TROPICAL EARTH RESOURCES SATELLITE (TERS)

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Abstract

The baseline of the Tropical Earth Resources Satellite (TERS) concept is a RS satellite with a pushbroom optical instrument in a true-equatorial orbit (1680 km). The swath-width of the high resolution multispectral instrument can be pointed anywhere between latitude 10°N and 10°S, which will offer the equatorial countries an opportunity to observe any part of their territory four times per day during daylight. A forward looking cloud sensor will give the possibility to detect which areas are free of clouds and to point the observation instrument acccordingly to specific clear areas. The TERS, which is conceived for the equatorial countries and Indonesia in particular, will complement the already existing and planned RS satellites, especially with regard to the improvement of the temporal resolution of the RS data on these countries. It is anticipated that such a satellite will enable monitoring of critical processes.

1. Introduction

Past earth observation programmes have created a growing need for remote sensing (RS) from space. A survey of existing and planned RS space programmes (excluding military and meteorological missions) shows that all the RS satellites of these missions have near-polar orbits. The orbits of these satellites induce two factors which by nature cause an unequal global distribution of the temporal resolution of the RS data. The temporal resolution is defined as the average elapsed time between two consecutive usable images of the same area.

The first factor is the cloud coverage which, especially in the equatorial region with its high cloud cover percentage of over 60%, lowers the temporal resolution of imagery taken in the visible and the infrared part of the spectrum. One could penetrate the clouds by taking images in the radio frequency part of the spectrum using a radar system. But this system has the disadvantage of the need for much electrical power, the high data rate, the "heavy" processing on the ground, the high technology it requires, as well as the experimental status of the applications. The second factor is that the equatorial region does not have the advantage of the increasing overlap to the poles, which in countries farther from the equator positively influences the temporal resolution of the RS data from near-polar orbiting satellites (fig. 1.1).

Due to both the cloud cover and the overlap there is such a difference in temporal resolution between the equatorial region and higher latitude regions that a RS satellite especially conceived for the equatorial region can be regarded as a welcome "gap filler".

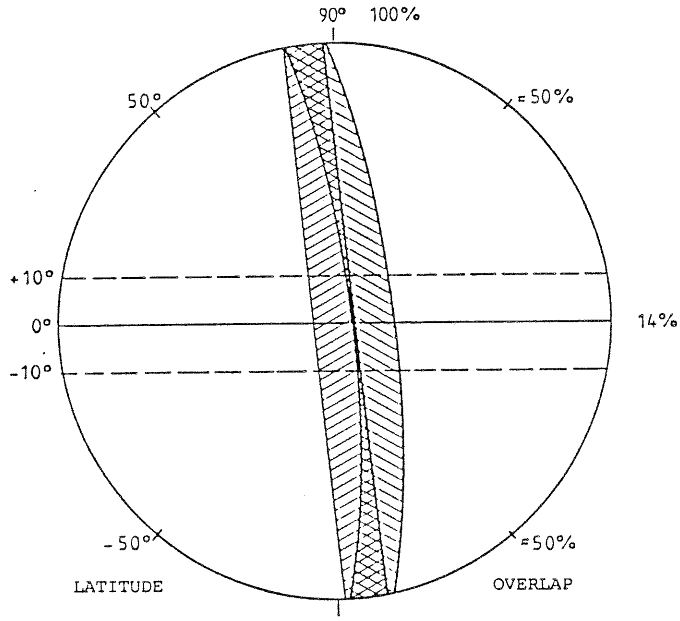

fig. 1.1 Swath-overlap of a near-polar RS satellite

An off-hand statement could be: "In order to provide the equatorial countries with a similar temporal resolution as obtained in the high latitude countries, one equatorial RS satellite is needed on each 4 or 5 near-polar orbiting RS satellites".

2. Background

The idea for a Tropical Earth Resources Satellite (TERS) was one of the options when the Netherlands Agency for Aerospace Programmes (NIVR) in cooperation with Dutch industries, was studying a successor for the second Netherlands Astronomical Satellite (IRAS), launched on 25 January 1983. A number of reasons induced the parties on the Netherlands side to approach Indonesia:

- The existing good relation between the two nations.
- Indonesia is ideally situated to benefit from a satellite RS system, designed for the specific needs of tropical countries.
- The feeling that the chances of getting such a project off the ground with a suitable single partner are much better than with a larger number of interested countries already participating from the beginning.

The TERS concept is similar to an idea (see reference), which in an earlier stage, was brought foreward by the Indonesian National Institute of Aeronautics and Space (LAPAN). Also it appeared that TERS would fit well in the framework of Indonesia's national space policies and the overall national development plan. A workshop held in Indonesia concluded that the TERS idea is feasible and at present the TERS is being studied by NIVR and LAPAN in a joint phase A study.

It is anticipated that after the feasibility studies also other countries can take part in the development of the TERS system.

3. <u>The system concept</u>

The baseline of the TERS is a RS satellite in a true equatorial orbit, which will be able to observe any area between 10° Northern and 10° Southern latitude with a spatial resolution of 20 meter. A satellite in a zero degree inclination orbit will have a viewing angle of 0° with respect to the local vertical when looking to the equator (nadir viewing) and a viewing angle varying with the orbit height when viewing at 10° latitude. Since the size of the instrument grows with the orbit altitude (given a fixed spatial resolution and swath-width) the height should be as low as possible; but on the other hand extrapolating the experience with RS from aircraft the viewing angle should not become more than about 45°. Looking at the different equatorial orbit heights where the number of orbits per day is an integer (fig. 3.1) the orbit at 1680 km is the lowest orbit where the viewing angle at 10° latitude is less than 45°. The 1680 km altitude with 11 orbits every 24 hours allows for 4 overpasses per day during daylight (7.30 to 16.30 hours local time). At each overpass the swath-width of the satellite, specified as 60 km at the equator, can be pointed to a preselected area by rotating the whole RS instrument. This "selective viewing" offers the equatorial countries an opportunity to frequently observe any specific part of their territory within the TERS coverage. It is anticipated that the swath-width can be pointed beyond the region between 10° Northern and 10° Southern latitude. Areas adjacent to the -10° to +10° region could be observed at the penalty of a viewing angle of more than 41,5° and a spatial resolution of more than 20 meter. The spatial resolution of 16 meter (panchromatic 8 meter) is specified at the equator.

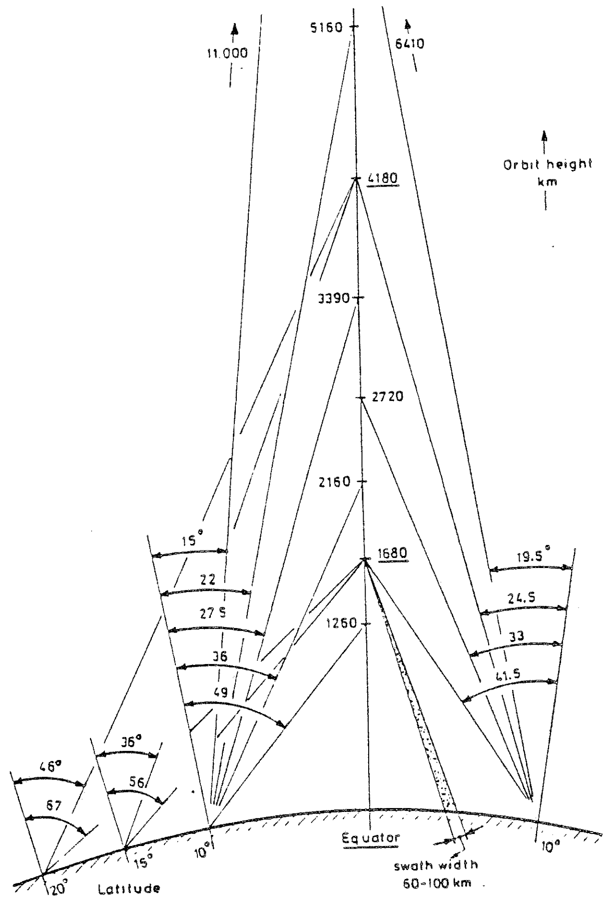

fig. 3.1 Orbit height versus viewing angle w.r.t. local vertical

Situated between 6° Northern and 10° Southern latitude Indonesia is covered by the TERS with a viewing angle of less than 41,5° and with a spatial resolution of better than 20 meters. Based on the main objec-

tives of Indonesia's development programme TERS has capabilities to provide information for the purpose of:
- Conceptual and comprehensive development planning.
- Evaluation, exploitation and management of natural resources.
- Monitoring of resources utilization and environmental conditions.
- Mapping and monitoring of settlement distribution.

The benefits of the TERS system are not necessarily limited to Indonesia. Other equatorial countries around the globe in Latin America/ the Caribbean (fig. 3.2), Africa (fig. 3.3) and South-East Asia (fig. 3.4) may also be interested in utilizing the TERS system.

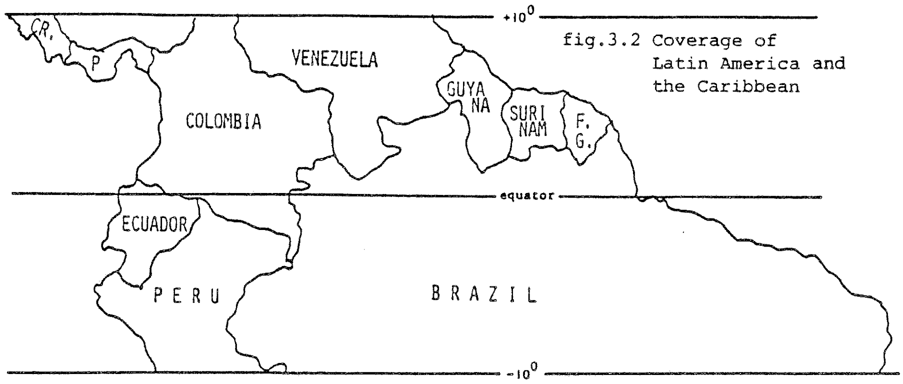

fig.3.2 Coverage of Latin America and the Caribbean

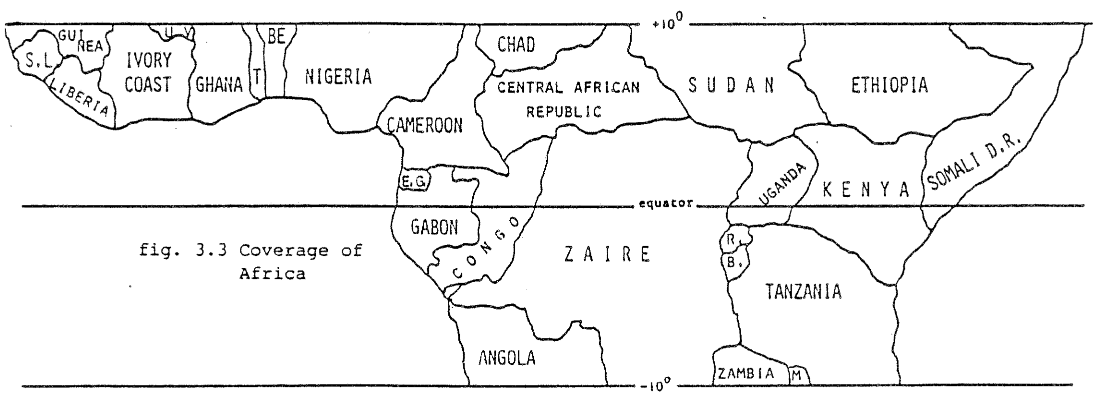

fig. 3.3 Coverage of Africa

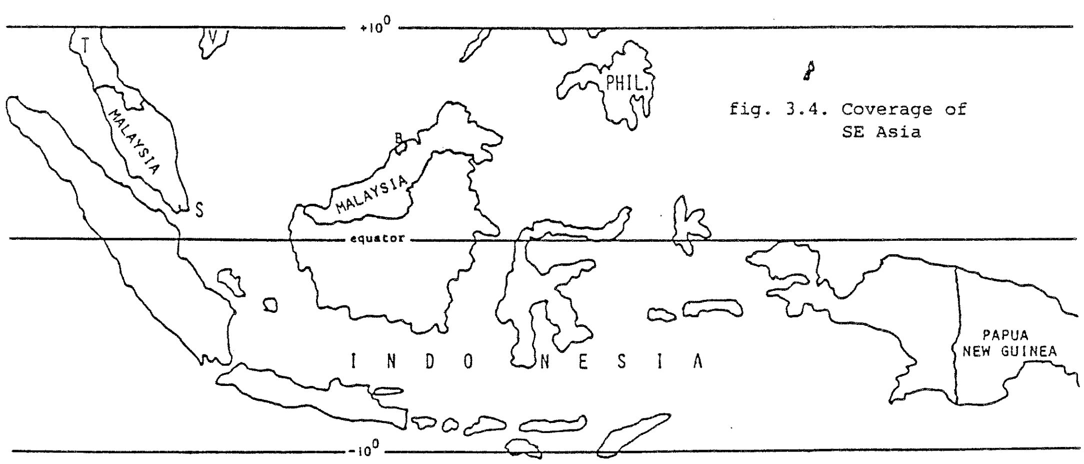

fig. 3.4. Coverage of SE Asia

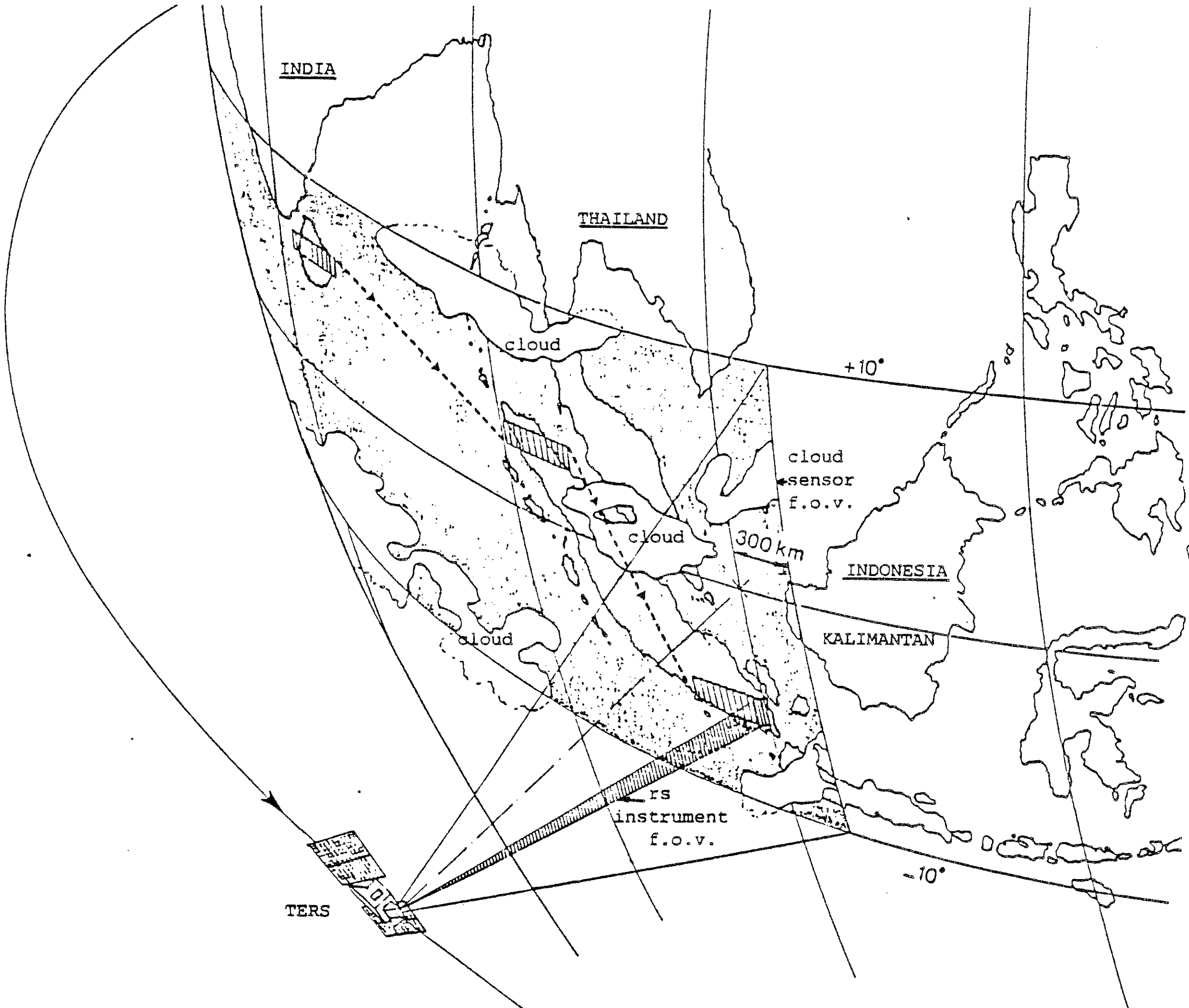

fig. 3.5 TERS concept

Conventional RS systems with imaging instruments in the visible and thermal infrared part of the spectrum are taking images irrespective of the cloud cover. In doing so the data storage system on-board (taperecorder) as well as the data processing on the ground is often burdened with the handling of useless (clouded) images.

In combination with the selective viewing capability of TERS a cloud sensor will offer the extra possibility to point at an alternative clear area when the area of primary interest appears to be clouded (fig. 3.5). The TERS cloud sensor is looking 300 km ahead of the RS instrument and passes on to the satellite transmitter the cloud distribution between 10° Northern and 10° Southern latitude. Before each overpass a list is made of the potential areas which should preferably be observed during this overpass. Taking the priorities, the acceptable cloud cover percentages, the expected cloud cover and the limitations of the instrument rotating mechanism a preliminary optimal observation programme is calculated by the groundstation computer. During the overpass the data of the cloud sensor is received by the groundstation. With this actual cloud cover data the optimal observation programme is recalculated and commands are sent to the TERS to direct the swath according the updated optimal observation programme. When at certain longitudes no areas are to be observed the TERS will be put in the standby mode. Fig. 3.6 shows an example of an operational observation sequence of the TERS over South-East Asia. When the cloud cover percentage of an area with priority x appears too high the swath is pointed to priority x + 1 (x = 1 to n). In this figure the depicted distribution of the clouds is deduced from the data of the Geostationary Meteorological Satellite (GMS) by a computer programme written and processed by LAPAN. Similar studies giving statistical data on the hourly, daily, seasonable and yearly variation of the cloud cover should also be performed for the Latin American/Caribbean as well as for the African region. The output of these cloud studies should give among others the following information:

- Average cloud coverage.
- Size of cloud free areas (the minimum size of holes in the clouds to "peep" into should be defined).
- Assessment of the capabilities of the monitoring function of TERS (at least one usable image each two weeks).

Using the unique possibilities of the true equatorial orbit: four observation opportunities per day, a coverage area of at least 10° Northern to 10° Southern latitude, the selective viewing capability combined with a cloud sensor, it could be stated that the TERS concept is an appropriate intermediate step between the conventional optical imaging systems which are hampered by clouds and the application of a radar system.

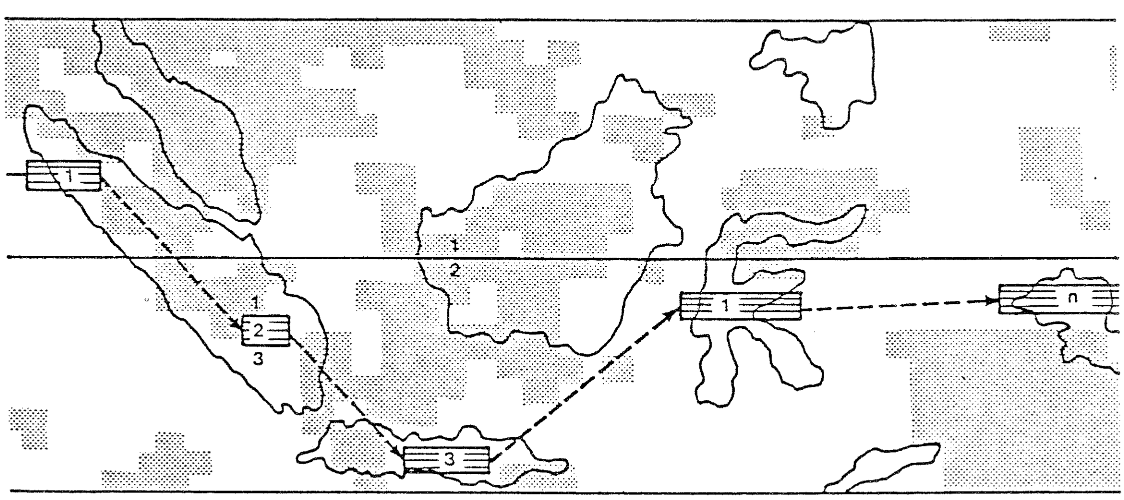

fig. 3.6 TERS operational sequence

4. The space segment

Given the maximum viewing angle of 45° with respect to the local vertical and the nominal coverage area, the altitude of the true equatorial orbit has to be 1680 km. Compared to the other RS satellites in orbits lower than 1000 km, the TERS (fig. 4.1) with its High Equatorial Orbit (HEO) has two particular driving design parameters for the satellite being the proton radiation and the RS instrument. The proton radiation at the height of 1680 km requires adequate shielding as well as radiation hardened detectors, lenses, mirrors, electronics and solar cells. Although a less radiation sensitive electronic design is selected the weight of the shielding is expected to be at least 35% of the total weight of the satellite. The other important design parameter is that the size and weight of the instrument are increasing with the distance between the RS instrument and the object to be observed. To comply with the specified spatial resolution and swath-width the preliminary design leads to a catadioptric configuration with a diameter of 40 cm and a length of 150 cm. The first estimate of the weight gives 750 kg for a TERS with one RS instrument and 1000 kg for a satellite with two instruments of 250 kg each. Since the potential (Indonesian) users are giving a much higher priority to an instrument in the visible (VIS) part of the spectrum than to the implementation of a Thermal Infra Red (TIR) instrument and the costs of a satellite with two instruments will be about 30% higher than the costs of a satellite with one instrument only, it was decided to choose the VIS instrument as a baseline. The RS instrument will be based on the push-broom principle using Charge Coupled Devices (CCD's). For each of the three spectral bands an array of 4 CCD chips with 2000 detectors each will be needed. On board four pixels are combined to have a high radiometric resolution and a ground resolution of 20 meter. The data of one of of the spectral bands is also available in a high resolution "panchromatic" mode with a resolution of 10 meters.

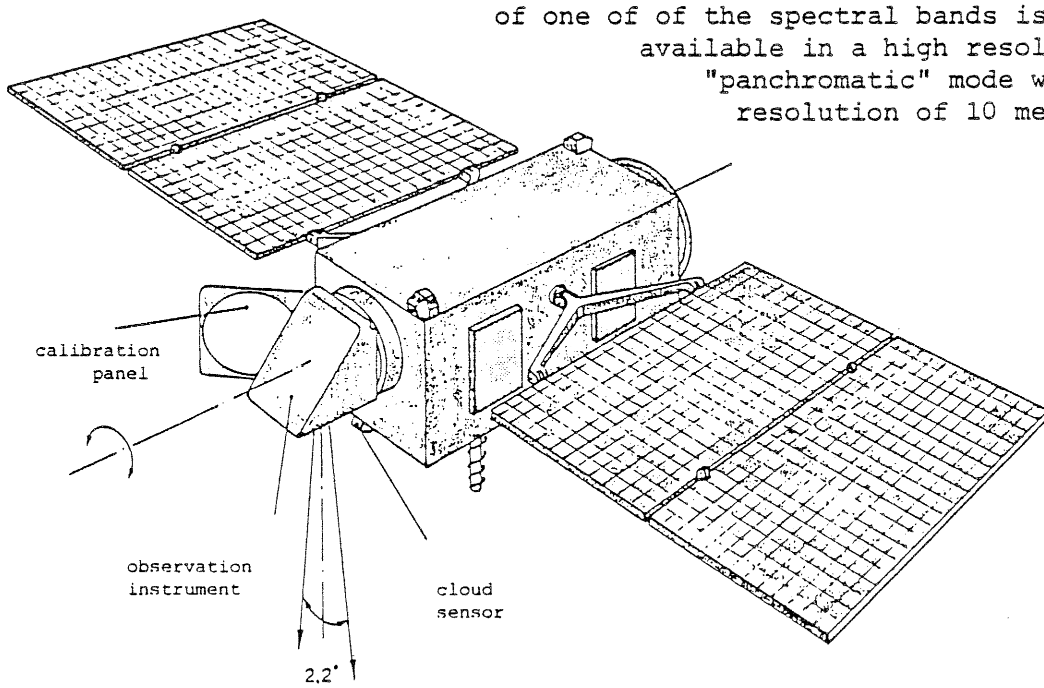

fig. 4.1 Artist impression of TERS

5. The ground segment

The high equatorial TERS orbit and the selective viewing combined with a cloud sensor are bringing in new possibilities in the field of RS satellite systems. As is shown in fig 5.1 the TERS will have one Satellite Control Centre (SCC) with the normal Telemetry, Tracking, Command and Monitoring (TTC&M) tasks. This station could be located at one of the RS data acquisition stations in order to simplify the interfaces with this groundstation. The TERS SCC with up and down link communications with the satellite is used for:

- Control of the satellite subsystems like: power system, thermal control system, attitude control system, on-board data handling system, radio frequency system, image system, cloud sensor etc.
- Programming of the on-board computer for system control.

It is anticipated that the SCC will not perform the sensor operations, as is the case in other RS satellite systems (e.g. LANDSAT or SPOT).

These sensor operations are controlled by the TERS User Service Centre (TUSC). This TUSC with an up- and downlink to the TERS could be located at or integrated with the RS data acquisition station and will provide the following functions:

- Handling of user requests for data acquisition.
- Reception of cloud cover data from the satellite.
- Calculate the optimal path of observations.
- Sending commands to the satellite to point the swath.
- Statistical analysis of cloud cover data for cloud cover prediction.
- Fast processing and dissemination of final products to users.
- Digital data and photographic processing.
- Archiving of a complete coverage at least twice a year.

As also shown in fig. 5.1 a communication satellite could be used for the transmission of processed data from the TUSC to (remote) users.

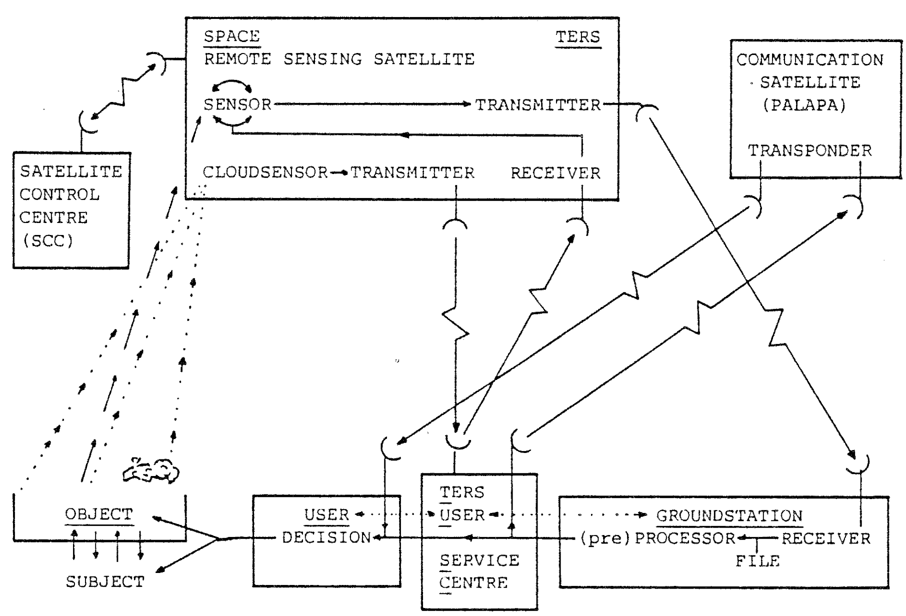

fig. 5.1 TERS blockdiagram

The RS data acquisition groundstation will preprocess and file the received data before delivery to the TUSC. Thanks to the high TERS orbit only one groundstation is needed to cover SE-Asia, one for Latin-America/the Caribbean and two for Africa. Because almost the whole land area of the equatorial region can thus be covered with only four groundstations which can receive the RS data in real time there is no need to have a tape recorder on board to store the RS data.

It is anticipated that the TERS will be compatible with other RS satellites in order to make optimum use of already existing X-band RS receiving and processing facilities. Since the TUSC of the user country or region sends the observation commands directly to the satellite the users have autonomous control over the performed observations.

6. Survey of TERS design parameters

TERS baseline:

High Equatorial Orbit
Altitude: 1680 km
Inclination: 0°
Stabilisation: 3-axis
Weight : about 750 kg
Swath-width: 60 km at equator
Scanning: push-broom
RS instrument: array of Charged Coupled Detectors
Spatial resolution: 16 m at equator (8 m panchromatic)
Spectral resolution: 3 channels between 0.5-1.1 micrometer
Off-nadir viewing: between 10°S and 10°N
Orbits per day: 11 (4 during daylight)
Operations: cloud sensor with selective viewing
RS data transmission: real time (no satellite taperecorder needed)
Operation control: user country or region with groundstation

The High Equatorial Orbit allows for:

- Optimal application of cloud sensor and selective viewing.
- A coverage rate of 4 times in daylight (7.30 and 16.30 hours LT).
- An appropriate intermediate step between:
  the conventional sensors (which are hampered by clouds) and
  the complex radar systems (which penetrate clouds).
- Only one or two data acquisition groundstations per continent.

Reference: J. Salatun, Harijono Djojodihardjo and Iskandar Alisyahbana "Satellite orbital considerations for Remote Sensing in Indonesia", Presented at the joint UN and FAO regional seminar on RS Applications, Jakarta, 19-28 November 1965.