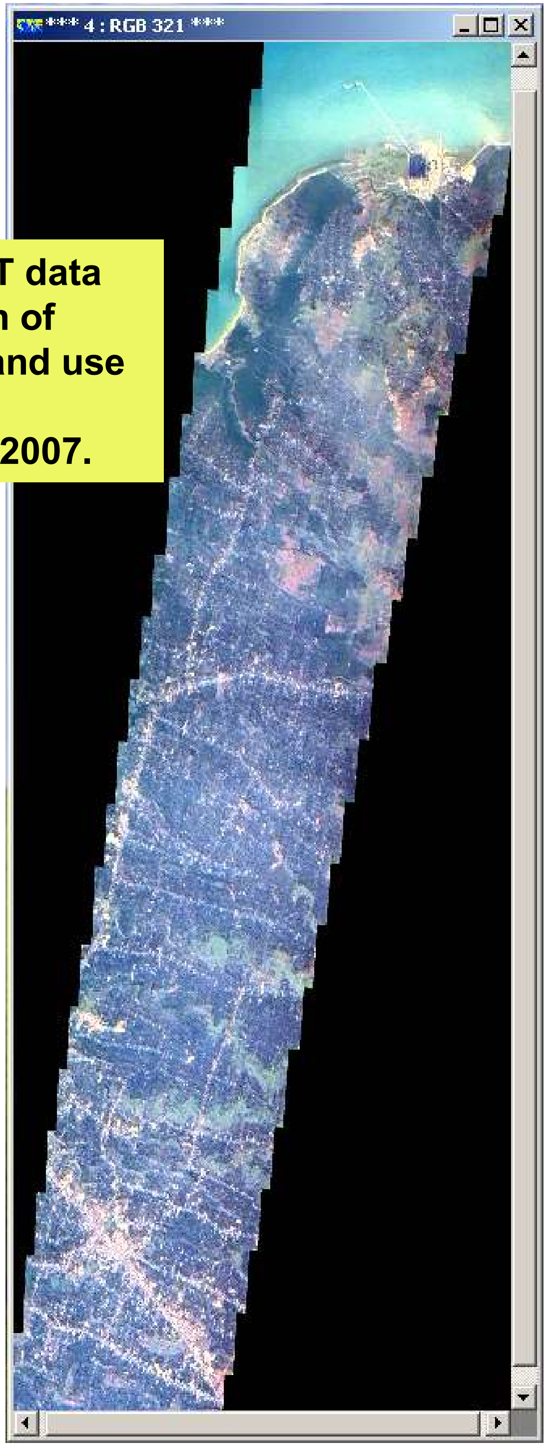
LAPAN-TUBSAT satellite video-stitch image frame of Mt. Semeru. The image frame show the crater and main direction of deposit flow on the volcanic slope, i.e. south-east direction, where it is dispersed further down the mountain slope. The location closer to the crated around the slope show that there are no or very little vegetation from the bright color, indicating mostly volcanic material. This suggest that the mountain frequently erupt discharging ash and other material. The volcanic mud is brought down the slopes with rain water around the lower mountain slopes in all direction in streams and rivers, predominantly to the south-east and east direction. Some of these rivers bearing volcanic mud deposits flow close to villages. In some areas downstream near villages the volcanic mud sediments settle as extended river embankments.

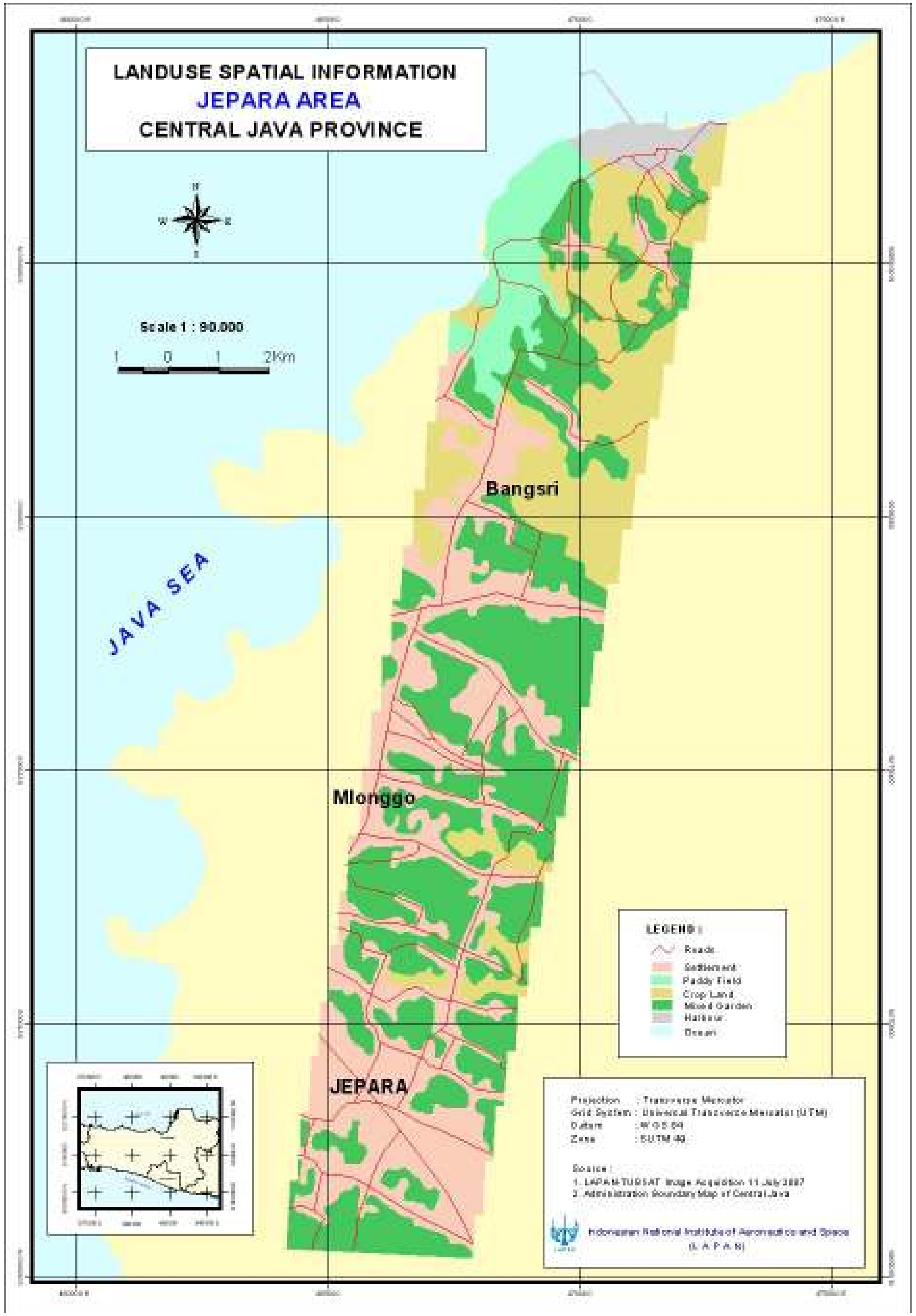

Note:
Interpretation and evaluation of LAPAN-TUBSAT satellite data in conjunction with other remote sensing or secondary data. Geometric correction is applied.
LAPAN
PROVINSI JAWA TENGAH
Kab. Magelang
Kab. Boyolali
Kab. Sleman
Kab. Klaten
PROVINSI DIY
435000 mT
440000
445000 mT
9170000 mU
9165000 mU
CITRA LAPAN TUBSAT
GUNUNG MERAPI
Skala 1:60.000
N
W
E
S
1 0 1 Km
Proyeksi : Transverse Mercator
Sistem Grid : Grid Universal Transverse Mercator
Datum : WGS 84
Zone : 49 SUTM
LEGENDA :
Batas Kabupaten
Batas Provinsi
Sumber Data :
1. Citra LAPAN TUBSAT Perekaman Tanggal 25 Mei 2007
2. Citra Landsat RGB 321 Perekaman Tanggal 06 September 2002
3. Peta Batas Administrasi Indonesia



Combined LAPAN-TUBSAT satellite data and Landsat data of Mt. Bromo and vicinity. The topography formation of the mountain crater is seen on LAPAN-TUBSAT satellite data.

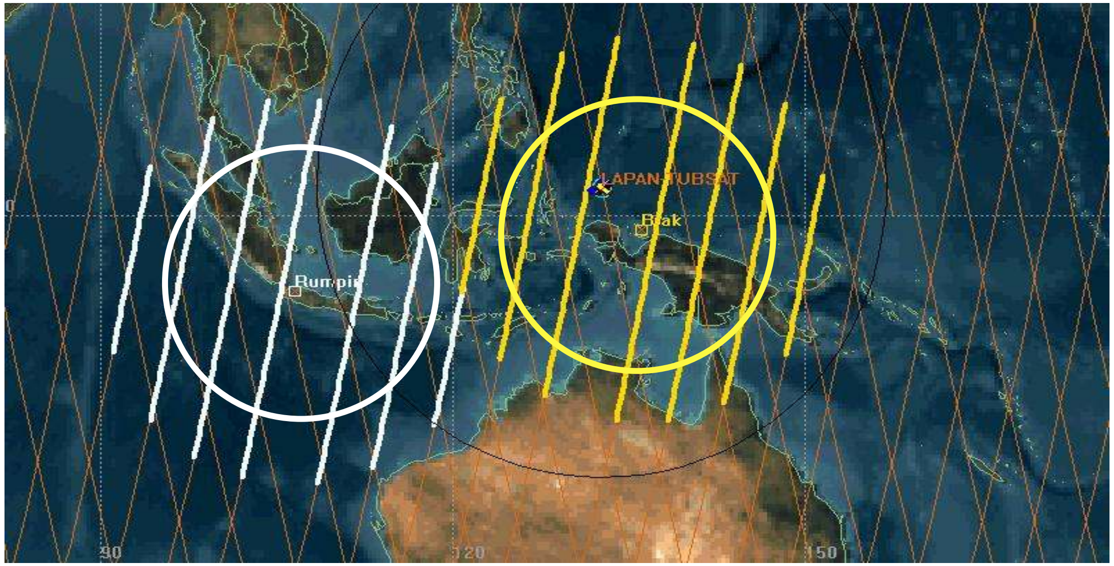
LAPAN-TUBSAT data after application of unsupervised land use classification. Jepara, 11 July 2007.





LAPAN-TUBSAT Micro-Satellite

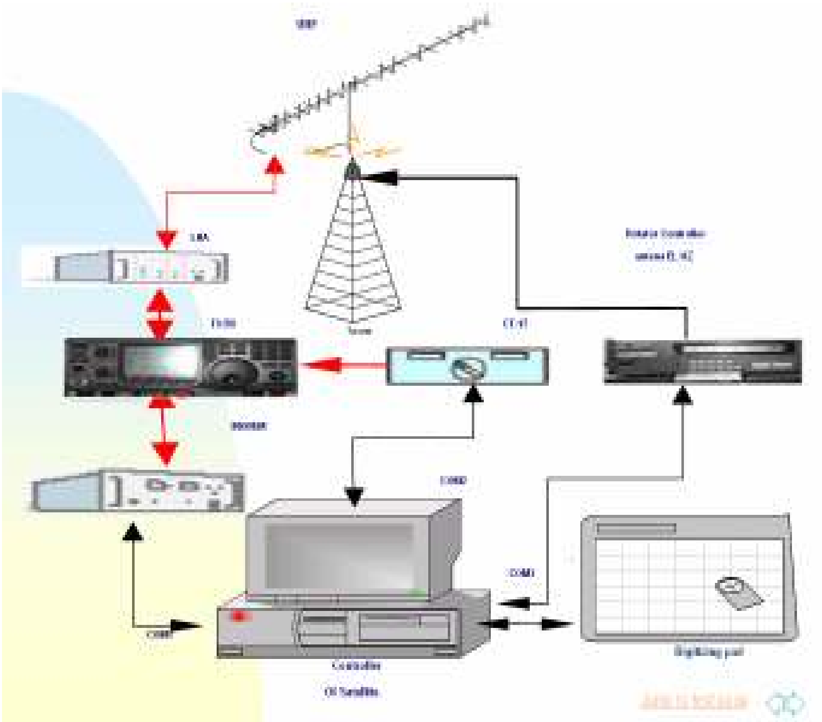
ORBIT

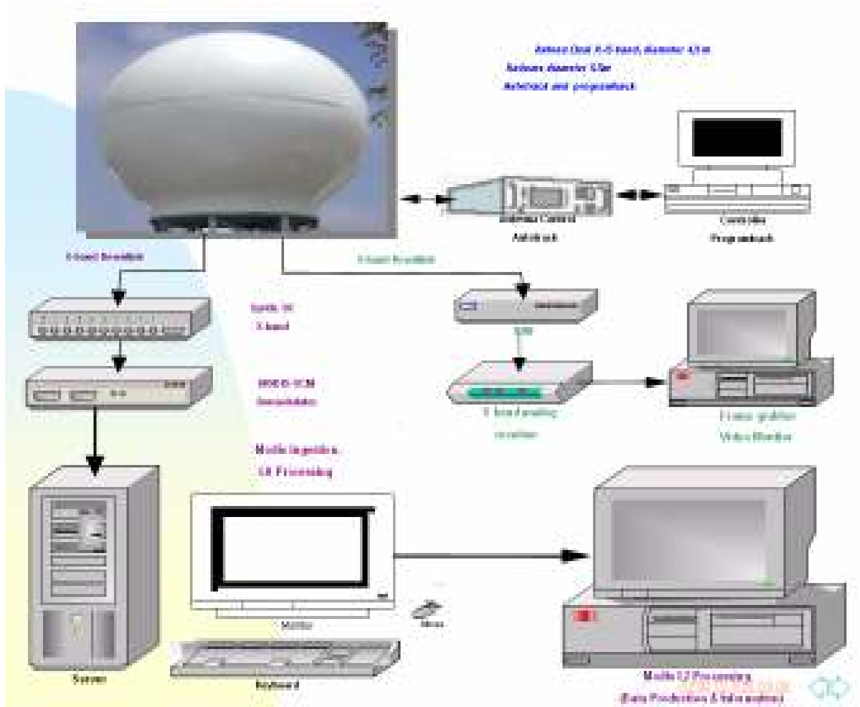


The micro satellite is in an altitude of around 630 km with 97.6^0 inclination and period of 99.039 minutes. The longitude shift per orbit is about 24.828 degree. Its ground track velocity is 6.744 km/s with an angular velocity of 3.635 deg/s, and a circular velocity of 7.542 km/s. LAPAN-TUBSAT satellite conduct 14.5 earth revolutions each day.

LAPAN-TUBSAT Micro-Satellite

GROUND STATION





LAPAN-TUBSAT TTC and S-Band Ground Station

LAPAN-TUBSAT ground station consists of two systems: one is the S-band system to receive the video image from the camera payload, and the other is the UHF TTC system to send command and receive telemetry from the satellite.

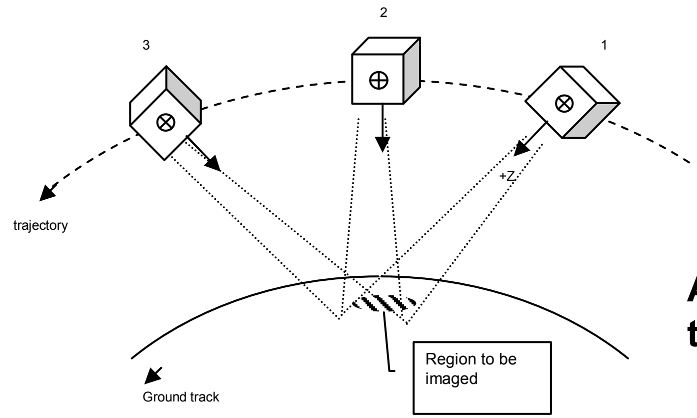
Guidelines for next step micro-satellite development.

1. **Development of the second phase satellite (after LAPAN-TUBSAT satellite) is carried out in Indonesia;**
2. **The second phase satellite is based on LAPAN-TUBSAT satellite bus with enhanced performance;**
3. **The effort to study a remote sensing satellite for food security mapping mission with multi-spectral imaging payload shall be continued;**
4. **Indonesia require a constellation of satellite missions in equatorial orbit;**
5. **Orbit inclination transfer method for small satellites, i.e. dog-leg maneuver shall be explored to put the satellite to equator orbit;**
6. **LAPAN-TUBSAT satellite shall be in operation in 2007.**

The result of transfer of knowledge, skill and experience shall without delay be put to good practice in satellite development due to the diminishing and eventual loss of the newly attained learning (skilled human resources) with increasing time.

Enhancement of mission performance (from assessment of LAPAN TUBSAT satellite operation):

1. **Global Positioning System (GPS) for data on satellite time and orbit position;**
2. **Satellite primary payload configuration shall be video cameras similar to LAPAN-TUBSAT satellite, with higher definition;**
3. **Attitude Determination and Control System (ADCS) for autonomous and programmed satellite platform attitude stability and payload pointing during earth observation data acquisition. Including GPS image data location;**
4. **Time and position tagged programmed satellite camera pointing attitude control to achieve autonomous camera lock-on to a geographic location under observation. Including GPS and ADCS operation for target location;**



Autonomous programmed target-lock operation.

5. **Solid state memory for payload and housekeeping data storage;**
6. **Use of satellite as space flight test platform for qualification of new space sub-systems;**
7. **Scientific research payload for atmosphere and other space environment research.**

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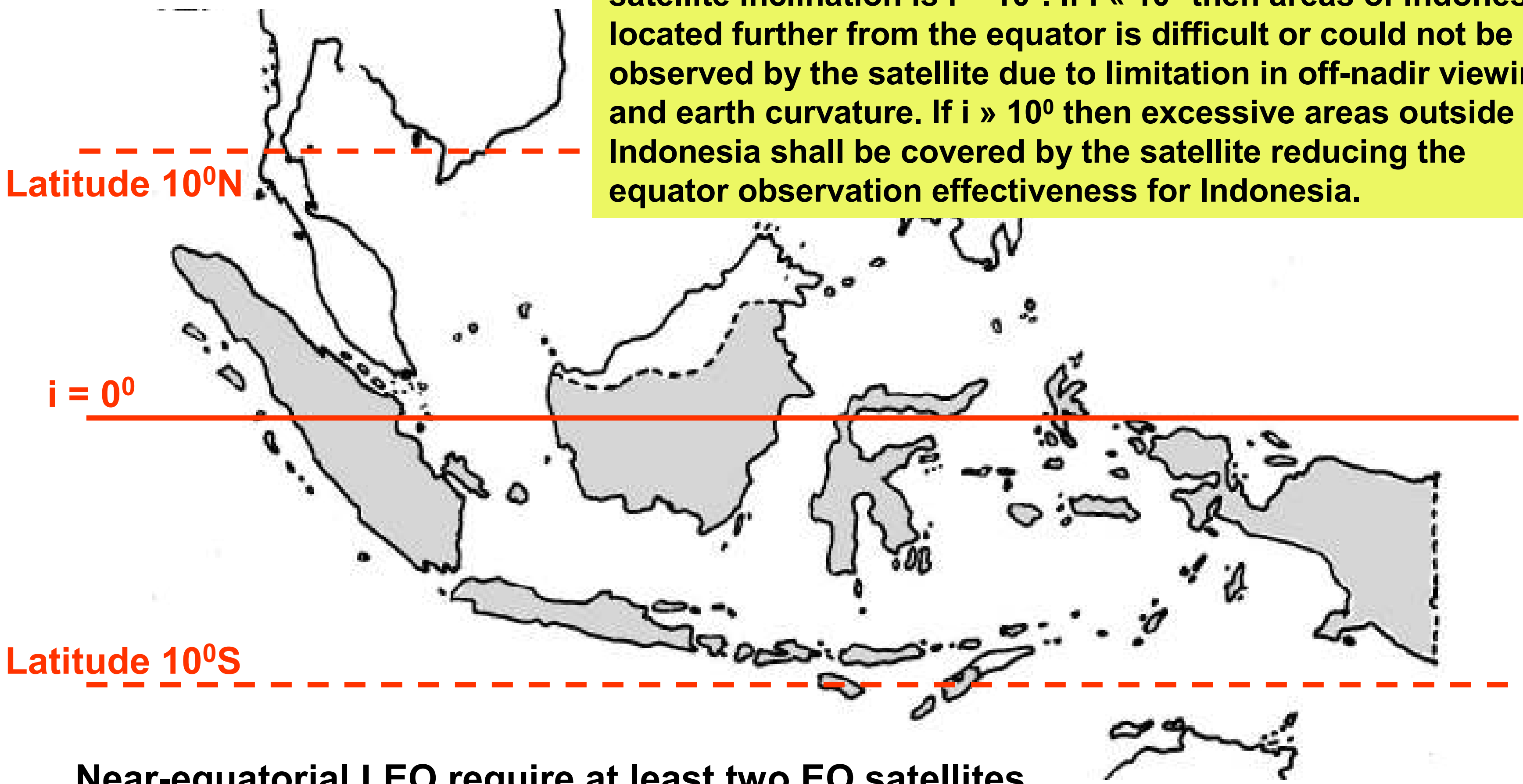
Developing an Equatorial Earth Observation Satellite System

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

For LEO orbits between 600 to 850 km the most effective satellite inclination is i = 10^0. If i « 10^0 then areas of Indonesia located further from the equator is difficult or could not be observed by the satellite due to limitation in off-nadir viewing and earth curvature. If i » 10^0 then excessive areas outside of Indonesia shall be covered by the satellite reducing the equator observation effectiveness for Indonesia.



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

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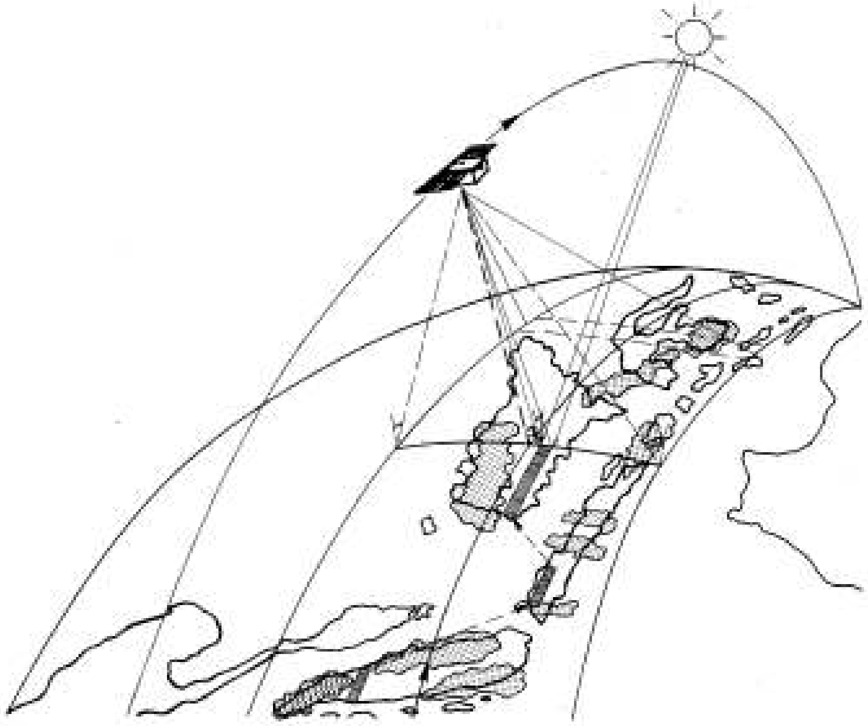
Developing an Equatorial Earth Observation Satellite System

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 near-equatorial inclination. Off-nadir pointing capability is used.

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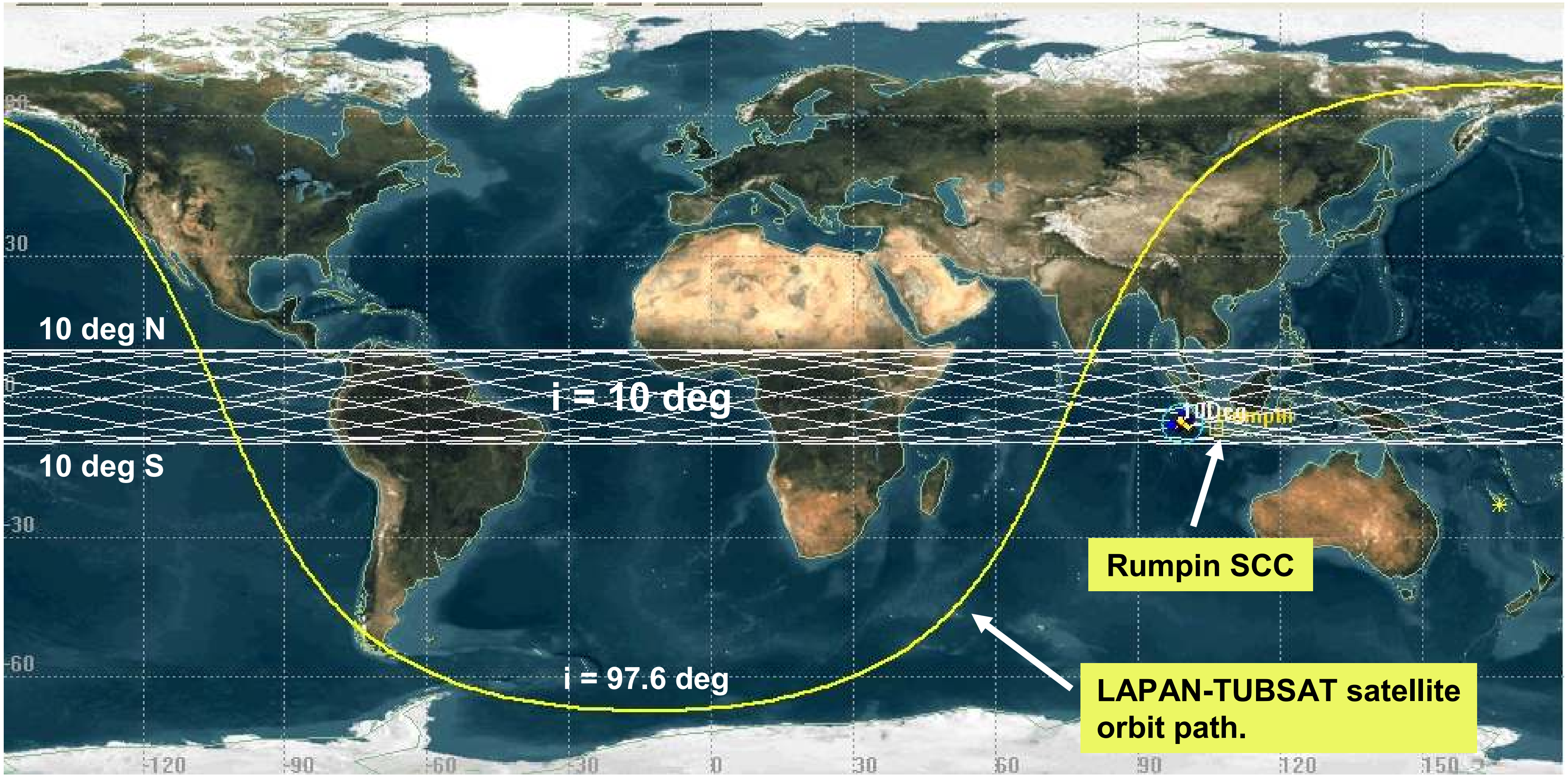
Indonesia

Developing an Equatorial Earth Observation Satellite System

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



Appreciation

In this opportunity we would like to express our highest appreciation to Indian Space Research Organization (ISRO) for the professional and successful launch of LAPAN-TUBSAT satellite into orbit as auxiliary payload of Cartosat-2 and SRE missions from SDSC Sriharikota, India on January 10, 2007. We would like to congratulate ISRO for the successful Cartosat-2 and SRE missions.

We also would like to express our highest appreciation to the Technische Universität Berlin in Berlin, Germany for the cooperation on transfer of knowledge, skill and experience of LAPAN-TUBSAT micro-satellite to LAPAN. A special appreciation to Prof. Dr.-Ing. Udo Renner and his co-workers for their expertise, supervision and friendly cooperative support.

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