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The SPOT Satellite Remote Sensing Mission*

SPOT will provide high resolution and a capability for stereo coverage and frequent access to user-specified sites

Abstract: *The Système Probatoire d'Observation de la Terre (SPOT), a general purpose remote sensing satellite system, is progressing toward an early 1984 launch within the French National Space Program, in association between France, Sweden, and Belgium. The background, mission objectives, and some technical characteristics of the system are described. Each of two identical telescopes has a capability for targeting the line of sight to either side of the satellite track, and for operating on a ground sampling step of 20 m (with three color bands) or 10 m (broad band). This flexibility, enhanced by an adequate choice of orbit, will enable more frequent sampling of specific target scenes, and provide for stereo coverage of important areas. Linear arrays of* CCD *detectors are expected to combine a high data rate (25 megabits/second/data channel) with good radiometric resolution. Data from the satellite will be accessible, either through the central facility in Toulouse (France) or through foreign authorized X-band direct read-out stations.*

Introduction

An essential condition for the rational management of terrestrial resources and environment is that a system be established in which meteorological, geological, geographical, and ecological information will be constantly updated. Space-based Earth observation systems offer a particularly powerful means of collecting such information systematically, and potentially with a short delay between data acquisition and availability. It is therefore felt that the development of space-based remote sensing methods for observing the terrestrial environment should become one of the key components of the current French space program.

The French Government decided in February, 1978 to undertake the development of the Système Probatoire d'Observation de la Terre or SPOT, the aim being to launch the first satellite in early 1984. Sweden and Belgium subsequently decided to participate in the program to which they are contributing some space- or ground-based hardware. As the management of resources can be achieved only through the monitoring of several kinds of physical parameters, the SPOT system has been designed as the forerunner of a series of Earth-oriented, ARIANE launched missions in low Earth orbit.

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The system comprises

- a multimission platform or bus,
- a mission-specific payload
  which together with the bus, constitutes the SPOT satellite, and
- a ground segment.

It is our purpose to describe the system and to provide an overview of the standard data products which are expected to become available to users the world over.

The Multimission Platform

The SPOT satellite concept requires that a large proportion of the development costs for the first mission should facilitate procurement and reduce lead times for later missions. This fundamental aim is achieved by adopting an architecture composed of two main parts (Figure 1):

- the "platform" carries mission-independent subsystems: attitude and orbit control, power supplies, onboard computer, telemetry and command equipment, etc.; and
- the "payload" includes the instruments and other mission-specific equipments.

The platform equipment should be essentially re-usable for other Earth observation missions.

One of the objectives of the SPOT program is to qualify the multimission platform (CNES, 1979) for operation within the design performance envelope. This envelope is briefly defined as follows:

- circular sun-synchronous orbits at altitudes between 600 and 1200km;
- local time of ascending or descending node: 0800 to 1600 hours;
- maximum payload weight: 800kg;
- solar array power: up to 1.8kW (beginning of life);
- design lifetime: 3 years;
- pointing accuracy: 0.05° (RMS); and
- drift: 6.10^{-4} deg/second (max).

The SPOT Satellite

SPOT MISSION OBJECTIVES

The objectives of the SPOT mission are to

- experiment on desirable characteristics of future (operational) remote sensing systems;
- build up an archive and make available a worldwide data base for cartographic and Earth resource exploration purposes;
- experiment on improving vegetative species discrimination and production forecasting based on frequent access and off-nadir viewing;
- build up a stereo archive of areas of recognized interest for purposes of
  —photointerpretation,
  —planimetric cartography at scales of 1/250,000 and cartographic updating at scales of 1/100,000 and 1/50,000; and
- qualify the multimission platform and a linear array camera in space.

SPOT MISSION SPECIFICATIONS

These objectives translate into the following specifications for the design of the payload and the choice of orbit:

- complete equatorial coverage capability when using the two-sensor system in a fixed, nadir looking operating mode;

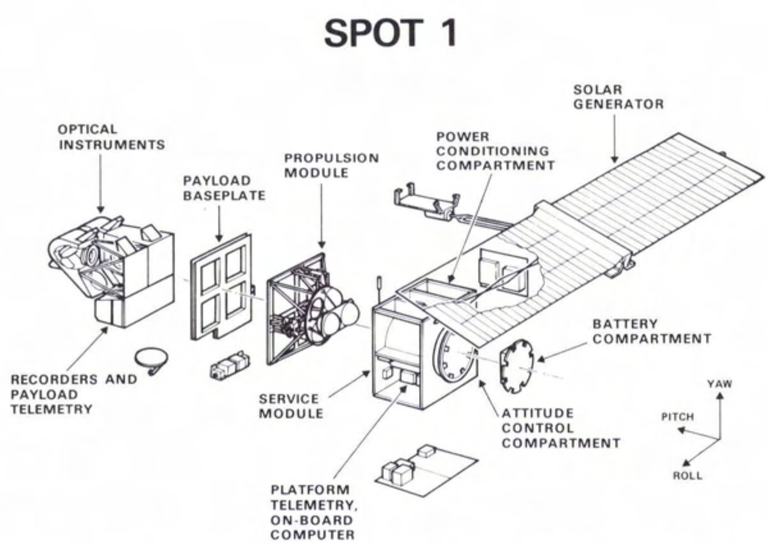

Fig. 1. Exploded view of the satellite. The scale can be estimated from the 2 m by 2 m payload baseplate.

- rapid access to any point on the globe, implying a possibility for observing designated areas more frequently than possible with nadir viewing only;
- acquisition of stereoscopic pairs over a short time span;
- high ground resolution; and
- spectral bands chosen to be good indicators for vegetation status and species discrimination.

THE FIRST SPOT PAYLOAD

To meet these requirements, the first SPOT payload includes two identical High Resolution Visible range instruments (HRV). The instruments are pointable in the across track direction in order to allow rapid access to any point on the globe and the acquisition of stereoscopic image pairs from different satellite passes (Figure 2). Data generated by the instruments are to be transmitted to the ground over the payload-specific X-band telemetry link or stored by means of two onboard recorders for later recovery by the Toulouse master station.

The HRV has been designed in order to achieve

- a multispectral capability with a ground sampling interval of 20 m;
- a 10-m sampling interval in a "black-and-white" mode;
- a cross-track pointing system to provide accessibility, slant, and stereo coverage capability;
- a bit rate within 25 megabits/second/data channel, expected to be reasonably compatible with data processing capabilities at user installations in the mid-1980's (the total telemetry rate is 50 megabits/second); and
- a basic 256 grey levels over the full radiometric range (8-bit coding in the multispectral mode).

These constraints result in the selection of a 60-km swath width for each instrument.

HRV instruments. Because high ground resolution was a basic mission specification, mechanical scanning systems were discarded from the outset.

The HRV instruments form images without any moving mechanical part (e.g., scanning mirrors, disk choppers, or mechanical modulators) being used; i.e., images are obtained using the "pushbroom" scanning mode (Boyle and Smith, 1970; NASA, 1972); (Thomson, 1979):

- each line of the image is electronically scanned by a linear array of detectors located in the instrument focal plane, and
- successive lines of the image are produced as a result of the satellite's movement along its orbit.

This system offers two major advantages:

- the "exposure" time for each ground point imaged is automatically maximized, and
- the principle of the instrument ensures excellent photogrammetric quality along the linescan axis.

A ground resolution of 20 m over a 60-km swath requires an array of 3,000 detectors per spectral band, sampled every 3 milliseconds, while a ground resolution of 10 m over the same swath width requires 6,000 detectors per line, to be sampled every 1.5 milliseconds. These requirements are met using charge-coupled device (CCD) detectors.

The sensitivity of the HRV sensor is such that reflectance steps on the order of 0.5 percent can be

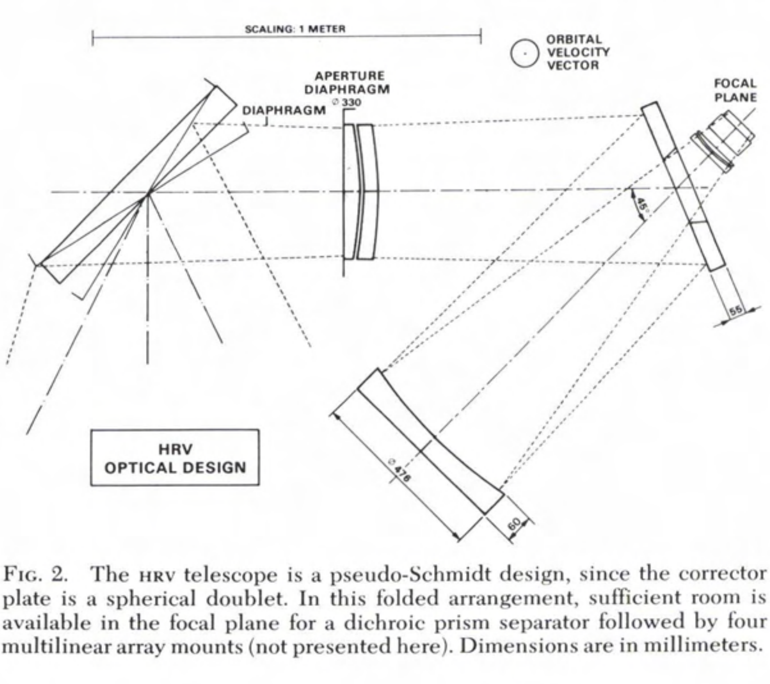

FIG. 2. The HRV telescope is a pseudo-Schmidt design, since the corrector plate is a spherical doublet. In this folded arrangement, sufficient room is available in the focal plane for a dichroic prism separator followed by four multilinear array mounts (not presented here). Dimensions are in millimeters.

detected under suitable conditions of illumination (i.e., sun higher than 30° above the horizon).

A basic requirement of all multispectral systems is the registration of different images of a given scene recorded in different spectral bands. The specification in this respect limits misregistration to no greater than 0.3 pixel (or picture element). By using a dichroic prism for spectral separation, effective point-to-point registration is obtained in the raw multispectral image. The panchromatic channel is separated from the multispectral channels in the instrument field of view. At any one time, the panchromatic scan line is, on the ground, 15 km ahead of the color scan line.

FIG. 3. The pass pattern within the orbital cycle is such that, if a pass is covered on day J, (a) the nearest pass for the next day $J + 1$ is covered $23^h\ 40^m$ later, and is located five tracks to the east. The two passes form a privileged pair for programming stereo coverage. (b) The adjacent track, immediately to the west, will be covered on day $J + 5$, about 4 minutes later in local time. This offers a possibility of re-attempting an observation that has been hampered by clouds. Theoretically, nC_2 different stereo pairs of any cloud free target area could be achieved within a 26-day period, where n is the number of tracks within a range of 435 km from the scene center (an increasing function of latitude). The B/H ratio of each pair is roughly proportional to the number of tracks between the observations, and to the inter-track distance (a de creasing function of latitude). In practice, a preferred B/H can be selected on regional-specific criteria such as cloudiness and relief.

OPTICS

The following elements comprise the optical system (Figure 3):

- a front end mirror that can be rotated about the roll axis, allowing selection of target scenes;
- a folded pseudo-Schmidt telescope, aperture $f/3.5$, focal length 1082 mm, (spherical corrector lenses);
- three dichroic prisms located at the focus for spectral separation; and
- four beam splitting prisms, one for each band, providing precise optical butting of four CCD sub-arrays into a single scan line.

DETECTORS

For each spectral band, the CCD scan line transforms the incident light into a sampled video signal. The amplifier gain can be adjusted by ground command to ensure an improved use at all times of the dynamic range of the encoder; adjustments are used in particular to compensate for large variations, along each orbit, of the angle of incidence of sunlight on the terrain.

The instrument design is based on the use of CCD linear arrays in which the individual detectors are 13 μm apart.

The pre-launch acceptance level for gain uniformity of individual detectors in each scan line is ±7 percent. Throughout the mission, periodic on-board calibration sequences will check detector drift against lamps and sunlight, providing a measurement of dark current and gain for each of the 30,000 active individual detectors or detector pairs. Short-term dark current stability is ensured by temperature control of the detectors.

CHOICE OF SPECTRAI BANDS

Thematic considerations have dictated, within technical constraints, the choice of spectral band position and width. in the multispectral mode, the major design objectives were

- consistent relationship between spectral reflectance and vegetational properties (Tucker, 1978; Bunnik, 1978);
- good discrimination within vegetated areas and within different soil types;
- compatible interpretation of spectral signatures obtained by Landsat D's Thematic Mapper and SPOT;
- improved radiometric sensitivity and resolution for surface water work; and
- at least one spectral band to provide some water penetration.

The major design constraints were

- limits of uniform and predictable detector sensitivity and sharpness of reponse (freedom from diffusion effects);

- wide enough spectral bands so as to ensure an adequate signal-to-noise ratio for the required radiometric resolution in all spectral bands;
- 20 nm separation between adjacent bands, as required by dichroic splitting system; and
- scattering and absorption characteristics of the atmosphere (Tanré *et al.*, 1979).

Three bands were thus selected for the multispectral mode:

(1) A green (500 to 590 nm) band centered around the 550 nm maximum in the chlorophyll reflectance curve. This band is on the long wavelength side of the broad attenuation minimum of water (Tyler and Preisendorf, 1962), thus giving access to turbidity assessment and bathymetric evaluation in the first 10 to 20 metres in clear water.

(2) A red band (610 to 680 nm), similar to the fifth channel on the Landsat Multispectral Scanner, which has been retained for the Thematic Mapper. It provides much information on crop identification, bar oil, and rocky surfaces. Atmospheric transmittance on a fine day is about 90 percent while water penetration is about 2 m with a surface reflectance of 4 percent (attenuation coefficient: $5 \times 10^{-1}m^{-1}$). This band corresponds to a high chlorophyll absorption (low vegetation reflectance).

(3) The near infrared band (790 to 890 nm) is the one that penetrates best through the atmosphere (transmittance is about 95 percent for a clear atmosphere model) and light haze. Vegetation stands out brightly and water surfaces appear very dark (1 percent reflectance with a high attenuation coefficient: 10 to $50m^{-1}$). Although silicon spectral sentitivity extends out to 1100 nm, it was decided not to extend the band beyond 900 nm in order to avoid response modulation by atmospheric water vapor and limit the smearing effect of electron diffusion within the detectors. Vegetal biomass can be evaluated with the red and near-infrared bands taken together. All three color bands are coded linearly on 8 bits, with a choice of ground controlled preset gains.

For the higher ground resolution black-and-white (so called panchromatic) mode, a broader spectral band was required. In order to retain a high capability for texture analysis in support of the color mode and a high information content over vegetated areas, the interval 510 to 730 nm was chosen for the broad band. The basic coding scheme is six bits linear with a choice of eight selectable preset gains. Higher radiometric resolution can be selected by ground command of a Differential Pulse Code Modulation System (DPCM) which compresses each three-pixel packet into 18 bits, while retaining an 8-bit equivalent radiometric resolution.

POINTABILITY

Upon commands received from the control telemetry link and stored in the onboard computer memory, the line of sight of each instrument can be steered to any of 91 orientations 0.6° apart in the object space. The central orientations are offset by 0.163° from the nadir so that, when both HRV's are operated jointly at ±3 steps, their swaths overlap by nominal 3 km (nadir).

It therefore follows that access can be programmed to any point target within an off-nadir angle of ±(0.163 + 27° + 2.065), translating on the ground as a band of access 950 ± 50 km wide centered on each satellite track. Selectable scene centers are about 10 km apart. However, perspective and distance degrade the cross-track resolution (increase the sampling interval) by up to 35 percent at the outer border of the access band. The higher off-nadir angles also impact the radiometric significance of a scene, due to the scene structure, the changing geometry of observation and illumination, and the increased airmass.

Where off-nadir radiometric effects are unwanted, a "radiometric corridor" about the nadir, approximately 200 km wide, could be defined for systematic coverage of extended areas. Within that corridor, the worst resolution is within 2 percent of the resolution at nadir, and the radiometric effects are coherent with those experienced with the Landsat MSS.

One immediate consequence of cross-track pointability is that access to specific targets can be obtained at shorter notice and much more frequently than with a fixed system. Comparing SPOT with and without this feature, accessibilities, measured as the number of access opportunities over an orbital period, are in a ratio 950 km/117 km = 8.1.

The main characteristics of the payload instruments, i.e., the HRV, are summarized in Table 1.

Payload telemetry system. Each of the two HRV instruments can operate in the multispectral mode (XS) and/or the panchromatic mode (P). The bit rate that can be transmitted by the payload telemetry system being limited to 50 M megabits/sec (i.e., 2 × 25 megabits/sec), only two of the four possible modes can be used at a time. In accordance with the applicable regulations, the transmission frequency is in the X-band (8.025 to 8.400 GHz).

The two preselected 25-megabits/sec data rates are merged (time-multiplexed QPSK) and fed to the transmitter and/or on board recorders for later transmission.

The payload telemetry system consists of an 8-GHz quadriphase modulator, a TWT with a nominal power rating of 20 W, a set of filters to limit the spectral band-width, and a fixed antenna

TABLE 1. MAIN INSTRUMENTAL PARAMETERS (FOR EACH INSTRUMENT)

	Color Mode	B/W Mode
Ground sampling step (m)	20	10
Array sampling period (m sec)	3	1.5
Spectral bands (μm)	×S1 0.50–0.59 ×S2 0.61–0.68 ×S3 0.79–0.89	P 0.51–0.73
Grey levels	256 (8 bits)	either 128 (6 bits) or 256 compressed to 6 bits
Data rate (M bits/sec)	25	25
Swath width (km)	60 (Nadir)	
Central viewing direction	+0.163 and −0.163 deg.	
Field steering direction	0 ± 45 steps 0.6° apart	
Outermost observable direction (deg)	±29.23	
Corresponding distance to track (km)	±475	

TABLE 2. PAYLOAD TELEMETRY

Payload telemetry system	
• bit rate	50 megabits/sec
• Transmission frequency band	8.025–8.400 GHz (Xband)
• type of modulation	QSPK
• transmitter radiated power	20 Watts
• total onboard recorder capacity	22 min/recorder

covering the entire cone of visibility of the Earth. It is compatible with acquisition by ground stations at a 5° elevation angle.

Two onboard recorders are used to store image data for later retrieval over the receiving station near Toulouse. In the nominal (push-pull) mode, one tape recorder is played back when it has been completely filled. While it is being read, the other recorder is used for recording new data. Night and ocean passes within range of the Toulouse station provide an average of 35 minutes of playback per 24 hours, without jeopardizing the real time capability.

In addition to image data, data concerning both the payload (calibration, synchronization) and the platform (attitude parameters) are multiplexed and transmitted by the payload telelemetry system. This ensures that all data required for the preprocessing of images are available together at the image receiving station.

THE SATELLITE ORBIT

Orbital parameters have been chosen as a trade-off between many, sometimes conflicting, criteria, which are summarized below.

As for previous remote sensing satellites, the orbit was to be low (600 to 900 km) to give high ground resolution, circular for a nearly constant scale of observation over all areas, near-polar to achieve a world-wide coverage, and sun synchronous and phased in order that successive images of each site be obtained under similar conditions of viewing and illumination throughout the year (Brooks, 1977).

The exact altitude of the orbit was chosen to adjust the phasing of the satellite in relation to the Earth according to the following requirements:

- Under cloud-free conditions, with both instruments blocked in contiguous nadir operation (total swath width, 117 km), a full coverage of the equatorial zone (worst case) should be possible. This, given an orbital tolerance of ±5 km, translates into a minimum of 353 satellite tracks round the globe in the orbital cycle. It also follows that the orbital cycle could be no shorter than 25 days.
- The opportunities to observe specific sites should recur regularly throughout the orbital cycle. This is achieved by selecting a phasing arrangement such that adjacent tracks are separated by a short time interval, sometimes called the sub-cycle. However, if the interval is three days or shorter, longer periods will exist during the orbital cycle during which particular sites cannot be observed. For instance, a "minimum-drift orbit" flying adjacent tracks on successive days, would have given the satellite eight or nine successive days of opportunity to observe an equatorial site, followed by at least 14 days without an opportunity at all; such a time gap was considered unacceptable. For testing the concept of frequent access, the maximum time gap between successive opportunities had to be no greater than say six days.
- Stereo coverage with $B/H \geq 0.5$ should preferably be obtained within 24 hours, in order to minimize reflectivity changes within the scene, and to improve the probability of success in cloud prone middle latitudes (the autocorrelation of cloud cover is high over one day, and almost nil over two days). As a consequence, the equatorial separation between day tracks flown on successive days had to be somewhere between 500 and 900 km.

Four orbits met the above set of criteria. They were close to either 14 + 1/4 or 14 + 1/5 revolutions per day. The final choice was made on the basis of less stringent criteria: number of opportunities for obtaining a good stereo pair in one cycle, possibility of obtaining stereopairs and a near-vertical view with a base to height ratio, $B/H \simeq 1$, at middle latitudes within 48 hours, etc. (Figure 4).

The choice of the equatorial crossing time was made to maximize the period of the year during

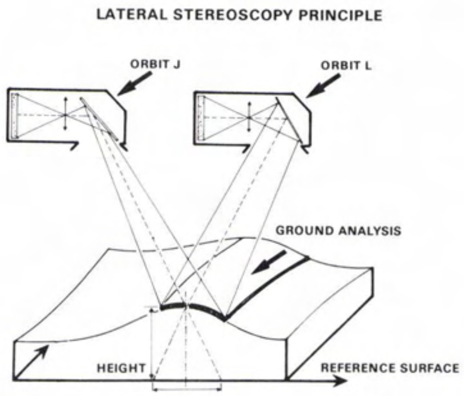

FIG. 4. Stereoscopy is obtained in a quasi-cylindrical geometry, rather than a conical one as in conventional stereoscopic vision. Previous experience with airborne radar imagery and Landsat indicates that stereo perception by the human eye remains adequate, and specific simulations (Cabrières *et al.*, 1979; Goetz *et al.*, 1979) have shown that, for $B/H \approx 1$, altimetric eye sensitivity is better than 1 pixel.

which the solar zenith angle is less than 60° at higher northern latitudes, in order to limit atmospheric scattering and maintain high radiometric resolution while limiting the extent of potential dazzling areas, where specular reflection of sunlight by water surfaces would hamper observation at low latitudes and particular seasons and viewing angles.

Significant parameters of the SPOT orbit are summarized in Table 3.

OPERATING MODES

The detailed commands for all satellite activities are compiled by the ground control segment according to users' requests and instructions by the mission control center and telemetered via the S-band platform control link to the onboard computer (OBC) for storage and subsequent execution. The full program is normally loaded on a 24-hour basis, as the satellite overflies ground control stations, taking into account the latest cloud cover information available, or the advent of urgent requests or situations. After executing the program, the OBC relays back to ground control, together with housekeeping data, reports of anomalous situations that might have occured outside the station visibility area.

Instructions issued to the satellite payload by the OBC include, as a function of satellite time, all particulars of operation for all payload subsystems.

Two major operating modes for the payload instruments are

(a) The twin mode in which both instruments operate jointly, six steps apart, with a 0.206° overlap. Their combined swath width is 117 km (nadir) to 150 km (extreme off-nadir situation). This mode is the prime mode for initial acquisition of systematic coverage, whether vertical or slant, over extended areas.

(b) The independently pointed mode in which the directions and resolutions of the HRVs are unrelated. It will be used upon request to acquire specific sample areas, and also to reduce time to completion of full coverage of cloud prone areas. Useful information cannot be retrieved from an instrument while its mirror is rotating, and two scenes will generally be lost during execution oı each pointing command; preference is thus given to acquisition of strips of several (say ten) scenes rather than single scenes.

TABLE 3. ORBITAL PARAMETERS OF SPOT

Revolutions/day	14 + 5/26
Nodal Period	101.46 min
Mean altitude (45° Northern Lat.)	832 km
Inclination	98.70°
Orbital (repeat) period	26 days
Number of tracks	369
Intertrack distance (equatorial)	108.4 km
Accessibility pattern at 45° latitude	1,4,1,4,1,4,1,4,1,4,1 days
Mean local solar time at descending node	$10^{H}30^{m}$

THE SUPPORTING GROUND SYSTEM

The ground system for SPOT performs three distinct functions (Figure 5).

THE MISSION CENTER

The mission center is responsible for mission management and, in particular, for scheduling image acquisition and processing in accordance with user requirements.

THE GROUND CONTROL SEGMENT

The ground control segment performs all satellite management functions, monitors satellite operation, generates commands, and establishes the orbital parameters.

It communicates with the SPOT platform in the S-band (2 GHz).

During the operational phase, the Toulouse station handles all ground command operations, the Kourou station in French Guiana acting as a backup station in the event of a failure or during maintenance. During the launch and acquisition phases, additional stations are used.

All command stations are linked to the control

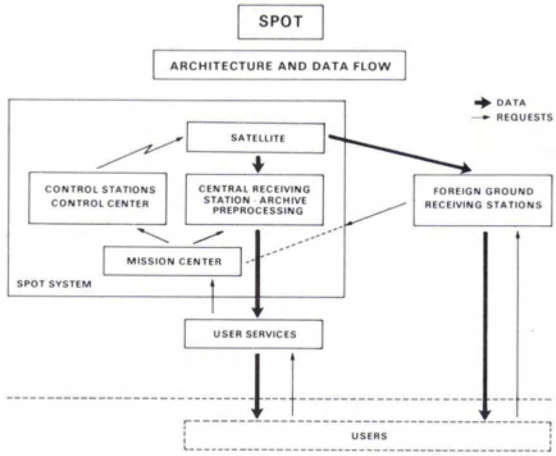

FIG. 5. The Mission Center plays a central role in ensuring acceptance and satisfaction of user requests, particularly when specific satellite programming is required. Requests will be channeled through the data distribution entities.

center by a communication network. The Toulouse control center processes incoming telemetry data, generates commands, and analyzes position and orbit data.

THE TOULOUSE IMAGE RECEIVING GROUND SEGMENT

The Toulouse image receiving ground segment receives the payload telemetry data, documents and stores the data, and preprocesses it into primary data products.

This segment comprises

(1) An image receiving station near Toulouse, which handles image data reception, decommutation, and recording of raw data.

The image receiving ground segment is compatible with both the SPOT satellite and Landsat D.

The station, equipped with a 9-m dish, acquires the image telemetry within a range of some 2600 km for SPOT. The continental day passes are normally exploited in the real-time mode, while the far Atlantic and night passes are used to dump the onboard recorders. An overall average of five passes of 11 min. each per 24 hours will result in the daily acquisition of some 740 scenes of 60 by 60 km.

(2) An image preprocessing facility which documents the raw data archive, produces quick-look imagery for all data received, and produces several types of preprocessed data products (Cabrières *et al.*, 1979). The types of products, to be described elsewhere, are supplied on standard support media and in formats compatible with those used for Landsat D, i.e., 241-mm film and CCT magnetic tapes.

Digital products come in CCT form, density 6250 bpi in a standard Band Interleaved format (BIL).

The French Space and Cartographic Agencies (Centre National d'Etudes Spatiales, Institut Géographique National) sponsor and operate jointly the preprocessing facility.

Downstream from the preprocessing facility, a specialized unit is being set up for the purpose of marketing and distributing on a commercial basis SPOT data received through French stations. Organizations which are already associated with CNES within the "Groupement pour le Développement de la Télédétection Aérospatiale" (GDTA)*, together with some industrial firms active in the field of remote sensing equipment, will be partners in the Unit, which will be known as "SPOT Image." The unit will

- inform users on data acquired, archived, and available from the French and foreign stations;
- distribute standard data products as produced in Toulouse by CRIS;
- produce and distribute custom-made data products and services derived from the standard products; and
- provide specialized services (education, data processing) related to the utilization of SPOT data.

SPOT Image is planning to set up a distribution network for data products, including a U.S.-based subsidiary.

OTHER STATIONS FOR DIRECT READ-OUT

The SPOT satellite is designed such that additional X-band stations can be hooked up for direct real time reception of image telemetry data. The onboard power system has been designed with sufficient capacity to operate the two HRV instruments and the direct telemetry link during up to 30 minutes of daylight per orbit. Technical constraints, such as maintainance of payload equipment temperatures and orbital periodic adjustment, are not expected to significantly limit the system capability. A suitable network of foreign stations might acquire in real time at least as many scenes as will be transmitted to the Toulouse master station (740 per day).

Although SPOT-specific hardware (receivers, bit synchronizers) and software are required at the ground stations, most of their hardware should be usable indiscriminately for the acquisition of space data from SPOT and other systems.

STATUS OF DEVELOPMENT

Milestones in the development of SPOT are, at the time of revising this paper, as follows: Industrial contracts had been signed in mid-1980 for the

* CNES's partners in the GDTA are the Bureau pour le Développement de la Production Agricole (BDPA), Bureau de Recherches Géologiques et Minières (BRGM), Institut Français du Pétrole (IFP), and Institut Géographique National (IGN).

optical sensors, the payload telemetry, onboard tape recorders, the multimission platform, and the image ground segment. Implementation phases for the complete satellite and the ground control and command segment have begun as a CNES in-house activity. A thermal and mechanical model of the instrument has undergone environmental testing (vibrations, acoustic noise, and thermal balance), and the optical performance in MTF and the alignment stability have been "checked" successfully to specifications before and after testing. The engineering model of the platform, due to be delivered, March 1982; payload engineering model delivered, May 1982; complete satellite engineering model assembled, September 1982; integration and testing of complete spacecraft protoflight model started, October 1983; and launch of SPOT 1, May 1984.

A back-up model (protoflight) is being built in parallel, and is likely to be launched to provide an extension of the service until 1988. Further extensions in time are under consideration, and the decision to move into an operational system will depend on the development of remote sensing applications in the next few years.

Concluding Remarks

While other future satellite systems for Earth resources are being considered in the U.S.A. (NASA, 1979; Colvocoresses, 1979) and are under development or consideration in other countries or Agencies (Japan, India, European Space Agency, Brazil, . . .), SPOT, flying concurrently with Landsat D and its follow-on, has been designed so as to be readily accessible to the world-wide user community. At the same time, while Landsat D will procure a wealth of improved spectral information, SPOT will provide higher resolution, with a capability for stereo coverage and frequent access to user-specified sites. We suggest that significant advantage can be derived from the simultaneous use of complementary capabilities of the two systems.

Low Earth orbit satellites possess a global capability, but costly investments are still required to provide the diversity and timeliness of information which are essential to most in-depth applications of remote sensing.

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