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The Spot Programme: Today and beyond 2000

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ABSTRACT

After SPOT 1 and SPOT 2, SPOT 3 is now on orbit, providing high quality images, as well or even better than expected. These performances, in terms of satellite and instrument capabilities, are described and the latest information on the use of these images is presented.
SPOT provides information as for example cartography, applications for agriculture, urban and country planning, forest inventories, construction and engineering,...
SPOT 4 is presently under construction, with an improved instrument (adding a medium infrared band to the three existing ones), and a new payload : VEGETATION to study the earth with the same spectral bands but on a wider swath width (>2000 km).
SPOT 5 A and B are studied in order to provide, between 2000 and 2010, the data and products needed by the users of geographical information.
The experience acquired with SPOT 1 and SPOT 2 has shown that the continuity of data is very important, especially for the development of operational methods by/for the users. Thus SPOT 5 A and B should provide the same types of products (in terms of swath width : 60 km, and spectral bands : green, red and infrared), with improved characteristics (especially for spatial resolution and stereoscopy).
The mission requirements of this future system, derived from technical and economical studies were undertaken by CNES and SPOT IMAGE in close connection with the users.

1. INTRODUCTION

The SPOT (*Satellite Pour l'Observation de la Terre*) earth observation satellite system was designed by the French Space Agency, CNES, and produced by France in cooperation with Belgium and Sweden. The Spot system comprises a series of satellites plus ground facilities for satellite control and programming and for image production. (cf. BAUDOIN 1992)
Products based on Spot satellite imagery are marketed and distributed by Spot Image, a CNES subsidiary.
The Spot programme is based on two key principles:

- continuity of customer services,
- steadily improving quality of Spot data and services in response to changing customer needs.

The system has been operational since Spot-1 was launched in 1986. Spot-1, -2, and -3 (all currently in orbit), will be followed by Spot-4, currently under construction, and later on by Spot-5. Spot-4 and -5 will ensure continuity of service until at least 2010, supplying users with imagery and products meeting their geographic information needs.
The experience acquired with Spot-1 and -2 demonstrated the importance of service continuity; without it, users cannot be expected to develop operational methods. On the other hand, future components of the system will meet new needs. Spot-4 will offer an additional spectral band in the mid-infrared (MIR)—also known as the short-wave infrared, or SWIR. Spot-5 will offer both higher resolution (5m) and a capability for acquiring fore-and-aft stereopairs during a single pass.
Technical and market studies undertaken by CNES and Spot Image in close cooperation with data users provided the main inputs in defining the mission specifications for Spot-4 and Spot-5.

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2. SYSTEM EXPLOITATION (SPOT 1-2-3)

2.1 Overview

The Spot system has been operational for over nine years thanks to Spot-1, launched on 22 February 1986, Spot-2, launched on 22 January 1990, and Spot-3 launched on 26 September 1993. Together, these three spacecraft have ensured continuity of service and met the satellite imagery needs of a vast, worldwide community of users.

2.1.1 Orbit

The mission specifications and the many associated constraints can only be met by placing the satellites in a suitable orbit. First, it should be **circular**, or have a **constant altitude** relative to the earth's surface. The mean orbital altitude is 832 km, the period 101.4 minutes. Next, to achieve reliable repeat access to all locations the orbit must be **quasi-polar**.
Spot satellites complete 14+5/26 (14.19) revolutions per day. Every 26 days they make a whole number of revolutions following one complete ground track cycle. The same pattern is then repeated over and over. When this condition is met, the orbit is said to be '**phased**'.
Because the valid comparison of images of a given location acquired on different dates depends on the similarity of the conditions of illumination, the orbital plane must form a constant angle with the Sun direction. This is achieved by ensuring that the satellite overflies any given point at the same local solar time. Thus, the orbit must be **sun-synchronous**.

2.1.2 The satellites.

With a launch mass of around 1,900 kg, each SPOT-1, 2 or 3 satellite includes two HRV (high-resolution visible) imaging instruments mounted side-by-side. The overall length of each HRV is 2.5 m for a mass of 250 kg. Onboard data storage is provided by two Odetics tape recorders with a capacity of 66 Gbits each, equivalent to 22 minutes' image acquisition time.
The prime characteristics of Spot imagery are high **geometric accuracy** and **radiometric quality**. In response to user needs, the main characteristics of the HRV imaging instruments were defined as follows: **high resolution** (10 to 20 m), geometric accuracy compatible with general mapping requirements at 1:50 000 scale and thematic mapping at 1:25 000 scale, and four spectral bands providing two operational modes:

- the **multispectral mode** (XS) comprises three wavelength bands and offers a resolution of 20 m. These bands are: green (0.50–0.59 µm), red (0.61–0.68 µm), and the near-infrared (0.79–0.89 µm), which are ideal for interpreting vegetation and other types of land use/landcover;
- the **panchromatic mode** (P) features a single spectral band from 0.51 to 0.73 µm with a resolution of 10 m. This is primarily for applications calling for fine geometric detail.

During vertical viewing, each HRV covers a 60-km-wide swath (or 'data strip'). In the "twin-vertical" viewing configuration, the two HRVs cover a combined swath of 117 km, including a 3-km overlap. Each HRV offers an **oblique viewing capability**, the viewing angle being adjustable through ± 27E relative to the vertical. This results in two major advantages: excellent **revisit capability**, plus the possibility of acquiring **stereopairs**. Oblique viewing greatly improves the flexibility with which repeat coverage of specific sites can be acquired. At latitude 45E (e.g. continental France), a region may be imaged once every 2.5 days.
Oblique viewing also makes it possible to acquire stereopairs at different viewing angles during separate passes. Stereoscopic imagery is useful wherever relief perception is important.

The stereo capability is further enhanced when two satellites are in service at once (e.g., Spot-2 and -3). Under these conditions, stereopairs can be acquired just 30 minutes apart.

2.2 Image acquisition and transmission.

Light scattered by the landscape is captured by the HRV imaging instrument, essentially a large telescope. The design uses focal-plane CCD (charge-coupled device) sensors in a "pushbroom" arrangement. The individual detectors of the CCD linear arrays are 13 µm square. They convert incoming light into electrical signals. Each detector receives light from a narrow strip of the landscape, the width of the strip (say, 10 m) corresponding to the detector field-of-view. The electronics ensures that each detector receives light from a narrow strip during the time (1.5 ms) it takes the satellite to move forward 10 m.
With 6000 panchromatic mode detectors each imaging a 10-m-wide portion of the landscape, the instrument instantaneously acquires a 60-km-wide 'data strip' perpendicular to the satellite ground track.
The quantities of data involved are enormous. In the panchromatic mode (10-m resolution), image data are acquired at the rate of 25 million bits/second. The image telemetry transmitter can down-link two panchromatic channels or two multispectral channels or one panchromatic and one multispectral channels from each HRV.

2.3 Data reception and processing

Image telemetry is received by two main receiving stations (known as Space Imagery Receiving Stations or SRIS) and a network of Spot direct receiving stations (SDRS). Each station is equipped with a tracking antenna, a demodulator and high-density digital tape recorders.
A receiving station can receive image telemetry whenever the satellite is within range, i.e. within a circle approximately 2500 km in radius. The telemetry data rate is 50 million bits/second. A SRIS station, such as that at Issus-Aussaguel near Toulouse, can receive up to 700 scenes, each covering 60 km x 60 km, per day.
The Space Imagery Rectification Centre, or CRIS, associated with the SRIS has two key functions. First, it systematically archives and catalogues all in-coming image data. Raw data are fed into the CRIS databank and relayed to Spot Image for transfer to DALI, a computerized, user-accessible catalogue of Spot imagery. Using the DALI system, users can remotely consult the catalogue and display images as digital quick-looks. The CRIS Centre's second function is image production to commercial quality standards.
There are two SRIS stations, one at Issus-Aussaguel, near Toulouse, in south-west France, the other at Kiruna in northern Sweden. Image data are also received by 14 SDRS stations in North and South America, Australia, the Middle East, Asia, and Europe.

2.4 Spot-1

Spot-1 has been in orbit for eight and a half years. During that time, image quality has remained constant. It is currently in the same orbit as Spot-2 and -3, on standby in a holding position. It can be activated for data acquisition and transmission to SDRS or SRIS stations on a few days' notice. To limit the cost of orbit control, CNES has developed an **"automatic storage mode"**. This involved important changes to the flight software. In this mode, each sunrise is used to re-initialize the automatic attitude and orbit control software. Even semi-major axis orbit adjustment manoeuvres are automatically programmed.
Without operator intervention, the satellite automatically transmits all essential status data (anomaly counts, maxima, minima, etc.) once per day to the Toulouse control centre. After operator analysis—a

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quick and simple operation—the data are added to the databank storing CNES's accumulated orbital experience.
Before Spot-3 was launched, Spot-1 resumed service on a number of occasions to increase the data acquisition capability of the overall system.
During the last three winter seasons, CNES ran various technology programmes to improve its knowledge of the behaviour of certain systems and subsystems under extreme conditions and to assess safety margins.
Around Christmas 1992, Spot-1's safehold mode was tested and all related functions and performance data validated.
Although initially built for a trial mission and a design lifetime of two years, eight and a half years in orbit have demonstrated the quality of both design and construction. Even now, Spot-1 remains an important source of information for the future. At the same time, it remains available to resume commercial service should the need arise.

2.5 Spot-2

Launched in January 1990, Spot-2 continues operational service, acquiring and transmitting image data to SDRS or SRIS stations. Spot-2's onboard tape recorders are no longer used. Although they remain in good mechanical order, the bit error rate is too high for operational use. Aside from the recorders and the failure of one of the image telemetry channels, Spot-2 is in good order. All image telemetry is transmitted using the backup channel.
The Spot-2 bus is in perfect order. All margins remain healthy and all nominal items are operational.
An experiment using Spot-1 and -2 involved moving the satellites to orbital positions allowing stereopairs to be acquired over certain portions of the earth just 30 minutes apart.

2.6 Spot-3

As mentioned above, Spot-3 was launched on 26 September 1993. This satellite features important design changes to extend the useful life of the onboard tape recorders. Today, after a full 12 months of operational service, both recorders are working perfectly. No errors have been detected when measuring bit error rates. This suggests that significant progress has been achieved.
Before the satellite could be declared operational, it had to be launched and placed in the required orbit. A complex series of mission analysis studies determined the optimal target orbit. The aims included: (i) to achieve three-satellite phasing in minimum time, and (ii) to give receiving stations optimal access to Spot-2 and -3.
Spot-3 is the prime system satellite. This means that its onboard recorders are exploited to the full. Certain SDRS stations have access to Spot-2, others to both Spot-2 and -3. Spot-3's image quality parameters are almost identical to those of its predecessors. Efforts are, however, in progress to improve the stability of certain parameters. These efforts are expected to show positive results in the near future.
Spot-3 differs from its predecessors in that it includes the POAM II passenger payload, a package developed by the U.S. Naval Research Laboratory to measure ozone and aerosol concentrations over the poles. Although it tooks some time to meet all requirements, the flexibility of the Spot onboard computer enabled the operators to improve the package's operation. Poam II data are now received daily by US stations. From all reports, the results are very encouraging, contributing to an improved understanding of the phenomena involved.
The quality of the Spot orbit control system and the excellent stability of the Spot bus are vital since POAM II measures the atmospheric extinction of the solar disc as seen through the upper polar atmosphere, at sunrise and sunset, 14 times a day.

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The Spot Control Centre monitors and controls the orbit of three Spot satellites while maintaining phasing and sun-synchronization, two essential conditions for successful acquisition programming.
The Spot system has evolved considerable since the single-satellite Spot-1 configuration. The current configuration offers both higher capacity for data acquisition and higher reliability.
All basic mission requirements are met by Spot-3. At the same time, Spot-2 offers additional capacity during periods of peak demand (spring in the northern hemisphere), improved programming flexibility, and the capability to acquire stereopairs in near real time. If required, Spot-1 can take over from Spot-2, providing exactly the same service. Should the need arise, Spot-1 could even take over from Spot-3, though in this case there would be additional demands on the SDRS network until Spot-4 could be deployed.
CNES and subsidiary Spot Image have thus made considerable progress in ensuring continuity of service and customer satisfaction.
Meanwhile, the Spot archives continue to grow, enabling thematic analysts to undertake ever richer multidate studies.
The Spot orbit can, however, only accommodate a limited number of satellites. CNES is therefore examining the most "ecological" way of disposing of the first satellite to prove unable to continue its mission. There are numerous possibilities, particularly as the satellite with the smallest propellant reserves still has 100 kg in its tanks.

3. DEVELOPMENT PROGRAMMES

3.1 Spot-4

The Spot-4 programme received French government approval in July 1989. The spacecraft is currently under construction. To minimize the risk of interrupting the data acquisition capability (i.e., in the event of the failure of one of its predecessors), will be ready for launch by mid-1995. If Spot-3 continues to operate normally, Spot-4 will be launched towards the end of 1997 (see Figure 1).
Spot-4 is an improved version of the first-generation spacecraft (Spot-1 through -3). Improvements include a new spectral band in the mid-infrared (1.58–1.75 µm) and the onboard registration of all spectral bands. This has been achieved by replacing the panchromatic band (0.51–0.73 µm) by band B2 (0.61–0.68 µm) operating in both a 10-m and a 20-m mode. In addition, the recording capacity of the onboard recorders has been increased from 22 to 40 minutes each, and the design lifetime extended from two years to five (cf. ARNAUD 1991).
As with the first-generation spacecraft, France is developping the Spot-4 satellite in cooperation with Sweden and Belgium.

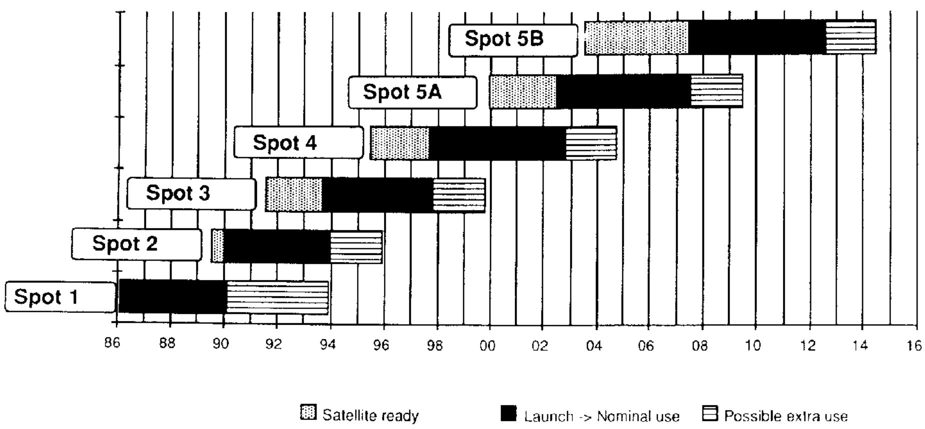

Figure 1: The SPOT continuity: Spot-1 to Spot-5.

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New MIR band. The decision to add a new spectral band in the mid-infrared (1.58–1.75 µm)—also known as the short-wave infrared, or SWIR—was taken following a comparative analysis of various improvements that became technically feasible around 1985. Although a thermal IR band would have been useful, this could not be achieved with a resolution close to 10 metres, as required to ensure consistent registration with visible image data. An additional visible band in the blue portion of the spectrum (0.5–0.6 µm) was envisaged then rejected because it appealed less than a mid-IR band from the image interpretation viewpoint.

The mid-IR is seen as vital for the improved interpretation of vegetation and to determine the water content of plants and crops. Mid-IR data are thus relevant to a wide range of economically important applications (agriculture, land use/landcover, environment, etc.).

The blue band, particularly useful for coastal and marine studies because of its good penetration in clear water, was felt to be a lower priority for other applications where the band generally provides exactly the same information as band B1 (green). In fact, the quality of the blue band is often less than that of the green due to higher levels of atmospheric scattering.

Onboard registration of 10-m imagery. The decision to replace the panchromatic band (0.51–0.73 µm) by the narrower band B2 (0.61–0.68 µm) operating in both a 10-m and a 20-m mode was taken in response a need expressed by a large number of users wanting to use 20-m multispectral data and 10-m panchromatic data simultaneously. This demands excellent registration, even in areas with rugged terrain. This is difficult to achieve with current Spot imagery because of a slight angular offset (about 1E) between the multispectral and panchromatic viewing planes.

The break in the continuity of Spot panchromatic products between Spot-1/-3 and Spot-4 (which will no longer be 'panchromatic', but 'narrow-band') can be overcome, where necessary, by simulating a panchromatic band (10 m; 0.51–0.73 µm) using band B1 (20 m; 0.50–0.59 µm) and B2 (10 m; 0.61–0.68 µm).

Passenger payloads. In addition to the main Spot payload comprising two HRVIR (High Resolution Visible and IR) imaging instruments, Spot-4 will carry four passenger payloads:

- **Doris** (precision satellite-based orbit determination and radiopositioning system) onboard package identical to those carried by Spot-2 and -3, except that the Spot-4 package will include experimental software to determine the spacecraft's position in real time to within a few tens of metres.
- **Pastec**, a technology demonstration passenger, to study the orbital environment.
- **Pastel**, or Spot laser communications passenger, using satellite-to-satellite laser communications to transmit image telemetry to ground over a high-bit-rate laser link via the Artemis geostationary relay satellite scheduled to be launched in 1996.

The fourth passenger, the Vegetation instrument is described below.

Vegetation. This instrument complements the HRVIR instruments. While Vegetation uses the same spectral bands, its revisit capability is much better. Vegetation will image virtually the entire globe once every day. This very-wide-angle (2000-km swath) instrument offers a spatial resolution of around 1 km and very good radiometric resolution. The spatial resolution is nearly constant across the entire swath (which is not the case of the AVHRR instrument carried by NOAA spacecraft). In addition to the HRVIR bands (B2, B3 and mid-IR), Vegetation features a band know as B0 (0.43–0.47 µm) for oceanographic applications. The Vegetation instrument is being developed as a European project with the cooperation of the European Union (EU), and several European countries (Sweden, Belgium, Italy).

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3.2 Spot-5A and Spot-5B

3.2.1 Continuity of service and new features.

Following Spot-4, the Spot family will continue with two new satellites, Spot-5A and Spot-5B, for which CNES is designing a new imaging instrument the High Resolution Geometry, or HRG. Design work began in 1989. The instrument is being designed to offer a higher spatial resolution, of the order of 5 m, and along-track, or fore-and-aft, stereo. This is expected to prove considerably more operational than the cross-track stereo capability of the HRV and HRVIR instruments (cf. FRATTER 1991). See figure 2.
Once the HRG design concept was clear, CNES began investigating instrument configurations featuring two to four HRGs. At the same time, mission studies were undertaken with users to help define their needs and the general characteristics of a system capable of meeting them. A working group known as "HRO", for "high-resolution optical", was set up. This brought together 20 or so French organizations seen as potential Spot-5 data users. The HRO group helped CNES and its partners to define user needs and hence technical requirements. One important aspect of this work involved the analysis of simulated Spot-5 imagery derived from either aerial photographs or image data returned by an airborne pushbroom scanner. In both cases the imagery was processed to resemble Spot-5 imagery as closely as possible.
In 1994, the design team proposed an instrument configuration based on these mission studies and the system definition study. The programme has been submitted for the approval of the French government and is expected to receive the go-ahead before the end of the year. As with previous Spot satellites, the Spot-5 programme will be undertaken in cooperation with Sweden and Belgium.
The Spot-5 programme is expected to include two satellites. Spot-5A should be ready for early launch by the end of 1999 with a nominal launch date some time in 2002. Spot-5B (assumed to be identical to Spot-5A) should be ready for early launch in 2003 with a nominal launch date some time in 2007. If all goes to plan, continuity of service should thus be ensured between 2000 and 2007.

		SPOT 1-2-3	SPOT 4	SPOT 5A - 5B
Instruments		2 HRV	2 HRVIR	3 HRG
Spectral Bands (µm) & Pixel Size	B1:0.5-0.59	20 m	20 m	10 m
	B2:0.61-0.68	20 m	10 m	10 m
	B3:0.79-0.89	20 m	20 m	10 m
	MIR:1.52-1.75		20 m	20 m
	Pan: 0.51-0.73	10 m		5 m
Swath width		2 x 60 km	2 x 60 km	3 x 60 km
Stereoscopy		Off track	Off track	Along track
Off track viewing		from - 27° to 27°		

Figure 2: Successive improvements to the SPOT family.

3.2.2 Three HRGs – three acquisition modes.

Full account has been taken of user requirements within the limits of budgetary constraints and design deadlines. Every effort has also been made to reuse or adapt equipment already used with success on earlier Spot spacecraft. Following the comparative analysis of a number of design solutions, the decision was taken to proceed with a Spot-5 payload comprising three identical HRG instruments, one looking forward, one looking down, the third aft.(see Figure 3). Each instrument can be used independently (see Figure 4a) or in combination with the others. Like the HRVs and HRVIRs, the

viewing direction can be adjusted between + and – 27E in the cross-track direction. (In terms of terminology, "oblique viewing" will be referred to as "cross-track" viewing.)
To meet different users' needs, the instruments offer three acquisition modes. These modes are:

- **multispectral acquisition mode (X)**, similar to but better than current XS mode;
- **stereo mode (S)**, offering relief perception and measurement of elevations with much higher performance than currently available stereo imagery;
- **high-resolution mode (H)**, offering improved spatial resolution and continuity with the current P mode.

A preliminary list of products has been compiled for each mode. This will be modified and expanded in response to market needs. Certain specifications such as the data strip (swath) width are common to all products. This will remain at 60 km for vertical viewing. The cross-track capability will also remain unchanged at ± 27E.
Note that no one HRG is dedicated to any particular acquisition mode. All three HRGs can supply multispectral, stereo, and high-resolution products.

3.2.3 Spectral band continuity and improved spatial resolution.

The Spot-5 spectral bands will be the same as those for Spot-4: B1 (0.50–0.59 µm); B2 (0.61–0.68 µm); B3 (0.79–0.89 µm); and MIR (1.58–1.75 µm). The panchromatic band will, however, return to the values used for Spot-1/-3 (Pan: 0.51–0.73 µm). As requested by many users, this will ensure continuity of the spectral bands established since Spot-1 (cf. LOUAHALA 1993).
Spatial resolutions will, on the other hand, be improved within the limits of technical and legal feasibility.
The high-resolution mode will go from 10-m to 5-m resolution and from one spectral band to four (PAN at 5 m and B1+B2+B3 at 10 m).
The multispectral mode will go from 20-m to 10-m resolution with the same spectral bands (B1+B2+B3 at 10 m and MIR at 20 m).
The stereo mode (with stereopairs acquired within seconds of each other) will go from 10-m to 5-m resolution and from one spectral band to two (Pan at 5 m and B3 at 10 m).
These choices reconcile the desire to transmit the largest possible volume of useful data while remaining within a data rate limit of 150 Mbit/s using data compression techniques compatible with multi-resolution imagery.
The decision as to which channel should offer 5-m resolution was based on the results of a large number of experiments with both Spot data and simulated high-resolution data. There was a clear preference (55%) for high-resolution panchromatic data, particularly for the visual interpretation of fine

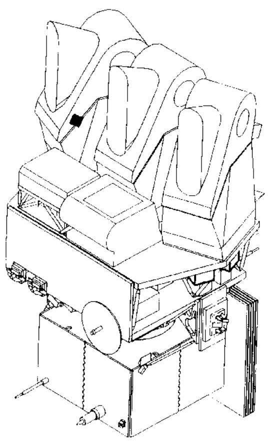
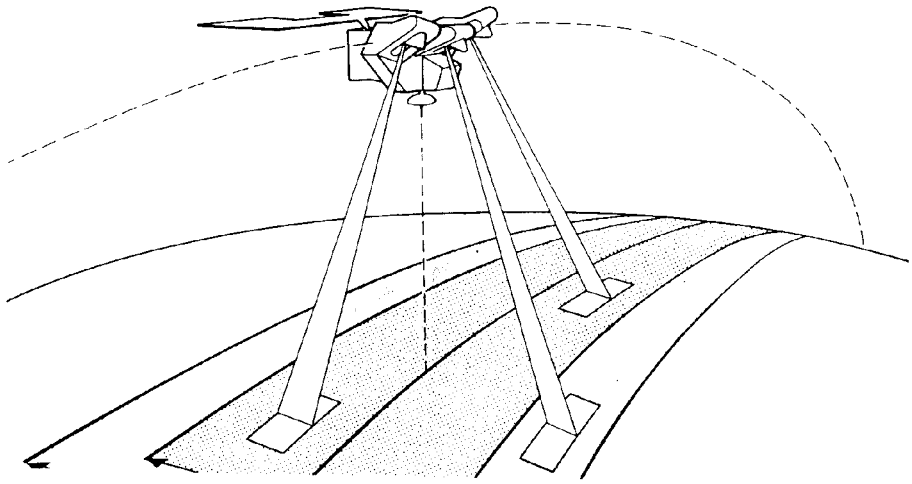


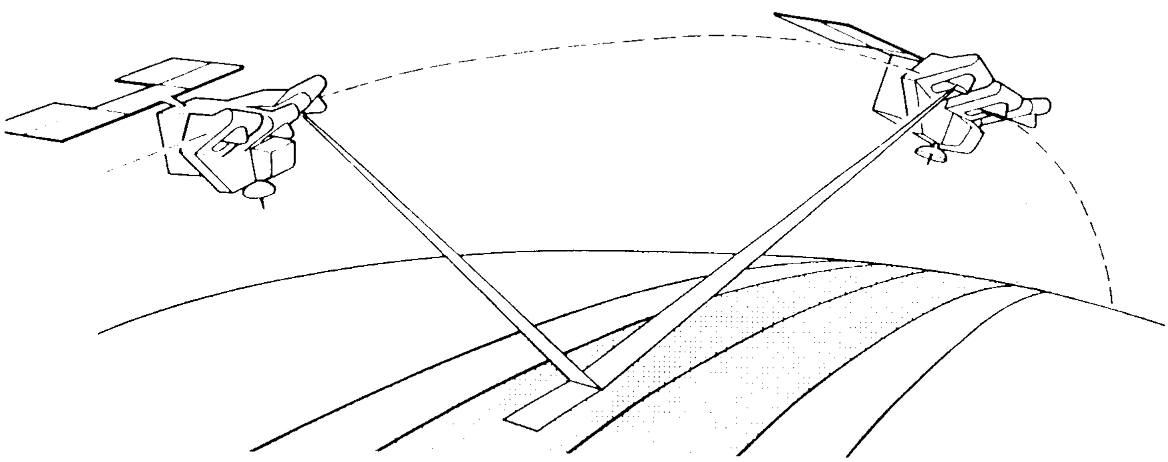
Figure 3: SPOT-3 platform and its three HRGs.

detail (cf. SEMPERE 1994) The second preference was the near infrared (45%) which would have been useful for areas affected by haze.

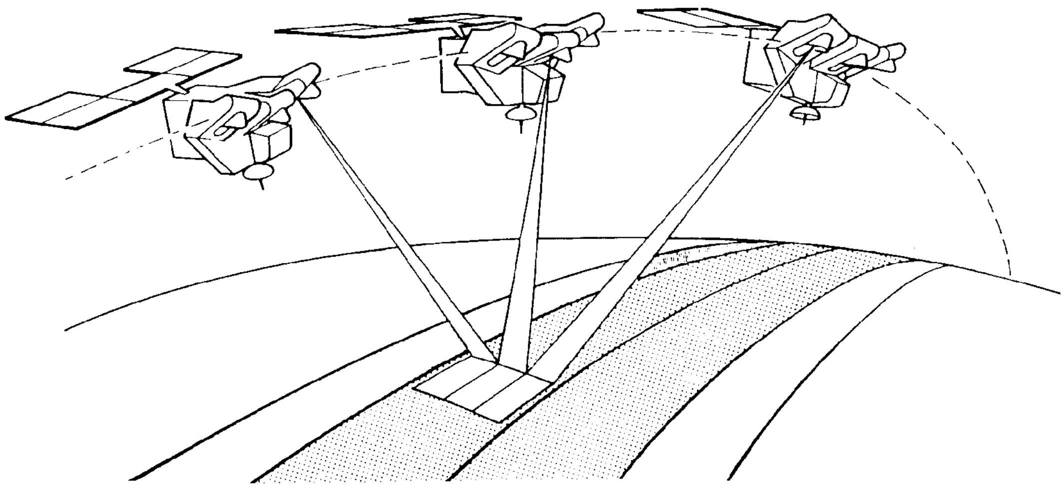
3.2.4 Three HRGs for stereo and vertical viewing



4a: Aquisition on three different types.



4b: Stereoscopic acquisition.



4c: Wide swath acqisition.

Figure 4: Acquisition modes with independant or combined HRGs.

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The aft HRG points 19.2E rearwards, the nadir HRG vertically down (0E), and the forward HRG 19.2E ahead of the satellite. The angles for this fore-and-aft configuration were chosen to produce stereopairs with a B/H ratio of 0.8 for the forward and aft pair of instruments and 0.4 for either the forward or aft instrument with the nadir HRG.(see Figure 4b)
The overall configuration is designed to meet the strong demand for stereo imagery (around one-third of the product demand generating about half the distributor's revenues) and the significant demand for vertical-viewing products (around one customer in four wants imagery with a viewing angle of less than 8E).

3.2.5 Maximum swath width: 240 km

Each HRG offers a cross-track swath width of 60 km for vertical viewing and up to 80 km for cross-track viewing. Using one, two or all three HRGs at once, it is possible to acquire multispectral (X) or high-resolution (H) data over large areas in a single pass. Two HRGs can cover from 120 to 160 km, three from 180 to 240 km.(see Figure 4c) Broad-swath imagery is seen as desirable by one user in three.

3.2.6 Radiometric and geometric quality

Customers using Spot data for mapping applications are the most demanding as regards image geometry. They should be happy with Spot-5 data. The specifications call for a planimetric accuracy of 10 m (rms) and an elevation accuracy of 5 m (rms). These figures are compatible with conventional mapping standarts at 1:50 000 scale.
Whether measured in terms of the MTF or noise, the radiometric quality of Spot-5 imagery will be equal to or better than that of Spot-4. Thematic interpretation specialists are assured of good visual interpretation and good control during digital processing.

4. APPLICATIONS

The market for Spot applications has expanded steadily since Spot-1 was launched in 1986. New applications have arisen, confirming the market's enormous potential.
Today's leading applications include topographic and thematic mapping, agriculture, forestry, geology, urban planning, the impact of major development projects, and the study of natural hazards.
Below we summarize the main trends in Spot data applications and the improvements Spot-5 will bring.

4.1 Mapping

Mapping and cartographic applications represent a significant slice of the market for Spot data. The spatial resolution and geometric quality of imagery returned by Spot is compatible with mapping to conventional accuracies at scales in wide demand for economic development planning at the national and regional levels (i.e., from 1:100 000 to 1:50 000). With Spot-5, there should be stronger demand still for mapping at 1:50 000. In certain cases, mapping at 1:25 000 will also become feasible.
Geospot® imagemaps—produced by rectifying and correcting Spot imagery to a given projection, then mosaicking and cutting to match local mapsheets—are already standard products. They register directly with local mapsheets and can be readily tailored to a wide variety of needs.

4.2 GIS

Satellite image data becomes much more usable and useful when combined with data from other sources in a geographic information system (GIS). After suitable processing, Spot data are a useful source of geographic information since they can be loaded directly into a GIS in digital form. Used in this way, Spot data provide exhaustive, up-to-date information on an entire area. In France, several regions (Midi-Pyrénées, Ile-de-France, Nord-Pas-de-Calais, Alsace) are currently setting up GIS systems to optimize the use of digital geographic information by local authorities responsible, at different levels, for planning and land use.

4.3 Environment

Environmental issues have become increasingly important in recent years. This trend is expected to continue and expand in the future.
The European Union uses high-resolution satellite imagery as basic input for compiling inventories of biophysical land use/landcover in all member states. This project comes under the Corine programme which aims to set up an EU-wide environmental database. The Corine Land Cover project produces land use/landcover maps at 1:100 000.
In France Spot data are used for national land use/landcover mapping.
The improvements that will come with Spot-5 should make satellite imagery more useful for local environmental monitoring, compiling inventories, conducting environmental impact studies, and assessing the damage caused by pollution.

4.4 Urban planning

Urban planning is another important area in which the demand for Spot data is growing. Over the last two years, the French Ministry for the Environment has undertaken a programme to study urban ecosystems within large conurbations using remote sensing to compile maps at 1:25 000. Satellite imagery has proved useful for gaining an overview of such ecosystems and for monitoring changes in time. The application of these techniques to a fast-growing metropolis like São Paulo, Brazil, proved particularly interesting, especially when it came to setting up a planning system.
On the question of planning, it is worth recalling the importance of relief and landforms and the accuracy with which these are portrayed by digital elevation models (DEMs) and stereo perception, two key Spot capabilities that will be greatly enhanced by Spot-5 thanks to fore-and-aft stereoviewing.

4.5 Agriculture

Agriculture is an area in which Spot data are now used on a large scale, particularly for major projects. High-resolution satellite imagery has demonstrated the feasibility of producing rapid estimates of crop acreages. This capability is now an integral component of the European Union's operational system for generating agricultural statistics as part of the Mars Project (Action IV).

4.6 Forestry

Several major programmes use satellite imagery to study **deforestation**. One example is the Seameo-France Forest Project for a number of countries in southeast Asia. Here, Spot imagery is used in conjunction with NOAA AVHRR images to study the fate of tropical forests and to help local authorities develop management strategies.
The addition of the MIR band to Spot-4 will improve the discrimination of vegetation cover and provide more information on plant health. The improved spatial resolution of Spot-5 should provide better information on forest stands and their boundaries.

'Photogrammetric Week '95', D. Fritsch & D. Hobbie, Eds., Wichmann Verlag, Heidelberg, 1995

4.7 Natural hazards

Natural hazards are yet another area in which Spot data is proving increasingly useful. Stereo and repeat imagery are useful for identifying areas exposed to earthflows (including land, rock and mudslides). Studies are in progress in Bolivia and Colombia to assess the potential of Spot digital data and derivative products for earthflow hazard mapping on the basis of geological, tectonic, morphological and other parameters.
Here too, the higher resolution and improved quality of Spot-5 stereo imagery will contributed to improved hazard assessment.

4.8 Market

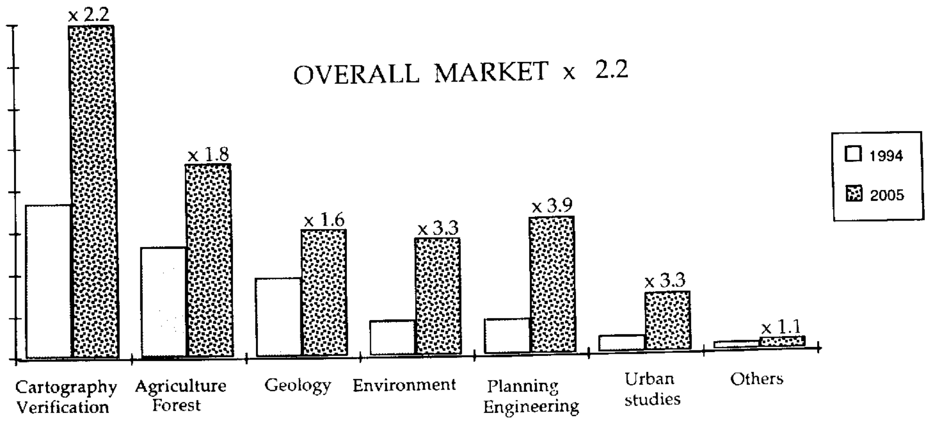

Figure 5: Market breakdown evolution from 1994 to 2005.

Figure 5 shows projected market trends for Spot data from 1994 to 2005. The figures are based on a market study that aimed to estimate the relative importance of major applications and the total demand. The study used data supplied by Spot Image and simple models to extrapolate current market trends on the basis of various assumptions concerning prices and competitors.

5. CONCLUSION

Today, after eight years of operation, more than three million scenes have been acquired. SPOT data are marketed on a non discriminatory basis by CNES subsidiary SPOT IMAGE.
As it is described, SPOT 4 and the new generation satellite SPOT 5 will offer a number of improvements for the study of Earth ressources and the local and regional environment.
SPOT data has become essential to a wide spectrum of users all over the world. These users can rely on the continuity and quality of SPOT images acquisitions which is essential to develop the operational use and to increase the market of earth observation from space.

6. REFERENCES

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