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ACCESS TO WORLD-WIDE GEOGRAPHICAL INFORMATION

ACCES A UNE INFORMATION GEOGRAPHIQUE MONDIALE

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ABSTRACT

The earth observation space program SPOT launched by France in association with Sweden and Belgium is described hereunder. Once the satellite, its orbite, sensors, spectral and spatial characteristics of data, acquisition modes of images, transmission and images storage systems are displayed the SPOT distribution network is introduced. This network is supported by the SPOT IMAGE Society in Toulouse - France and by subsidiary companies. One of them, SIS, settled in Australia is in charge of the distribution of data in Australia and in the South Pacific countries. The existing and planned receiving stations and preprocessing centers are also presented hereafter. In conclusion the characteristics of the present SPOT mission based upon 4 satellites are described and the future SPOT generation of satellites with new technical specifications and higher ground resolution (3 - 5m) is introduced.

RESUME

On présente le programme spatial SPOT lancé par la France en association avec la Suède et la Belgique. Après une description du satellite, son orbite, ses capteurs, les caractéristiques spectrales et spatiales de ses données, ses divers modes d'acquisition d'images, ses capacités d'enregistrement et de transmission, on introduit le réseau de distribution de la Compagnie SPOT IMAGE. Ce réseau s'appuie notamment sur des filiales dont l'une SIS située en Australie

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est chargée de la commercialisation des données sur l'Australie et l'ensemble des pays du Pacifique Sud. On introduit enfin le réseau des stations de réception établies ou en cours d'établissement. En conclusion, on précise la durée des missions spatiales actuelles basées sur 4 satellites et l'on introduit la génération future des satellites SPOT dont la résolution (3 à 5m) et les spécifications techniques offriront de nouvelles possibilités d'observation.

INTRODUCTION

SPOT, the pre-eminent system of the ongoing collection of geographical information, is unique in the world of space-based Earth observation. With ground resolutions of 10 and 20m, SPOT offers unrivaled geometric accuracy, unparalleled acquisition flexibility, and the major innovation of stereoscopic imagery. These and other features make SPOT remarkably suitable for a wide range of applications including mapping, inventorying of renewable and non-renewable natural resources, planning of civil engineering works, urban planning and development, and more generally, all fields calling for accurate, up-to-date geographical information.

The SPOT satellite-based Earth Observation system is a French program with the participation of Sweeden and Belgium. The first satellite, SPOT 1, was launched in february 1986. Its successor SPOT 2 was launched in January 1990. SPOT 2 will be followed in due course, by SPOT 3 and SPOT 4, the latter featuring a number of important technical refinements. Together, these spacecraft will ensure continuity of service until the year 2000 and beyond. This continuity will enable satellite-based remote sensing to expand into many key areas where it has yet to gain wide acceptance.

Right at the outset of the SPOT program, the French governement adopted a pragmatic and realistic approach to the organization and management of the spacecraft and ground facilities. In particular, the roles of the State and industry were clearly defined on the following basis :

- CNES (Centre National d'Etudes Spatiales, the French Space Agency), acting on behalf of the State, to act as overall program leader and manager with full responsibility for satellite launches and orbital exploitation, and related funding ;

- Industry, through SPOT IMAGE, to manage the marketing and commercial promotion of the SPOT satellite and the image data they return.

SPOT IMAGE is present in the South Pacific Region through its subsidiary SPOT Imaging Services Pty Ltd (SIS) located in St Leonards, North of Sydney. SIS commercialisation zone extends from Australia to all countries of the South Pacific.

SPOT - THE SATELLITE

SPOT Orbit

Orbiting satellites for earth observation have an original orbit. The type of space mission imposes a great number of orbital constraints.

First of all, we want to obtain images which have the same characteristics whatever the point observed ; the orbit must consequently be circular, that is to say its altitude relative to the Earth must be constant. In reality, even with a circular orbit, there will be light altitude differences between the poles and the equator due to the flattening of the Earth (the Earth's radius is 20kms longer at the equator than at the poles).

Next, we want to obtain images of all the regions of the Earth. To meet this requirement, we choose a quasi-polar orbit. The Earth rotates about its own axis inside this orbit and the sub-satellite point will trace the Earth's surface at regular intervals. It is important to dispose of a functioning cycle permitting to repeat the observation of a point regularly. In order to create this observation cycle, the satellite completes a whole number of revolutions along its orbit while the Earth completes a whole number of revolutions about its axis of rotation. The satellite and the Earth thus return to their starting points. In these conditions, the orbit is said to be "phased" relative to the Earth.

SPOT, whose orbit is at an altitude of 828kms (at the equator) completes 14 - 5/26 revolutions per day. In 26 days (or 26 Earth revolutions), it describes a whole number of revolutions and the subsequent tracks of the satellite on the Earth's surface will repeat the first pattern over and over. To ensure that the satellite covers every point on the Earth's surface during this cycle, the field of observation of the two imaging instruments is greater than the distance between two adjacent tracks. This is achieved using the so-called "turn vertical" viewing configuration in which the spacecraft ground track bisects the swath imaged by the two instruments.

On SPOT the maximum distance between the ground tracks is 108km (at the equator) and the combined field of view of the two instruments in the twin vertical configuration is 117km, which insures a complete coverage of the Earth in a single 26-days cycle.

It is also necessary that the plane of the orbit be at a constant angle relative to the sun, because valid comparison on images of a given point acquired on different dates depends on the similarity of the conditions illuminations. This achieved by ensuring that the satellite overflies any given point at the same local (sun) time, which in turn, requires that the orbit be sun-synchronous.

Nominally, the satellite passes a descending node (intersection of a descending of south-bound track with the equator) at 10.30 a.m. of each day. The time (i.e. local sun time) at which SPOT passes over any given region will be within +15 to -15 minutes of the nominal time throughout the year, and will be followed to the +5 to -5 kilometers precision of the previous track.

To sum up, the orbit of both SPOT 2 and SPOT 1 is circular (828 kms, at the equator), sun-synchronous (10.30 a.m.) and in phase (26-days cycle).

The Payload

The SPOT payload consists of two identical instruments called HRV (High Resolution Visible).

To meet the requirements of SPOT users, the following principal characteristics have been adopted for the SPOT optical instruments :

- High resolution (10m and 20m) in order to establish topographic maps at 1:50 000 with required geometric accuracy and thematic maps up to 1:25 000 scales.

- Four spectral bands corresponding to two spectral modes :

The multispectral (X) mode , made up of three spectral bands, corresponding to a ground sampling interval, of 20m. The bands are : green (0.5 - 0.59 micrometers), red (0.61 - 0.68 micrometers) and the near infra-red (0.79 - 0.89 micrometers), which together insure improved spectral response to chlorophyll and specifically to the response peak in the green band, strong absorption in the red, and pronounced response in the near infra-red that human eyes cannot detect.

The panchromatic (P) mode, which corresponds to a spectral band extending from 0.51 to 0.73 micrometers and a ground sampling interval to 10m. This mode is intended primarily for applications calling for fine geometric detail.

In addition to these, the SPOT satellite provides the possibility of varying the viewing direction of +27° to -27° relative to the vertical and to the satellite's orbital plane. This feature has two major advantages : excellent revisit capability and stereoscopic vision for acquiring stereopairs.

With an appropriate remote-control ground orientation of the entry mirror of each HRV instrument, it is possible to observe interesting regions that are not at the vertical of the satellite. They can be spread out in an "observable corridor" extending 450kms on both sides of the satellite ground track. The width of the strip effectively observed varies between 60kms for nadir imagery and 80kms for extreme oblique imagery (viewing angles of + 27°).

Observation acquisition is controlled by the SPOT on-board computer according to a working plan sent to the satellite once a day from the Control Center. An imaging sequence may provide for successive operation in the panchromatic or multispectral mode and for changes in the viewing direction of each of the satellite's instruments.

This oblique vision capability is used to increase the frequency observation of certain specific sites. For example, at the equator, the same region can be successively accessible on nine separate occcasions during each 26-days orbital cycle, which corresponds to 126 rimes per year or an average of once every 2.9 days.

At latitude 45° (France), a given region can be observed 12 times during an orbital cycle, which corresponds to an average of 2.1 days with a maximum interval of 4 days and a minimum of 1 day.

Repeated observation of a given region at given intervals provided by oblique viewing is extremely useful for investigating rapid dynamic phenomena such as crop ripening and as a means of increasing the probability of obtaining high-quality images in regions frequently covered by clouds (tropics).

The oblique viewing capability also makes it possible to obtain stereopair imagery of a same scene taken under angles during different successive satellite orbital passes. The ratio between the observation base (distance between the two satellite positions), and the height (altitude of the satellite) can be as high as 1. The main applications for stereoscopic imagery are in photogrammetry and photo-interpretation, two disciplines which require relief perception.

Image Acquisition

Solar light reflected by the landscape is captured by the optical instrument ; in this case, a telescope of which the principal characteristics (focal distance and diameter of the lens) are initially determined by the resolution requirement.

SPOT telescope provides a ground resolution of 10m, is 2.5 in total height and has a mass of 250kg. Two identical HRV (High Resolution Visible) instruments are mounted on the satellite.

Once light has entered the optical system, the next step is "image acquisition". The SPOT imaging instruments use linear arrays of detectors located in the telescope's focal plane. They are photodiodes of very small dimensions (3 microns x 13 microns) who convert the incoming light into electrical signals.

Earth detector analyzes an element of the landscape (10m for example), the width of the strip corresponding to the

detectors field of view. It receives light from this landscape zone during the rime that the satellite has progressed 10m, that is 1.5ms. This image acquisition technology overcomes the need of a mechanism in the instrument focal plane of which the technology is excessively complex for such high resolutions.

The image is constituted, line by line, every 1.5 milliseconds, as the satellite progresses (this principle is said to be the "push-broom" technique). The detectors used are of the Charge Coupled Device-type (CCD). The 6 000 photodiode detectors per scanline in the panchromatic mode are used to analyze a landscape swath of 60km long oriented perpendicularly to the satellite ground track. The swath is analyzed in a single stip (10m-wide portion sample). The length of the image line corresponds to the optical instrument (HRV).

- The signal output is the amplified, then digitized by an ADC (analog-to-digital converter). For each spectral strip it is possible to select, by remote control, one of the 8 gain values available.

The volume of the data involved is enormous : image acquisition with a resolution of 10m corresponds to 24 millions bits per second. SPOT can transmit over two channels at a time, one must choose between two panchromatic and two multispectral channels each of which are issued by one instrument (with 6 possible combinations).

Image Storage and Transmission

When considering SPOT Image data transmission to ground, two cases must be considered : either the satellite is within range of an image of a receiving station or out of range.

In the first case, image data modulates a transmitter carrier signal so that they are transmitted directly to earth bu the transmitting antenna.

In the second case, image data are first recorded by on-board magnetic recorders then played back during a subsequent pass within range of one of the main receiving stations (Toulouse or Kiruna), using the same system of transmission.

An image receiving station can receive satellite telemetry on an 8-GHz, provided that the satellite be within its coverage range, that is to say, a circle with a radius of about 2,500km. This limit corresponds to a spacecraft elevation of at least 5° above the horizon.

THE SPOT DISTRIBUTION NETWORK

SPOT IMAGE S.A. is the company acting on behalf of CNES for the commercialisation of the SPOT images. It was set-up in 1982 to address the world-wide market. SPOT- IMAGE has built a network of subsidiaries and distributors to help in this task.

SPOT Subsidiaries

SPOT IMAGES Corporation, based at Reston (Virginia), was incorporated in 1982. The company was set up to serve the North American market and to offer its customers a wide range of remote sensing data, products and services. Image data of US territory is supplied to SPOT IMAGE Corporation by the two Canadian direct receiving stations.

The company's production facilities at Reston are designed primarily to transform image telemetry recorded on high-density digital tapes by the Canadian receiving stations into digital and photographic products.

In late 1988, SPOT IMAGE decided to set up a second subsidiary company, known as SPOT Imaging Services (SIS), to serve the South Pacific market. SIS is located in St leonard, North of Sydney Australia, and its commercialization zone includes Australia as well as all countries of the South Pacific. SIS not only distributes data, but also Derived Works and Products such as satellite image-maps thematic maps, etc... SIS is in constant relationship with its parent company SPOT IMAGE concerning catalogue extracts, programming of the satellite and production of the images. SIS can provide any public information about SPOT and the SPOT products. SIS can also take orders and deliver products within the shortest turn-about time as possible.

The SPOT Distributors

On the eve of the SPOT 1 launch in February 1986, the SPOT IMAGE network already boasted some 37 distributors and agents worldwide. Most of the organisations concerned are private sector companies with experience in remote sensing. The efforts of these companies and their teams have contributed greatly to the promotion of SPOT technology.

SPOT IMAGE and the newer distributors and agents rely on the experience and know-how of these terms in their continuing efforts to expand the market. All contribute their technical skills and marketing talents to the overall promotion effort, primarily in exchange for an appreciable economic return.

Today, the SPOT IMAGE distribution network comprises 58 distributors and agents in 48 countries.

The SPOT Receiving Network

The SPOT satellites transmit their image data to a steadily expanding network of receiving stations.

- The two major space imagery receiving stations, at Toulouse and Kiruna as SRIS-T and SRIS-K, offer a combined coverage encompassing the northern polar zone, all of Europe, and North Africa.... These are the only stations to receive imagery of areas outside their direct coverage zones using the satellite's on-board recorders. Each station can receive up to 250 000 scenes per year.

The stations are associated with space imagery archiving and preprocessing centers, known as CRIS-T and CRIS-K respectively.....

- Direct receiving stations in the following countries :

  Canada : two stations covering Canada and the USA down to the Rio Grande river.

  India

  Europe : the station is located in Mas Palomas in the Canary Islands (Spain).

  Brazil

  Thailand

  Japan

  Pakistan

  South Africa

  Saudi Arabia

  Israel

  Australia : the antenna is located in Alice Spings ; the images are stored and processed in Canberra ; both facilities are operated by the Australian Centre for Remote Sensing.

CONCLUSION

SPOT is healthy : after 4 years in orbit SPOT 1 is still in good shape (except for the on-board tape recorders) ; it is still usable for direct reception of images. SPOT 1 has been placed on a storage orbit while SPOT 2 is fully operating. SPOT 3 and SPOT 4 will follow in due time.

SPOT IMAGE S.A., the company in charge of the commercialisation of the SPOT images, is distributing products

worldwide to numerous users for a number of different applications ranging from cartography to agriculture or mineral exploration.

SPOT 1, 2 and 3 have the same design. SPOT 4 will be added a new spectral band in the middle infrared. It will still have the same ground resolution (10 meters pixels). For the next generation of SPOT satellites, the ground resolution will be increased (3 to 5 meters pixels) and new features concerning the stereo capability will be added.

The SPOT program and the SPOT series of satellites will most certainly be one of the most important Earth observation programs at the turn of next century.

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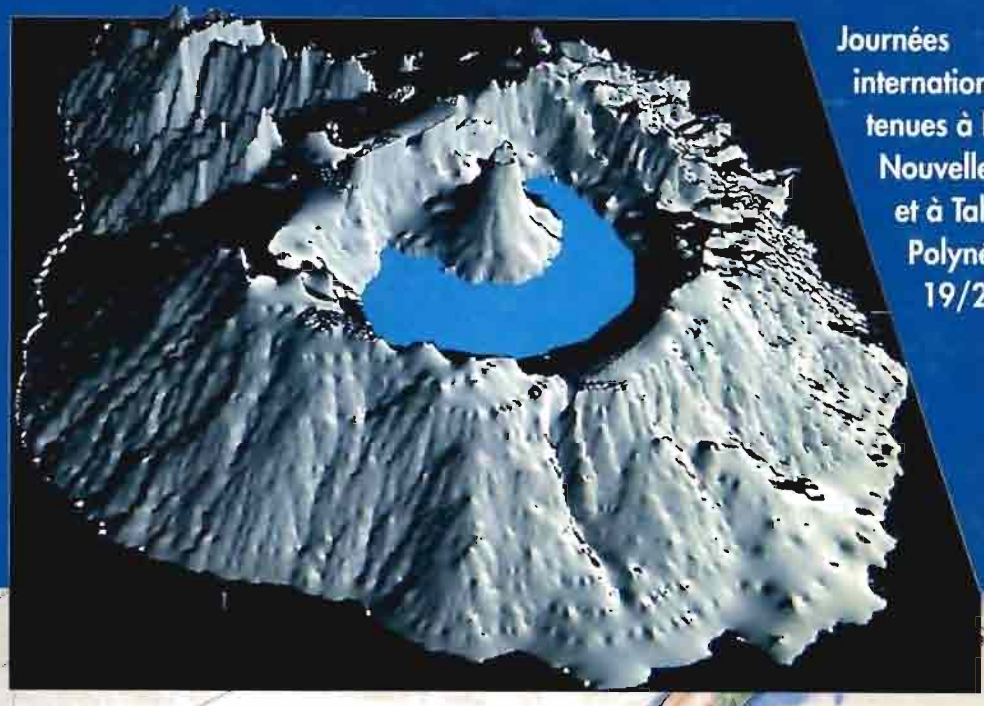

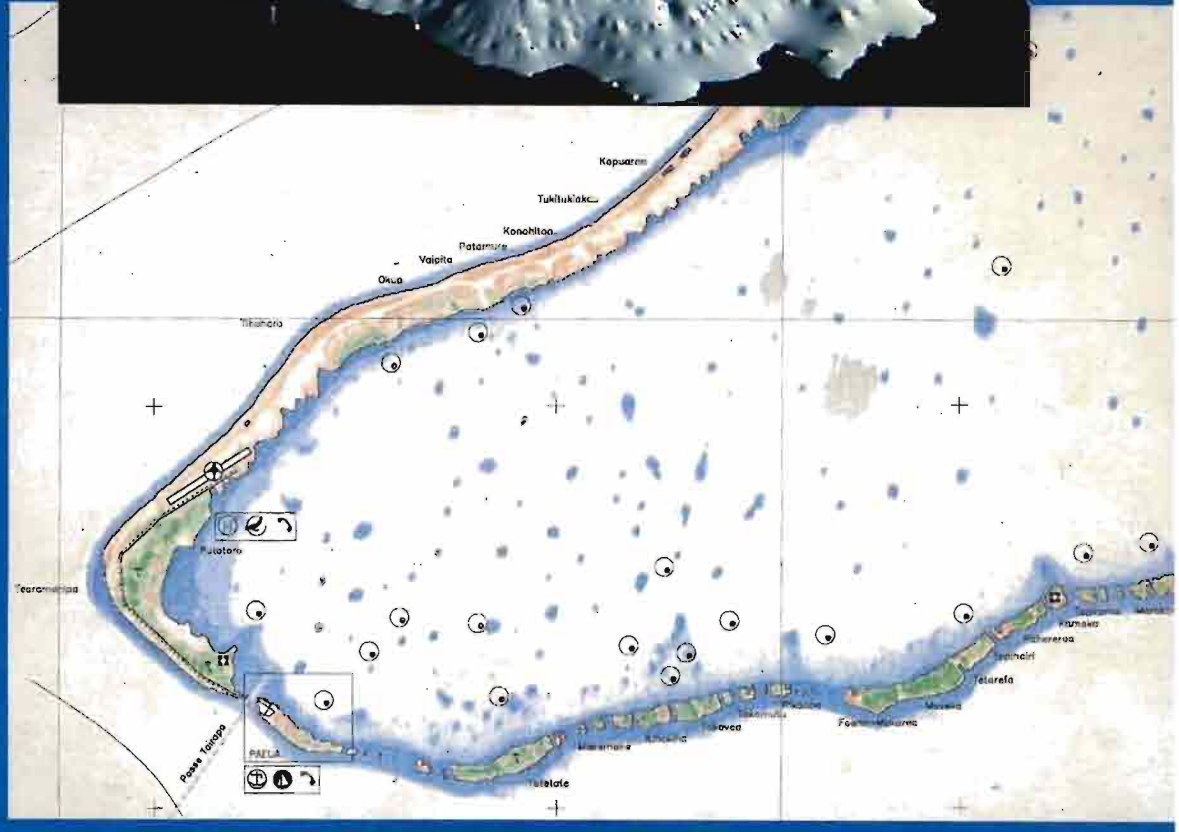

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