# BEYOND SPOT 5: PLÉIADES, PART OF THE FRENCH-ITALIAN PROGRAM ORFEO

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**ABSTRACT**

This paper presents how Pléiades HR, the next French Earth Observation system which will succeed to SPOT 5, complementing it without replacing it, has been defined and decided. It describes the characteristics and performances of the system which will serve civilian and Defence applications and should be a key element for GMES and GEO initiatives., at European and International levels.
From an user's analysis 10 new systems, based on small satellites, have been identified to fulfil most of the needs. After comparison, the highest priority was given to the development of high resolution systems, either with optical sensors or SAR instruments.
Within a cooperative program, ORFEO, settled between France and Italy, high resolution SAR data should be provided by COSMO-SkyMed developed under Italian responsibility whilst high resolution optical images will be acquired by Pléiades HR, developed under French responsibility..
With its two satellites, to be launched in 2008-2009, Pléiades HR will provide high quality images, not only in terms of resolution (0.7 meter at nadir) but also in terms of MTF (0.2 at system level) and geometrical accuracy: Even without using any Ground Control Point absolute location accuracy should be better than 10 m. Orthorectified images will be produced as standard products for easier integration in Geographical Information Systems (GIS). The high agility of the platform and sensor will optimize acquisition of images either in stereoscopic or monoscopic mode on areas of very diversified sizes and shapes.
A Preparatory Program has been undertaken with scientists, image processing specialists and end users in order to develop operational tools and methods for 2D or 3D applications of high resolution SAR and optical images.

**RÉSUMÉ**

Ce papier présente la genèse de Pléiades HR, le prochain système qui succédera, sans le remplacer, à SPOT 5. Il décrit les caractéristiques et les performances du système qui servira des applications civiles et de défense, constituera un outil adapté à l'initiative européenne GMES et qui pourra s'intégrer dans le GEOSS préconisé au niveau international par le GEO.
Une étude utilisateurs a permis d'identifier 10 composantes spatiales, des constellations de petits satellites, pour satisfaire la plupart de leur besoins. Après comparaison, la plus haute priorité à été donnée au développement des systèmes à haute résolution, aussi bien dans le domaine optique que dans celui du radar.
Dans le cadre du programme ORFEO fruit d'une coopération entre la France et l'Italie des données haute résolution radar seront fournies par COSMO-SkyMed, développé sous responsabilité italienne, alors que des données optique à haute résolution seront fournies par Pléiades HR développé sous responsabilité française.
Avec ses deux satellites, qui doivent être lancés en 2008 et 2009, Pléiades HR fournira des images de haute qualité, non seulement en termes de résolution (0,7 m au nadir) mais également en termes de FTM (0,2 au niveau système) et de précision géométrique : même sans utiliser de points d'appui la précision de localisation absolue doit être meilleure que 10 m. Les images orthorectifiées seront produites en tant que produits standard pour permettre une utilisation plus facile dans des Systèmes d'Information Géographique (SIG). La grande agilité de la plate-forme et du capteur permettra d'optimiser l'acquisition des images soit en mode stéréoscopique soit en mode monoscopique sur des zones de forme et de taille très variées.
Un Programme Préparatoire a été engagé avec des scientifiques, des spécialistes du traitement d'images et des utilisateurs finaux pour développer les outils et les méthodes nécessaires aux applications 2D et 3D de ces images haute résolution radar et optique.

## 1. INTRODUCTION

In spite of the technological and operational success of the SPOT program from the launch of Spot 1 in 1986 up to now with its three satellites in orbit (Spot 2, Spot 4 and the last one Spot 5) commercial benefits from the image market had been less than expected. This is due, on one hand, to more competition with new image providers, and on the other hand to a lower development than expected of new applications.

Even if for SPOT 5 some private investments were possible on the Ground Segment and on the HRS instrument, a fully market driven approach could not be pursued after SPOT 5 and new objectives and solutions had to be found.

Several programmatic scenarios had been envisaged, taking into account the new Earth Observation background from the mid nineties, with the development of high resolution systems such as Ikonos from Space Imaging or Quick Bird from Digital Globe, and also with the new Landsat policy.

From a technical point of view the feasibility of small satellites has been proven. Two new Earth Observation systems, called 3S (Spot System Successors) has been defined by CNES to provide both high resolution (about 80 cm with 3S1) and wide field (as for SPOT 5 with 3S2) with much smaller and cheaper satellites than the previous SPOT (Baudoin 1999)

New objectives were proposed in 1999:
- Looking to more innovation with smaller and cheaper satellites for developing constellations of mono-sensor satellites instead of larger multi-sensors satellite;

- Developing dual systems which could be used by Defenses as well by Civilian bodies;
- Finding new and important European partners;
- Developing the use of Earth Observation by scientists and institutional bodies.

This paper presents how Pléiades HR has been decided, describes its characteristics and performances and indicates which actions are undertaken for preparing the users to the best use of Pléiades data combined with other space, airborne and ground sources of information.

- Chapter 2 presents the mission analysis from which several systems have been proposed,
- Chapter 3 explains how Pléiades HR has been chosen among the previous candidates
- Chapter 4 details the Pléiades HR system and its performances.
- Chapter 5 presents, as a conclusion the ORFEO Preparatory Program and international initiatives which should help users to better benefit from Earth Observation.

## 2 MISSION ANALYSIS

### 2.1 User's needs assessment

In order to identify which space systems should be developed users were consulted, within a dedicated expert group and through several meetings with the different user communities. Results from other European studies, such as ERSIS, made by major European industries for ESA, were also taken into account.
For each of the main application domains information needs had been evaluated and possible sensors to get these information identified.

SAR and optical sensors are both required for most of the applications, the first one mainly for its all weather capacity, the second one for its better visual interpretation. It is also acknowledged that external data from ground or airborne surveys are in most cases needed to get reliable and accurate information from space imagery.

**2.1.1: Cartography:** For basic mapping, land use planning, urban surveys or telecommunication the use of space imagery is already mature and well known (Konecny, 1999), even if the complementarities and competition with aerial photographs are still evolving quickly.
Three types of data are requested: high-resolution (metric or sub metric) optical imagery, wide field imagery for medium scale mapping of large areas and radar acquisition when all weather capabilities are needed.

**2.1.2 Agriculture:** Precision farming, agricultural control and crop statistics are application with great potentialities for Earth observation if efficient methodologies could be used to extract useful and accurate end users' information. From current experiments this appears to be feasible but has still to be confirmed and operationally implemented.
Several types of data are needed but the key parameters are the number (6 to 20) and choice of spectral bands with a very good revisit time (to provide weekly information).

**2.1.3 Forest:** Space imagery (SPOT, ERS, Landsat, ..) is already used for forest inventories but new application areas could be envisaged for timber management or ecological surveys. Many Earth Observation data are needed, from very high optical photograph (relevant to airborne sensors) to multi/superspectral data, radar imagery (P or L band) and thermal data (especially for forest fires)

**2.4 Hydrology:** Water is considered to be one of the most important issues for the future. Its management, either to provide fresh water or to avoid catastrophic floods could be facilitated using Earth Observation data, such as metric optical or radar imagery and especially accurate Digital Elevation Models derived from stereoscopic or interferometric data. Most of the potential users (insurance companies, water providers, civil protection, ..) are not yet familiar with such remote sensing data and they should be involved as soon as possible in the development of the applications.

**2.1.5 Geological prospects:** Geology was one of the first application domains of Earth Observation and remains an important one, with a very diverse need of data, at several resolutions, with as many spectral bands as possible, and with always stereoscopic and/or interferometric demands.
It is noted that for mining surveys there is a special interest for hyper spectral data.

**2.1.6 Dynamic geology and associated risks**: As for hydrology the potential interest of Earth Observation for dynamic geology and associated risks (earthquakes, volcanoes, landslides, ..) is far to be fully exploited and GMES initiative could help to develop the use of space data, coupled with continuous ground surveys, for such applications. The needs for high resolution, either optical or radar (X band), and for fast services (within few hours or days) have been identified as well as complementary sensors (wide field, thermal, SuperSpectral and C or L SAR).

**2.1.7 Marine applications:** Even if Pléiades has not been designed to fulfill marine applications, some of these applications could be envisaged, either for oceans, sea ice or littoral surveys, especially with wide field imagery and C band data.

### 2.2 Sensor assessment

As a result of these mission analysis 10 sensors (or acquisition techniques) have been identified to fulfil most of the users' needs. The required parameters are described in Table 1.

| Component | Resolution (m) | Swath width (km) | Band number * | Revisit time (days) |
|---|---|---|---|---|
| WF: Wide Field | 2-5 | 40-100 | 3-4 | 3-7 |
| HR: Optical HR | ≤1 | 10-30 | 3-4 | 1-2 |
| SS: SuperSpectral | 3-10 | 100-300 | 6-20 | 1-2 |
| HS: Hyperspectral | 5-20 | 50-300 | 30-200 | 2-7 |
| TH: Thermal | 1-40 | 100 | TBD | <1 |
| C: SAR C | 2-4 | 50-300 | 1-2 | 1-5 |
| X: SAR X | 1-5 | 10-300 | 1-4 | <1 |
| L: SAR L | 2-10 | 50-100 | 1-4 | 1-7 |
| P: SAR P | 5-10 | 70-100 | 1-4 | 1-7 |
| IF: Interferometry | 1-5 | 70-100 | NA | NA |

* For SAR the number of bands is the number of polarisation channels

Table 1: Sensors requirements

The tenth acquisition technique has been added to fulfil the need of 3D information mainly requested for cartography, hydrology and risk management. Radar interferometry (IF) has been found the best technical way, from space, to provide such information with a metric accuracy, improving current altimetric information given by SPOT 5 with its HRS instrument. Such data could be provided by 3 micro satellites placed almost on the same orbit as a SAR satellite, according to the Interferometric Cartwheel concept created by D. Massonnet (Massonnet, 1999).

These 10 sensors have been compared in terms of user's interest, operational maturity, compliance with National and European space policy (innovation, industrial impact, sovereignty, ..) and cost. The user's interest is shown in table 2.

| **Application** | **Sensor needs for the application domain** |
|---|---|
| Mapping | HR, WF, X ,IF |
| Agriculture | SS, WF, C |
| Forests | SS, WF, L |
| Geology | HR, L, WF, C, IF |
| Marine | C, X |
| Risks | X, C, WF, TH, IF |

Table 2. Sensor needs for application domains

## 3 PLÉIADES HR DECISION

### 3.1 Several possible programmatic frameworks

Even if all these sensors have an interest for some users it could not be possible for CNES to develop them all together. Cooperation(s) and/or partnership(s) had to be identified to develop the most important Pléiades components (a component is a constellation of small satellites associated with a single sensor)

Three types of co-operative framework had been identified:

- multi-national cooperation under ESA responsibility, whenever possible, especially for developing new systems;
- PPP, public private partnership when the market could be sufficient to cover the recurrent costs.
- bilateral cooperation for components with a strong Defense interest;

Among all the possible components two of them have been considered with the highest priority: Optical High Resolution and SAR X for which a bilateral co-operative framework has been searched as those systems have a strong Defense interest. As it will explain in the next paragraph such cooperation has been found with Italy, to share the development of these two high resolution systems.

In spite its great interest the Wide Field component has not been considered with the highest priority, as SPOT-5 fulfill perfectly this mission for the time being (as ENVISAT is currently fulfilling the SAR C mission). Nevertheless the continuity of these missions should be guaranteed and follow-on systems have to be decided soon.

For the Interferometric Cartwheel which has a great technical interest several programmatic and cooperation frameworks are still possible and evaluated, but no decision is expected in the near future.

Due to its potential market interest, especially for precision farming, the superspectral system has been proposed through a Public Private Partnership (PPP) but up to now such solution could not be implemented.

Other systems considered as less operational in a near future time scale (L and P band SAR, thermal and hyper spectral imagery) are not envisaged to be developed by CNES.

### 3.2 An agreement found with Italy

Since beginning 1999 possible co-operations were envisaged and the most fruitful co-operation scheme was found with Italy, as its approach for its COSMO-SkyMed program was very similar to Pléiades, with a its dual oriented objectives and multi-sensors approach..

An intergovernmental Agreement was signed by France and Italy in January 2001. It is an Umbrella Memorandum of Understanding, which gives the overall objectives and implementation rules of the co-operation. Its main purpose is the development and exploitation of a Dual System, ORFEO, with two high resolution components, one with two optical satellites under the leadership of France, the other with four SAR-X satellites under the leadership of Italy. The extension of the co-operation to other countries can be envisaged, and France has already set up co-operation agreements with Belgium, Sweden, Spain and Austria.

### 3.3 Pléiades HR realization confirmed

The agreement with Italy has allowed CNES to concentrate its studies on the optical high resolution system whereas SAR data should be acquired from COSMO-SkyMed. Definition studies have confirmed the main technical choices and the possibility to develop and launch the two satellites within the foreseen cost envelop. Therefore the C/D phase was confirmed by the CNES Board mid 2003. Cooperation Agreements have been signed with some European partners: Sweden, Belgium, Spain and Austria. Now the two satellites are under construction with Astrium as prime contractor and Alcatel Space as a major sub-contractor.

The first satellite should be ready by mid 2008 and the second one by end 2009.

## 4 PLÉIADES HR CHARACTERISTICS AND PERFORMANCES

### 4.1 Main Mission Requirements

Pléiades HR is designed to fulfill civilian and Defense needs which implies confidentiality and security constraints from one side as well as easy and quick access through Internet from the other side. At system level optical data from Pléiades HR should be, as much as possible, easily combined with other types of data and especially SAR from COSMO-SkyMed.

Pléiades HR will provide Earth observations in black and white (panchromatic band) with a 0.7 m resolution at nadir, and in color (four spectral bands in the visible and near infra red range) with a 2.8 m resolution at nadir.

The image swath will be larger than 20 km.

The Pleiades HR satellites will orbit the Earth during at least 5 years on a quasi-circular, sun-synchronous orbit of 695 km altitude, with a 10h30 descending node local time.

Worldwide coverage and a daily accessibility to any point on the globe are requested, and fulfilled by the use of two satellites simultaneously in orbit with a 180° phase shift.

### 4.2 Satellite architecture

The main design drivers for the satellite architecture (Fig. 3) are the image quality, the agility and the image location accuracy. The image quality drives the instrument size. A high agility requires a very compact design, with a few stiff appendages. As a consequence, the instrument is integrated inside the bus. A high image location accuracy is achieved by minimizing the interface between the instrument and the bus. The star trackers and the gyroscope heads are directly supported by the instrument to avoid any thermal distortion that could be induced by the bus.

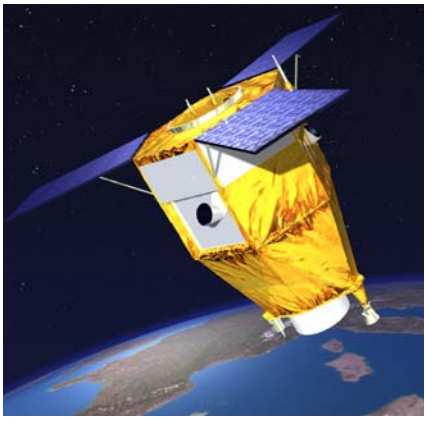

Figure 3 : Satellite In-Flight Configuration

The bus structure is build on an hexagonal shape, with three solar arrays at 120 deg, and three star trackers in a quasi tetrahedron configuration, optimizing the attitude determination accuracy. This configuration authorizes an easy accommodation of the instrument focal plane radiator for maximum heat dissipation (Fig. 4).

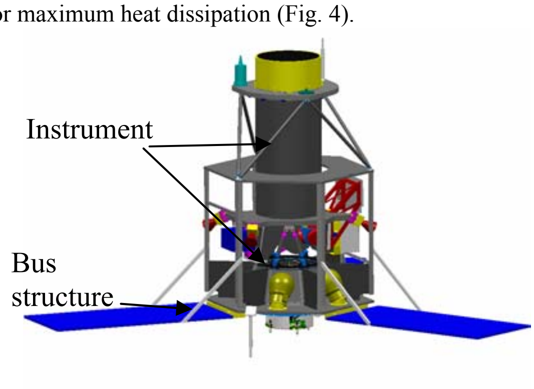


Figure 4 : Instrument accommodation inside the bus

An antenna support structure is used to carry the Earth-pointing antennas and for the instrument baffle.
The solar arrays are mounted directly on the bus structure without any drive mechanism to ensure a maximum stability. Their first flexion mode frequency is increased by the use of stiffeners when deployed.
Moreover the low mass (<1000kg) of this very compact satellite make it compatible with a large series of low cost small launchers (among them Rockot, Soyouz, PSLV,...).

### 4.3 Instrument

The optical solution chosen for the telescope is a Korsch type combination (Fig. 5). The imaging geometry optimization induces a primary mirror size of 650 mm diameter.

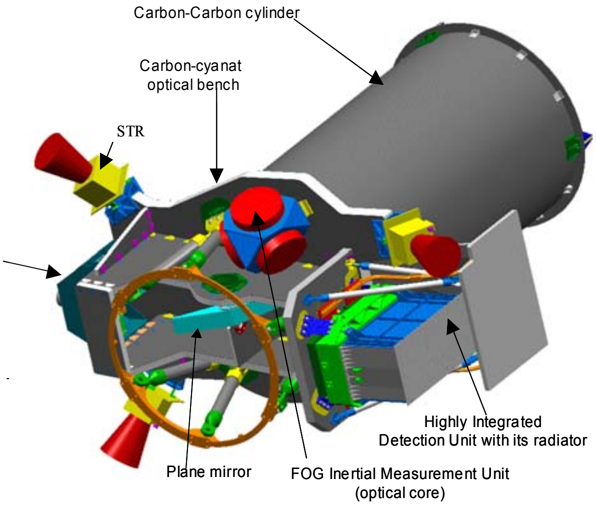


Figure 5: Instrument Configuration

The instrument includes a focus function based upon a specific finely regulated thermal control of secondary mirror structural support.

The instrument includes also an internal shutter to protect it from the sun radiation in non-operational phases such as launch, attitude acquisition, or safe modes. This solution avoids an external shutter that is generally heavy and complex.

TDI (Time Delay Integration) detectors are used for panchromatic detection, with a maximum of 50 integration lines. They can be used thanks to an optimized guidance strategy of the satellite line of sight including micro-vibrations levels minimization, specific geometrical accommodation of detector lines in the focal plane to minimize optical distortion effects. Five detectors of 6000 pixels each are used; each pixel having a size of 13 µm. A lateral anti-blooming structure located in the imaging area of the detector array prevents from light spreading along the columns.

The multi-spectral detection is realized with 5 detectors, each containing 1500 pixels (13 µm size). Each detector set consists in a four lines assembly, enabling four colors imaging (blue, green, red, near infrared). Interferometric filters directly stickled down on the detector glass window provide spectral separation of these four channels.

The focal plane is constituted by two symmetrical arrangements of those detectors. To acquire images over a field of view of 20 km, each line of sight is composed by 5 consecutive linear arrays; generating images of 30000 columns in the Panchromatic channel and 7500 columns in the multispectral channel. Among 5 linear arrays of each retina, 2 operate by reflection and 3 by transmission across a beam splitter mirror device (Divoli) which allows all the points in the field of view to be acquired almost simultaneously (Fig. 6). This great proximity in time makes the reconstruction of the continuous image line insensitive to the parallax effects introduced by the relief, and by temporal attitude variations between the 2 acquisitions of the same point on the ground (by 2 adjacent linear arrays).

Thanks to a separation mirror, the XS and PAN viewing planes are separated only by 1.5 mrad in the field, which makes PAN and Multispectral channels registration possible by a rather simple ground processing (re-sampling).

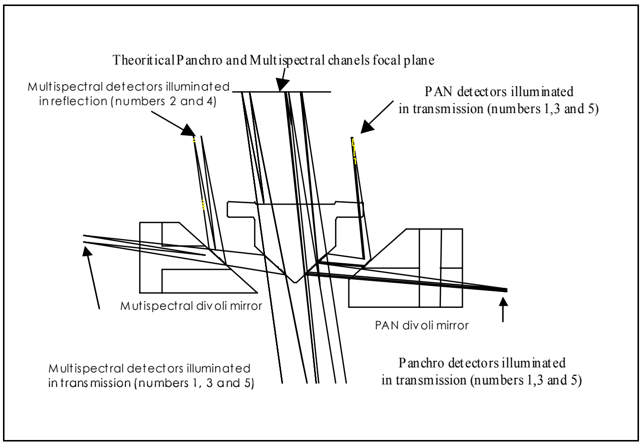


Figure 6 : PAN and Multispectral bands linking and separation principle

**4.4 Payload Data Handling and Transmission**

The video data are output from the instrument at 4.5 Gbits/s total output rate, are compressed in the Payload Data Compression Unit. A wavelets transform algorithm is used, that enables the compression ratio to go up to 7, while in standard operation the ratio is 5.

The compressed data are then memorized in the Solid State Mass Memory (SSMM). This memory has a storage capacity of 600 Gbits. The maximum image data input rate is 1.5 Gbits/s. The output rate is nominally of 465 Mbits/s, on three individual channels of 155 Mbits/s each.

The data are then coded following a trellis-coded scheme in 8-PSK type modulators coupled to Traveling Waves Tube power Amplifiers (TWTA). They are multiplexed and down-linked with an omni-directional 64° aperture horn antenna.

These high storage capacity and high transmission rate allow high reactivity of the Pléiades system with few ground image receiving stations. Coupled with high agility, a great amount of user's requests can be satisfied within one day due to 24 hours reprogramming capabilities offered by centralized data collection.

**4.5 Attitude and Orbit Determination**

In order to reach very high level of ground location accuracy, i.e. 10 m for 90 % probability ground circular error without ground control points (GCP), new very high precision technological developments have been taken into account for Pléiades HR satellite attitude restitution.

The autonomous orbit determination is performed by a Doris receiver, which allows reaching an accuracy of about 1m (on the three axes).

The attitude determination is performed by a gyro-stellar system. Very accurate solid state gyroscopes are used to ensure high accuracy attitude determination while maneuvering. Fiber Optic Gyros (FOG) allow high performances, such as a scale factor stability of a few ppm, a random drift of 0.002 deg/h, and an angular random walk of 0.0002 deg/root-hour. Both star trackers and inertial measurement unit have separated optical heads and electronic units. The optical heads are placed onto the instrument structure to minimize the thermal distortion with respect to the instrument line of sight

**4.6 Ground Image Processing**

Radiometric quality of the images results from the combination of the instrument performances with optimized image processing which can remove many defects (noise, blurring, ..)
Ground image quality enhancement relies on restoration process. Due to the medium performances of the instrument, raw images down-linked from board are relatively "blurred" at Nyquist sampling frequency (fe/2), that is for 0.7 m resolution (ground sampling frequency at nadir). The simulated pictures (Fig 7) show how image restoration can improve the raw image quality:
To make it sharper, restoration process raises the high frequencies in the image. In the Fourier domain, this corresponds to multiplying the image spectrum by the inverse of the MTF, to aim for a frequency response of 1 over the interval [-fe/2, fe/2]. In fact, a more sophisticated

Pléiades raw image (D=0.65m) | Pleiades restored image (D=0.65m) | Raw image for D=1.30m

Fig 7 : Panchromatic image restoration

deconvolution filter has to be applied in order to avoid artifacts due to divergence near fe/2 frequency.
Restoration of image contrast is performed by linear filtering, to which a noise correction process is added to limit initial image noise from being amplified by deconvolution. This de-noising process relies upon a wavelet transform operation of the image, on which threshold techniques are applied.
The resulting panchromatic Modulation Transfer Function (MTF) at system level is 0.2 at Nyquist frequency (while the value was 0.09 at instrument level), and much higher for lower frequencies, with a signal to noise ratio kept to 90 (at nominal Earth radiance) by this restoration process.
It shows that The Pléiades Panchromatic image has an information content of higher quality than a non-restored image that would have been acquired by a much larger and therefore far more costly instrument.

### 4.7 Deliverable products

Pléiades HR should deliver ready-to-use products which could be easily integrated in GIS and/or transformed into thematic information while combined with other satellite, airborne or ground information. Standard products are not any more raw data but accurately corrected images, using internal calibration parameters, ephemeris and attitude measurements.

A "perfect sensor" image can be generated, removing all distortions excepted parallaxes due to the terrain altitude. Basic images will contain both panchromatic channel (at 0.7 m resolution at nadir) and multispectral ones (4 bands with 2.8 m resolution at nadir) already registered and merged. Among these standard products three examples can be given:

- Orthorectified products will be generated using a Digital Elevation Model (DTM). Each product will contain 5 spectral bands (panchromatic, B0,B1,B2 and B3) re-sampled on a same 0.7 m cartographic grid.
- Simultaneous stereo pairs or triplets will be provided, with different coverage sizes (up to 300km x 20km or 150km x 40km). From these stereo data DEM could be derived with a very high altimetric accuracy (about 2 m)
- Mosaics (up to 120km x 120km) using images acquired from the same orbit, thanks to the agility of the system.

With the panchromatic and multispectral bands images could be visualized either in black and white (Fig.8), in true color (Fig. 9) or in false color (Fig. 10)

Fig. 8 Panchromatic image

Fig. 9 True color image

Fig. 10 False color image

### 4.8 Acquisitions capabilities

**4.8.1 Imaging modes:** Each satellite should be able to deliver more than 250 images per day (a 450 image capacity could be achieved sometimes). In all modes, the system should be able to deliver as well false color images, and true color ones, using the four channels blue, green, red, and near-infrared.

Due to its high agility and high performance of the guidance algorithms, the satellite is capable to image targets along any ground direction within 47° of vertical viewing position, with very low maneuvers durations between two consecutive images.

This allows many types of acquisition modes :

- Multi-spot mode, (Fig. 11) where the satellite acquires many targets around the satellite ground track, even in fore and aft stereoscopic mode if required

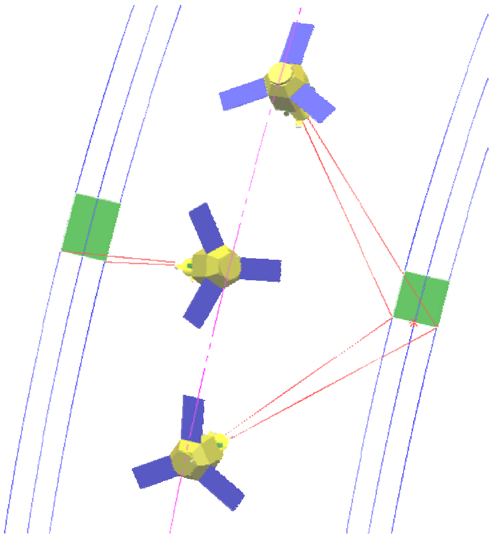

Fig .11 Multi-spot mode

- Covering or Mosaic mode, (Fig. 12) where swath enlargement is obtained by contiguous strips, even in East/West direction of acquisition

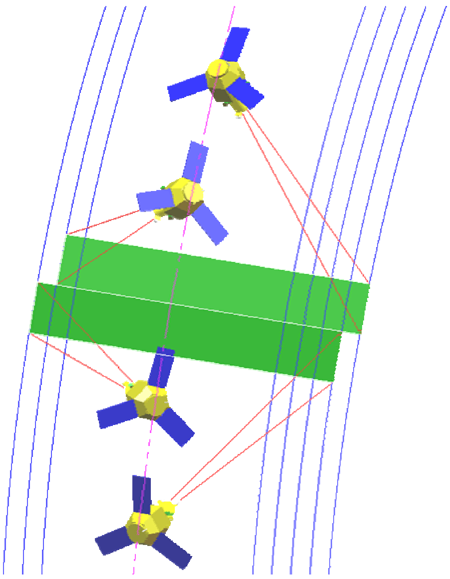

Fig 12 Mosaic mode

**4.8.2 Mission capabilities** have been studied at CNES using a mission simulator. The mission simulator processes the system programming loop and allows the measurement of mean acquisition capability for a world wide annual order book, and of instantaneous acquisition capability for standard daily programming requests.

A an example the following situation has been analysed, corresponding to a possible mission over Europe :

- 40 monoscopic targets of 15 km of diameter to be daily acquired, over an overall area of interest of 1000 x 1000 km²

In this case (Fig. 13), 24 targets over 40 have been acquired in one path with 20° inclination access authorized.
Only a few more (27) can be acquired if the authorized inclination access is extended to 30°, due to the extensive area of the theater.

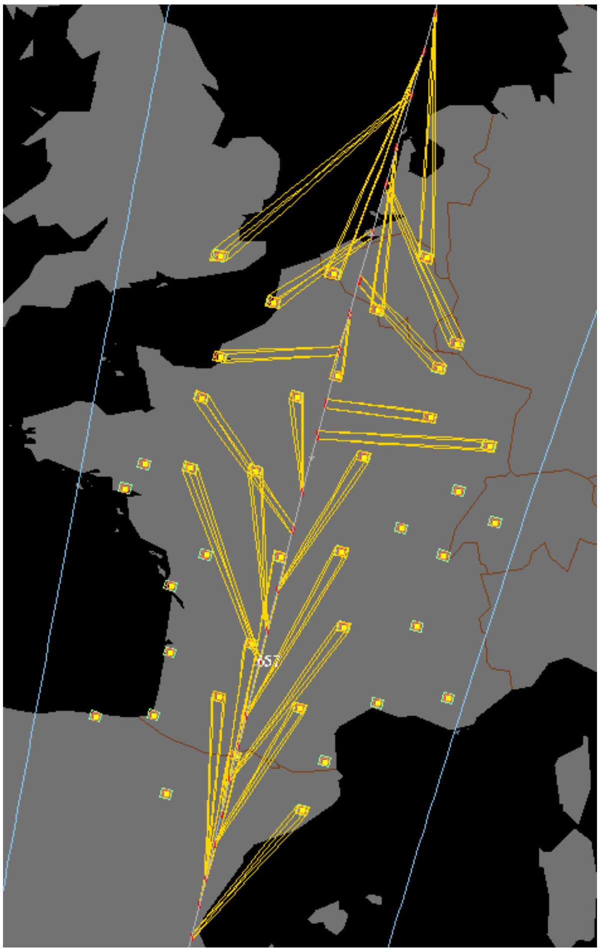

Figure 13: Instantaneous performances with 20° access

**4.8.3 Stereoscopic capabilities**

The high agility at low angles enables low B/H stereoscopic acquisitions with rather advantageous lengths.

Table 14 shows the maximum length of stereoscopic coverage acquired from the same orbit with different B/H, either for stereo pairs or for triplets.

Tri-stereo consists in acquiring an image triplet with the central image acquired in vertical sighting in the pitch (fore/aft) direction. This type of acquisition becomes increasingly important where urban information acquisition is concerned, as it is used both to restore terrain contours (using the stereo conditions) and to obtain exhaustive object images by avoiding hidden faces using vertical sighting. These image acquisitions are particularly useful given the very low available B/H as they are also used to improve correlation processing, and to limit disparity between stereo images.

| B/H | Stereo length | Tri -stereo length |
|---|---|---|
| 0.15 | **20 km** | **-** |
| 0.2 | **60 km** | **-** |
| 0.3 | **120 km** | **20 km** |
| 0.4 | **175 km** | **60 km** |
| 0.5 | **225 km** | **90 km** |
| 0.6 | **280 km** | **120 km** |
| 0.7 | **300 km** | **145 km** |
| 0.8 | **300 km** | **175 km** |
| 0.9 | **300 km** | **205 km** |
| 1 | **300 km** | **255 km** |

Table 14 : Maximum length of stereo coverage

### 4.8.4 Instantaneous mosaic coverage capabilities

High agility allows also swath enlargement by contiguous strips, even in East/West direction of acquisition. Mosaic images ranging from 60 x 200 km2 (3 strips) to 120 x 65 km2 (6 strips) with 20° access authorized, and from 60 x 340 km2 (3 strips) to 140 x 105 km2 (6 strips) with 30° access authorized, can be acquired.

### 4.8.5 Mean Acquisition capabilities over a year

Due to high agility coupled with high image storage and downlink capacities, Pléiades satellite coverage capability reaches around 30 000 $km^2$ per orbit (summer season) and an average area of more than 2 500 000 $km^2$ over a year. This annual capacity includes weather statistics, that is corresponds to cloud free images.

## 5 CONCLUSION

Pléiades is not the SPOT-5 follow-on program but more a new concept for Earth Observation, which is proposed, through a wider European cooperation, to satisfy the needs of all scientific, institutional (including Defense) and private users for satellite imagery.

The Optical High Resolution component of Pléiades, Pléiades HR, has been decided and is in its realization phase. With its two satellites it represents the French part of the ORFEO program which is completed by four SAR-X satellites provided by Italy within its COSMO-SkyMed program. The two systems will provide high-resolution (metric) imagery with a very short revisit time (24 h for optical, 12 h for SAR) to satisfy dual requirements, as defined in an intergovernmental agreement between the two Countries.

Beyond this current industrial realization there is still a need to develop new tools and/or new processes to optimize the use of these future data. This implies close links with the different user communities, value-added companies and all actors involved in Earth Observation.

In order to prepare users in France and Italy, then in Europe, to ORFEO utilization an ORFEO preparatory program has been settled in 2003. It should last from 2004 to 2008. Two complementary aspects are identified: methodology (tool development) and thematic applications (tool usage to get useful information from image data). Tools and processes are developed by scientists in close cooperation with image processing specialists for end users who should assess these tools and implement them within their routine processes.
Seven work axes have been defined, while differentiating 2D methods from 3D methods.

For 2D methods:
– Multi-scale, multi-resolution issues and coupling with exogenous data
– Very High Resolution SAR data
– Object models and statistical / dynamical image analysis
– Scene models and global/structural image analysis

For 3D methods:
– Urban studies from optical images
– Deformation characterization
– 3D models from SAR data

There is also a need to develop, with European and maybe not-European partners new systems providing SPOT-5 like data, whose demand is increasing either from the current SPOT users or from new ones.

The Global Monitoring for Environment and Security (GMES), at the European level, as the Group on Earth Observations (GEO) at the international level are encouraging initiatives which should help for a decision to implement the necessary space and ground infrastructures within the proposed Global Earth Observation System of Systems (GEOSS) which should be defined by the end of this year and decided next year for a 10 year period.

## REFERENCES


Baudoin A., 1999, The current and future SPOT program. ISPRS Workshop Hanover 1999

Baudoin A., 2001, « Pléiades: a Multi Mission and Multi Cooperative Program", 52 nd International Astronautical Congress/Toulouse, France, October 2001

Caltagirone F., 2000, COSMO-SkyMed Mission Overview Proceeding of NATO/SET Symposium on Space-Based Observation Techniques Samos – Greece 2000

Damilano P., 2001, "Pleiades High Resolution Satellite: a Solution for Military and Civilian Needs in Metric-Class Optical Observation", 15th Annual/USU Conference on Small Satellites, August 2001

Konecny G., 1999, Mapping from Space - ISPRS Workshop Hanover 1999

Kubik P., 2002, "Pleiades-HR image quality design", ACSM - ASPRS 2002 Annual conference proceedings

Massonnet D., 1999, Capabilities and Limitations of the Interferometric CartWheel, *CEOS SAR Workshop,* Oct. 1999, Toulouse, paper 136


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