CNES MAG

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SPACE ● INNOVATION ● SOCIETY

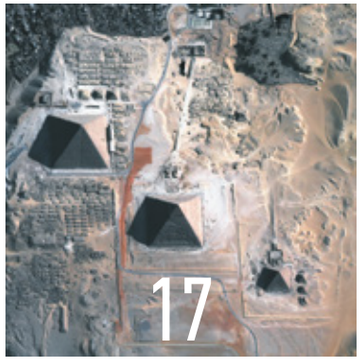
#67
February 2016

OBSERVATION

SATELLITE IMAGERY PLANETARY SOLUTIONS

cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

INSIDE



PARTNERS

Mentioned in this issue: p.7/10 CESBIO biosphere research centre; p.8/21 Spot Image became part of Airbus Defence & Space in 2008; p.9 SERTIT regional image processing and remote sensing department; p.10 LEGOS space geophysics and oceanography research laboratory; p.7/11 IGN, France's national mapping, survey and forestry agency; p.11 CLS (Collecte Localisation Satellites); p.23/31 DGA, the French defence procurement agency.

[+] View additional content on our website wherever you see this sign.

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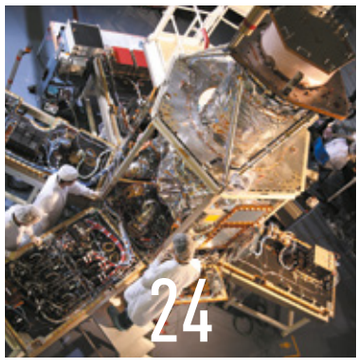

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UNITED STATES

While the United States has its own fleet of satellites, the Pleiades constellation was called on to track business activity in Chicago.

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EUROPE

Sweden and Belgium. From SPOT 1 onwards, the Swedish and Belgian governments and industries have been closely involved in civil Earth-observation satellite programmes.

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AFRICA

Nigeria. The African office of the World Health Organization (WHO) relies on Pleiades imagery to keep a check on vaccination campaigns in Nigeria.
Morocco. The CESBIO biosphere research centre is conducting a study on water resource management in the Tensift watershed near Marrakesh as part of the SPOT 4/Take 5 experiment.

P. 11

ASIA

Nepal. Pleiades is the system most often activated by the International Charter on Space and Major Disasters. It was called into action on 25 April 2015, when an earthquake hit Nepal.
Indonesia. Through its INDESO centre, the Indonesian government is seeking to promote sustainable shrimp-farming practices vital to the local economy.

CONTRIBUTORS

HÉLÈNE DE BOISSEZON

Heading up the 14-strong team at the Image Analysis and Products department based at CNES's Toulouse Space Centre, Hélène de Boissezon is in charge of image-processing activities for users. She helped to pick the case studies in this issue and put us in touch with the people behind them.

BOYD VINCENT

Boyd Vincent began his career as a translator more than 25 years ago. He first got interested in space in the 1990s and hasn't looked back since. As the 'English voice' of *Cnesmag*, this wordsmith likes to quote the English rhetorician I.A. Richards, who claimed that *"translating is probably the most complex type of event in the history of the cosmos".*

OLIVIER PASCAUD

Olivier Pascaud is our official portrait photographer and a contributor to *Cnesmag* from its early days. For him, photography provides a wonderful opportunity to meet inspirational people and enjoy life-enhancing experiences. For this issue, his camera captured the personality of Bertrand Labilloy.

FRÉDÉRIC QUIGNAUX

QuiSprod is a team of experienced journalists with a talent for staging and screening news and information. For this issue, they show us in a series of videos how satellite imagery has become such a vital tool in so many areas.

CNES MAG

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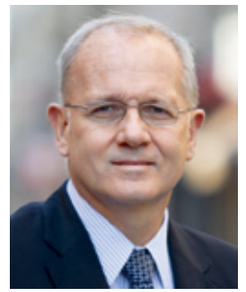
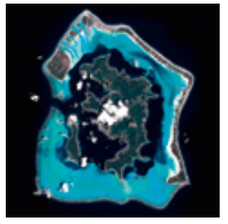
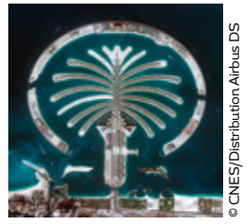
EDITORIAL



The Djebel Amour mountain range in the Saharan Atlas was brought to the world's attention when, a few days after the SPOT 1 satellite was lofted into orbit on the 16th flight of the Ariane launcher on 22 February 1986, we contemplated with awe the first picture of our planet from a civil Earth-observation satellite. It was the result of an ambitious and persevering space policy shaped and pursued by CNES that laid the foundations for a fully-fledged ecosystem in the Toulouse region of Southwest France whose success today reaches well beyond national borders, since our industry is exporting Earth-observation satellites—the distant descendants of SPOT 1—all over the world. From that defining moment, satellite imagery has become an integral part of our lives and not a day goes by without us being able to view the beauty of nature (Bora-Bora in the Pacific), its moods (the tsunami in Japan) or how humans are transforming it (Palm Island in Dubai), because only satellites can offer planetary solutions.
And it is to sustain these solutions for the future that CNES is drawing on a 30-year heritage of innovation to conceive through the THR-NG new-generation, very-high-resolution programme the children of SPOT 1—or indeed, the children of Djebel Amour...

JEAN-YVES LE GALL
CNES PRESIDENT





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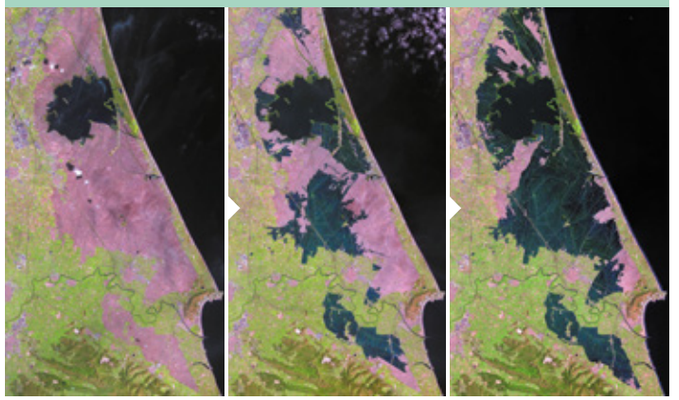
REFERENCE IMAGE

The globe in all its glory

Combining revisit frequency and precision, the Sentinel-2 satellite acquires detailed 7-metre-resolution imagery of the Pyrenees every five days, a fine example of the capability afforded by this new optical Earth-observation system developed by the European Space Agency (ESA) for the European Union. For the Copernicus programme, CNES is working with France's national mapping, survey and forestry agency IGN to produce a high-quality reference global image accessible via the Sentinel-2 workspace–a world first.



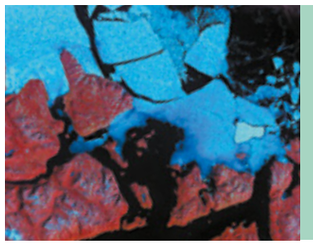
Irrigated rice crops (black zones) near Valencia, southern Spain.

TAKE 5

TIME-SERIES OF IMAGERY

Imaging points of interest with a satellite on a repeating ground track is an effective way of detecting land-surface change. The resulting time-series of high-resolution optical imagery find many applications in agriculture, land planning and monitoring of coastlines and continental waters. In 2013, at the suggestion of CNES and the CESBIO biosphere research centre, SPOT 4's orbit was lowered by three kilometres to acquire simulated time-series of some 50 sites imaged every five days and ready users for data from the Sentinel-2 mission, which has the same five-day revisit rate. Dubbed Take 5, this experiment received an enthusiastic response from users and with support from ESA was duplicated with SPOT 5, which imaged 150 selected sites from April to August 2015.

[+] VIDEO – **TAKE 5 REPORT FROM CNES IN TOULOUSE**
CNES.FR/CNESMAG67-TAKE5

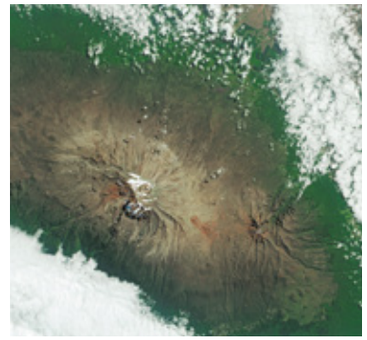


350

The data collected during the Take 5 experiment have already been downloaded by 350 users, chiefly research scientists.

FROM SPOT IMAGE TO ADS

A CUSTOM SERVICE



Mount Kilimanjaro, Tanzania.

After selling satellite imagery worldwide for more than 30 years, in 2008 Spot Image joined the Airbus Defence & Space (ADS) group. With the SPOT 6-7 and Pleiades satellites, it offers a unique portfolio and a highly flexible range of data products. For example, customers can task the satellites themselves 24/7 from the comfort of their own office via GeoStore, an online tool like no other on the market today, or contact a dedicated custom-service team. This proximity service is backed by a global network of 140 distributors in touch with local needs. For large orders or customers requiring strict confidentiality, ADS goes even further and offers direct data access through a receiving station. It currently has 40 customers using this solution.

DISASTERS

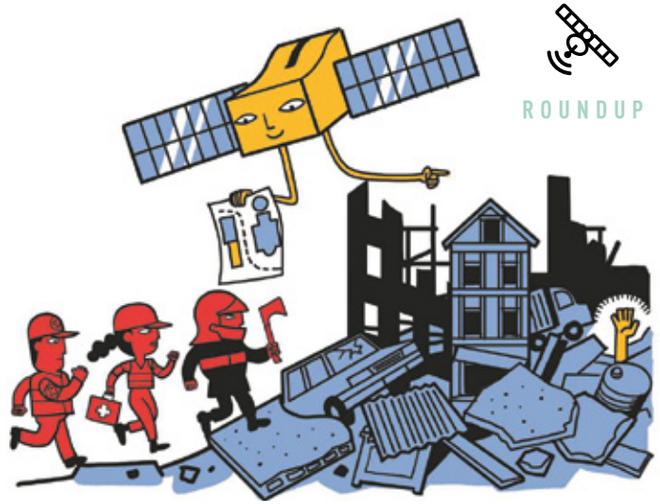
SATELLITE IMAGERY FOR FIRST RESPONDERS

In the wake of a natural or man-made disaster, it's often hard to gauge response requirements from the ground. The International Charter on Space and Major Disasters and its 15 signatory space agencies, among them CNES, supplies optical and radar satellite imagery of disaster zones. This imagery is processed as top priority and sent out to relief teams in the field to give them a clear and current picture of the situation. The charter sprang into action when Nepal was hit by an earthquake in April 2015 (see photo) to pinpoint the most heavily damaged buildings and identify impassable roads.
The charter today counts 56 users authorized to activate it, including several United Nations organizations and all requesting nations. CNES was one of the charter's founding agencies back in 2000. SPOT 6 and SPOT 7 have now joined the charter's fleet of satellites, while Pleiades' revisit capability and superior resolution make it the most frequently tasked optical system.

DEFENCE

PLEIADES ON THE FRONT LINE

In September 2015, Russia committed significant air assets to Latakia airbase in Syria to combat terrorist group Daesh. Military planners used Pleiades imagery in the month leading up to this deployment. The imagery also helped to estimate the number of helicopters, transport and fighter aircraft deployed by Russian forces and determine what would be needed to better protect and defend this strategic platform (radars, air defence systems, stronger perimeter fencing and passive protection, etc.). Some of these details can be seen in the image.



SERTIT

GETTING GEOGRAPHIC INFORMATION TO THOSE WHO NEED IT

In the event of a major disaster, emergency responders need clear "crisis maps" to save lives. This is the job of the emergency mapping team at the SERTIT regional image processing and remote sensing department, which processes satellite images acquired immediately after a disaster. These images are interpreted and information is extracted in just six hours by SERTIT's experts, who sift through the spectral details and turn them into maps useable by non-experts. Using Pleiades' capabilities to pinpoint damaged buildings and infrastructure, blocked roads and areas where populations have sought refuge, SERTIT helps teams on the ground to direct relief efforts to where they are most needed. On call round the clock, all year, the department also lends its support during reconstruction or to aid development, and for preservation of natural resources and land planning, transforming satellite imagery into geoinformation in the form of maps, geodatabases and 3D products, mostly for institutional customers.

30 MILLION

Images collected since 1986 by the SPOT satellites, a heritage that CNES and Airbus Defence & Space are set to make available to the international community through the Spot World Heritage programme, for which 200,000 images are already being prepared. The images will be downloadable free of charge for non-commercial uses via the Theia portal
+ WWW.THEIA-LAND.FR

240,000 SQ.KM

The area covered by each Pleiades satellite every day. That's a lot of coverage, but not enough to stay ahead within the 2020-2030 timeframe. THR-NG plans to extend daily coverage to 600,000 sq.km.

600

Images supplied on average by each Pleiades satellite every day, demonstrating the system's exceptional acquisition capacity.

HIGH RESOLUTION IN A NUTSHELL

SWATH

This is the width of the observed strip of terrain along the satellite's ground track. It is 20 kilometres for Pleiades in nadir viewing mode.

RESOLUTION

This indicates, in metres, the level of detail visible in an image: the lower the figure, and therefore the higher the resolution, the finer the detail.

SUPERMODE

A mode that produces a single image at a resolution of 2.5 metres from two panchromatic (black-and-white) images acquired simultaneously and offset horizontally by 5 metres and vertically by 2.5 metres.

CALIBRATION

A raw satellite image cannot be overlaid on a map. To be able to read it, the image has to be tied to and aligned with known reference points (landmarks).

GYROSCOPIC ACTUATOR

This is a momentum wheel mounted on a gimbal so that it can pivot, thus increasing the satellite's agility.

STEREO- AND TRI-STEREO VIEWING

Two or three images of the same area of interest acquired from different angles can be used to map and view its relief.

Crops in the Al Haouz plain, chiefly wheat (green) and scattered olive groves (dark green).

CESBIO

MANAGING WATER RESOURCES IN MOROCCO

The CESBIO biosphere research centre provides expertise in water resource management, observing croplands and helping to devise monitoring solutions geared towards establishing sustainable farming practices. It is currently conducting a baseline study on water resource management in the Tensift watershed near Marrakesh. Olive and orange groves and wheat fields abound in this region that is feeling the effects of global warming. Using time-series of high-resolution imagery throughout the growing cycle, research scientists are tracking crop growth at individual field level. Investigations conducted as part of the SPOT 4/Take 5 experiment led them to develop an original tool that encourages more rigorous irrigation management and more virtuous practices in arid regions. CESBIO is now applying the know-how acquired in Morocco to research in the Midi-Pyrenees region of Southwest France, Tunisia and Arizona.

ISIS

A SPACE LIBRARY FOR RESEARCH SCIENTISTS

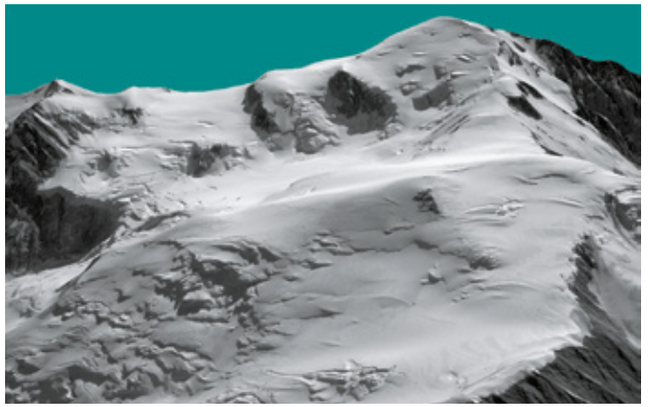
CNES is helping to advance science through the ISIS[1] programme that offers access to the millions of images acquired by the SPOT and Pleiades satellites. Since 1998, research scientists working in laboratories in the European Union have been able to request archive imagery or tasking of high-resolution optical satellites to image areas of interest, all at reduced cost.

+ HTTP://WWW.ISIS-CNES.FR

1. Incitation à l'utilisation Scientifique des Images Spot.

LEGOS

GLACIERS UNDER CLOSE WATCH



Glaciologists at the LEGOS space geophysics and oceanography research laboratory use satellite imagery to map glacier relief in close detail. Pleiades data are perfect for this task and for compiling time-series. In August 2012, digital elevation models of the Mont Blanc massif generated from Pleiades data and compared with satellite images acquired in 2003 by SPOT 5 revealed that its glaciers had thinned at a rate of 10 metres a year.

VIDEO – **FACE TO FACE WITH GLACIOLOGIST ÉTIENNE BERTHIER**
CNES.FR/CNESMAG67-GLACIERS

IGN

2015 MAP OF FRANCE

Construction of Lyon's new football stadium.

For the second year running, France's national mapping, survey and forestry agency IGN[1] has released satellite coverage of metropolitan France accessible via its Geoportail platform. Simply enter SPOT and the years 2014 and 2015 are displayed. The maps were generated from 1.5-metre-resolution images acquired by the SPOT 6 and SPOT 7 satellites between April and October. The satellites' agility enables rapid coverage to precisely track the most notable landscape changes. Geoportail is thus a mine of information for the public and professionals alike. The 80-strong team at IGN Espace continues to develop renowned expertise in tasking Earth-imaging satellites and processing their imagery, for the benefit of government ministries and industry. From its inception encouraged by CNES in 1989, this national competency centre contributed to the development of Spot Image.

+ HTTP://WWW.GEOPORTAIL.GOUV.FR/ACTUALITE/305/LA-FRANCE-DE-2015-EN-INSTANTANE

CLS

MAKING SHRIMP FARMING MORE SUSTAINABLE

Nearly three-quarters of shrimps and prawns consumed around the world come from Asia, especially Indonesia. Poor management of organic waste in the ponds where they are farmed can have a devastating effect on coastlines, as pollution finds its way into lagoons and can render neighbouring farms sterile. Through its INDESO[1] centre, the Indonesian government is seeking to promote optimized, sustainable farming practices in this sector vital to the local economy. CNES subsidiary Collecte Localisation Satellites (CLS) has been delivering satellite data and ocean models to this turnkey centre for several months now. Research scientists can thus use optical imagery to devise methods for surveying farms, ponds and shrimp densities. The centre is currently working to define indicators for types of farming (traditional, intensive, etc.) in order to monitor, check and optimize production.

1. INfrastructure DEvelopment of Space Oceanography.

#COMMUNITY

Every day, CNES engages with you on social networks and you share your thoughts and questions with us. Below is a selection of messages that caught our attention. Join the conversation!

@ MARINA TYMEN

Consultante & formatrice #reputation #RPcrise #socialmedia | spécialiste #MSGU @VISOV1 | #Avgeek @AvgeeksFR | chargée de cours fac | ex-#comcrise #CM @AirFrance

30 Earth-observation satellites launched by @CNES. We can now see features from space as small as 50 cm, 30 cm with some satellites! #CNEStweetup

@ VINCENT SARAGO

Earth Observation specialist @Effigis and Owner & GeoSpatial dev @RemotePixel - Web Mapping, Remote Sensing, Cloud Computing, GIS

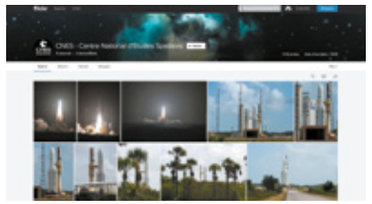
Easily access #Sentinel data with #PEPS website by @CNES https://peps.cnes.fr

@ J-C BERTHON

Software engineer at SCISYS. Free/libre advocate, traveller, curious and cyclist.

13 years since SPOT 5 launched, I remember the lift-off well.

NEW CNES FLICKR ACCOUNT



We have a new Flickr account address! See the most stunning images from the Pleiades and SPOT satellites at flickr.com/cnes.

@ HUB REMOTE SENSING

Humboldt´s remote sensing group focuses on a better understanding of coupled human-environment systems based on remote sensing data and geoinformation.

Opening the archives: ~15k #SPOT #worldheritage images freely available through @CNES, more to come: bit.ly/1HwJgsG #opendata

A WEEK WITH THE CHARTER TEAM

Ever wondered what a week is like for our duty engineers staffing the International Charter on Space and Major Disasters? They can be called on at any time to deliver satellite imagery to emergency response teams. Read their accounts at plus.google.com/collection/Q7vux.

> plus.google.com/+CNESFrance

CNESfrance @CNES YouTube CNES

VIDEO

What is reinsurance?
cnes.fr/cnesmag67-bertrand-labilloy

Q & A

BERTRAND LABILLOY

FOUNDED 70 YEARS AGO, THE CAISSE CENTRALE DE RÉASSURANCE (CCR) covers exceptional risks for its insurer clients and the public interest. Its Chief Executive Bertrand Labilloy explains how Earth-imaging satellites have improved damage assessment.

WHAT ARE CCR'S MISSIONS?

Bertrand Labilloy: CCR is a public reinsurance firm whose main business is to provide cover for risks that can't be insured satisfactorily on the markets. The main risk is natural disasters, which account for 60% of our business.
We also offer traditional reinsurance cover in more than 50 countries.

HOW DOES CCR HELP TO MANAGE NATIONAL GOVERNMENT RISKS?

B. L.: We contribute mainly through our risk expertise.
For natural disaster risks, we rely on a repository of data supplied by the insurers we cover.
Our researchers have also developed a model that simulates different types of natural hazards, which allows us to precisely assess risk exposure anywhere in France.
This expertise serves national and local government for natural disasters and for agricultural and weather risks, as well for acts of terrorism or war and nuclear risks.
CCR is also helping to assess emerging risks like cybercrime.

WHEN IS CCR CALLED ON TO ASSESS THE COST OF DAMAGES AFTER A NATURAL DISASTER?

B. L.: Immediately after a major natural disaster we conduct an initial assessment for insurers to give them an idea of the extent of their liability and claims provisions they will need to set aside.
Local governments also eye this initial assessment so they can gauge damage to their infrastructures and thus better manage the crisis.

WHAT ASSESSMENT TOOLS DO YOU USE?

B. L.: Our information comes from four sources: first, data collected in the field via claim forms; second, comparison with disasters of like amplitude that have occurred in the relatively recent past; third, an assessment of the hazard's intensity plugged into our own simulation model to gauge costs; and fourth, direct assessment in which analysis of satellite imagery plays a key role.
Satellites allow us to gauge both the extent of affected areas and the precise damage sustained by each building and infrastructure.
Satellite Earth imaging is therefore crucial for us.

CAN YOU GIVE US AN EXAMPLE OF WHEN SATELLITE IMAGERY HAS HELPED YOU GAUGE THE IMPACT OF A NATURAL DISASTER?

B. L.: Among recent events, I could mention the floods in Lourdes in June 2013, the Montpellier region in September 2014 and Southeast France in October 2015. Flooding is one of the main natural hazards we're exposed to in metropolitan France. But satellite imagery would be equally valuable to us in the event of an earthquake, hurricane or volcano eruption, to which our overseas territories are more exposed.

HOW DO YOU GAIN ACCESS TO SATELLITE DATA?

B. L.: We signed a partnership in 2013 with the SERTIT regional image-processing and remote-sensing department at Strasbourg University (see Roundup p.9) under which, working closely with CNES, they provide us with satellite data analysed by their rapid mapping team.

BERTRAND LABILLOY
CEO OF CCR

"THE ADVANTAGE OF SATELLITE IMAGERY IS THAT WE'RE ABLE TO UPDATE OUR PICTURE OF THE TERRAIN WITH UNEQUALLED FREQUENCY."

A dedicated portal like the PEPS platform CNES has set up in France to provide access to data from the European Sentinel satellites (see In Figures p.18) is also an effective way of assuring data distribution.

DO YOU SEE OTHER USES FOR SATELLITE IMAGERY IN THE FUTURE?

B. L.: We could use data directly in the numerical natural hazards model we've developed ourselves to gain an even more precise picture of conditions on the ground, since the key factor when assessing the cost of a natural disaster is detailed knowledge of the economic assets and activities at a given address. We've undertaken a study with Meteo France, the national weather service, to gauge how much natural disasters are likely to cost in the future: basically, we can expect to see a twofold increase by 2050.
And three-quarters of this increase will come not from a greater frequency or intensity of natural disasters, but because more insured wealth will be located in higher-risk regions.

HOW COULD YOU GET MORE OUT OF SATELLITE IMAGERY?

B. L.: In three ways: through improved resolution, revisit frequency and retasking of image acquisitions from one orbital revolution to the next, in other words satellite agility.
For example, floods in the Cevennes region of southern France are very sudden but flood waters also recede very quickly, so if you miss the peak of the flood, you could greatly underestimate your real exposure. That's why having a constellation of satellites would be of value.

"SATELLITE EARTH IMAGING IS CRUCIAL FOR US."

THE NEXT GENERATION OF VERY-HIGH-RESOLUTION EARTH-OBSERVATION SATELLITES IS SET TO PROVIDE 30-CM IMAGERY. HOW DO YOU EXPECT TO BENEFIT?

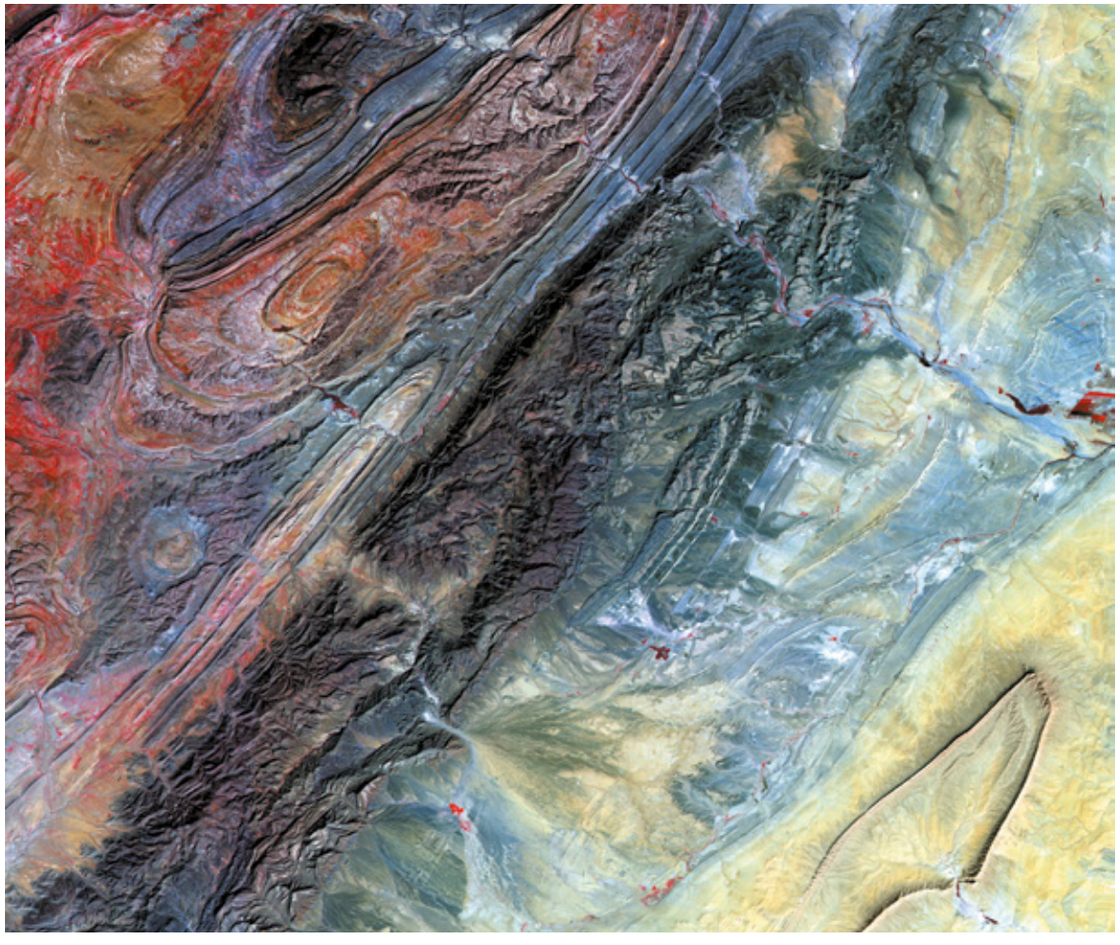
B. L.: A lot! First of all, by saving time and gaining precision in our direct assessments of damage, thanks to a home-by-home picture of the actual damage.
We're also expecting to increase the accuracy of our numerical land surfaces model and obtain a 3D map of the national territory to generate our own risk-exposure model.
The advantage of satellite imagery over more-conventional aerial assets is that we're able to update our picture of the terrain with unequalled frequency.
In Réunion, for example, lava flows change the geography very quickly every time there's an eruption and such changes affect run-off of rainwater from the slopes of the volcano, thereby altering the risk.

HOW COULD CNES'S EXPERTISE ASSIST YOU FURTHER?

B. L.: We'd really like to see CNES develop radar sensors to complement optical imagery and see through the frequent cloud cover in the event of flood conditions. That said, CNES is already a great help to us by making it easy to obtain satellite data, coordinating the supply of raw data and experts able to interpret them. This involves a broad panel of players, notably the overseeing Interior and Environment ministries.
It's very reassuring and expeditious for us to be able to call on CNES's responsive space experts in the event of a crisis.

Profile

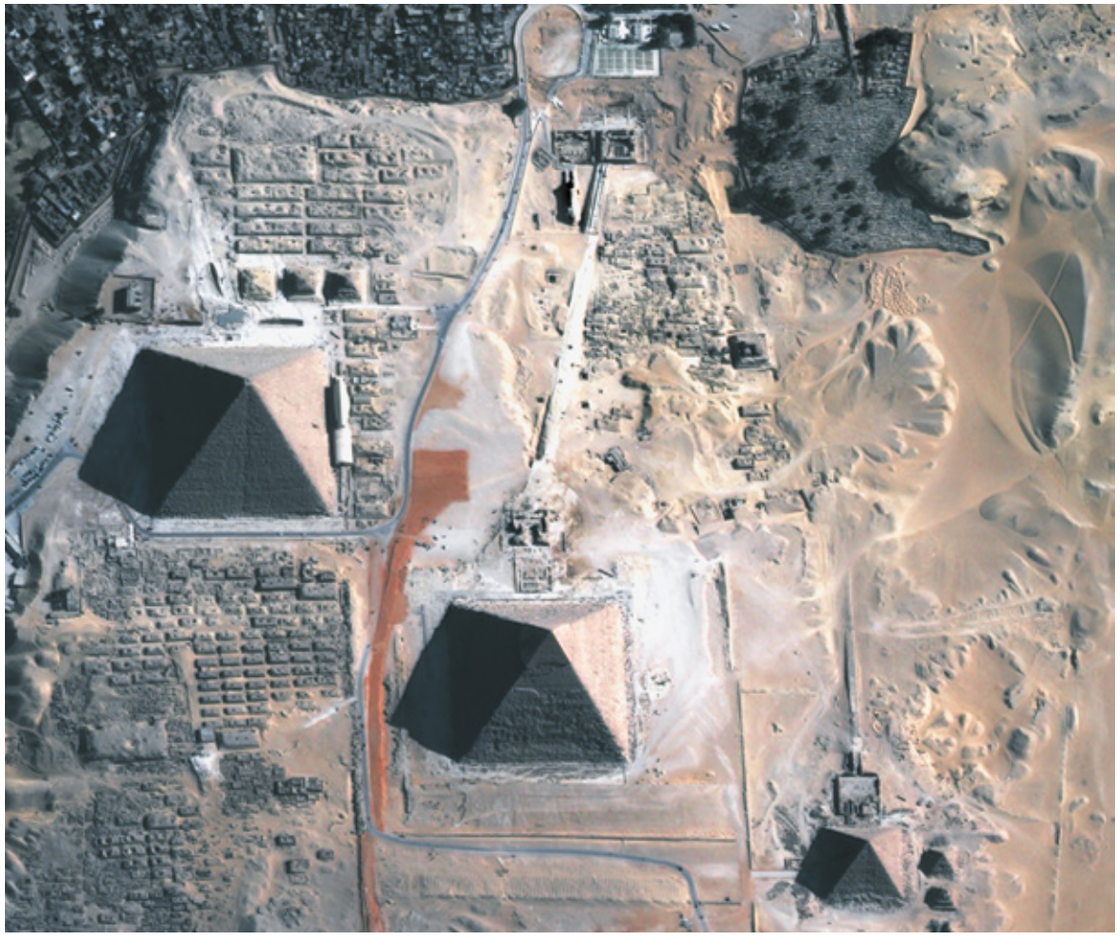
2015
Appointed CEO of CCR
2006
Director of Economic and Financial Affairs at the French insurance federation FFSA
1999
National expert on secondment to the European Commission.
1996
In charge of international affairs at the insurance office of the French Treasury



DJEBEL AMOUR IMMORTALIZED

This historic view of the Amour Range (Djebel Amour) from February 1986 is the first acquired by SPOT 1 to qualify its 'pushbroom' technology, very similar to that used by photocopiers. The 20-metre-resolution image offered a level of geometric quality unequalled at the time. This site in the Saharan Atlas was chosen for its exceptional winter light and because its location made it easier to directly downlink images to the Toulouse Space Centre. Scientists use false colours to highlight features that interest them. Here, vegetation sensed in the infrared band is shown in red.

IN PICTURES

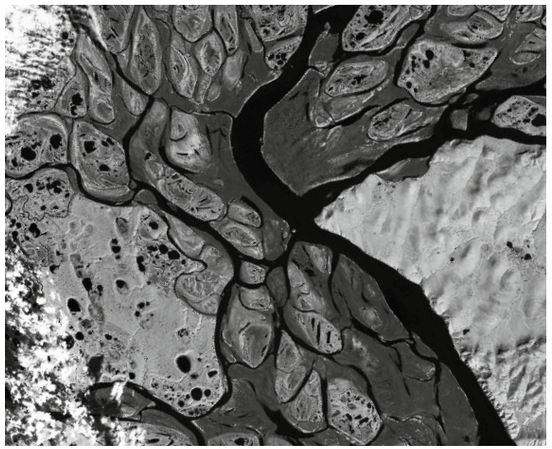


DESERT LOSING GROUND

In order of size, Khufu (the Great Pyramid), Khafre (Kephren) and Menkaure (Mykerinus) are the pyramids lying alongside the Great Sphinx in Giza. "Surrender, you're surrounded!" seems to be the message in this image that reveals the city inexorably closing in on the pyramids. The 70-cm resolution image, resampled to 50 cm, was acquired during in-orbit commissioning of the first Pleiades satellite, launched in December 2011. It helped to qualify the satellite's instruments and strikingly shows how the city is encroaching on the desert. Local authorities are even considering erecting a fence to protect the Giza complex.

N°1

With more than 1,000 customers in 100 countries and more than 1.5 billion daily users, Airbus Defence and Space remains the leader in the satellite imagery market.



NETWORK

Named after the daughter of Uranus and Gaea, the Greek gods of the sky and the Earth, the Theia land surfaces data and services hub created in 2012 encompasses 11 public research institutes. It delivers local and global data on climate, biodiversity, the water and carbon cycles, and evolving human activities. But the platform does more than simply provide data products, networking more than 400 research laboratories. Theia's members are chiefly scientists and public bodies bound by a convention renewable every four years. Other data hubs are in development that could also potentially make use of optical imagery, notably the Ocean and Form@Ter solid Earth data hubs.

7 petabytes

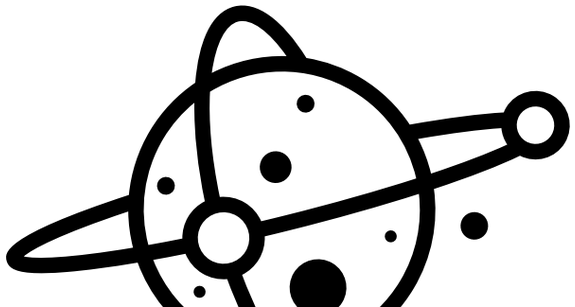
THAT'S HOW MUCH DATA WILL BE STREAMING DOWN FROM THE SENTINEL SATELLITES BY 2017.

To cope with these kinds of volumes, CNES's Sentinel Product Exploitation Platform (PEPS) has been sized to hold up to 20 petabytes of data–that's one quadrillion or 1,000 terabytes! Designed to store data from Sentinels 1, 2 and 3, PEPS will disseminate radar, optical and altimetric imagery to a broad panel of users. For example, it could target firms with free turnkey data in the cloud and on-line, on-demand image processing, including on smartphones, to nurture new applications.

4.1 billion

That's the value of the world space remote-sensing market in dollars. An economy sustained by 30 or so satellite manufacturers and launch service providers, eight commercial operators, under ten ground equipment manufacturers and some 300 service suppliers.

(Source: *L'Usine Nouvelle*)



EARTH IMAGING

HIGH-RESOLUTION EXPERTISE

WITH THE SPOT SERIES OF SATELLITES THAT IS CELEBRATING ITS 30TH ANNIVERSARY ON 22 FEBRUARY, CNES HAS BEEN A TRAILBLAZER IN EARTH IMAGING—AN ADVENTURE MARKED BY GIANT LEAPS IN TECHNOLOGY, CONTINUOUSLY IMPROVED PERFORMANCE AND INCREASINGLY VIRTUOUS SYSTEMS THAT HAVE CHANGED HOW WE SEE OUR WORLD FOREVER.

THR-NG simulation of Port-de-Bouc on France's Mediterranean coast.

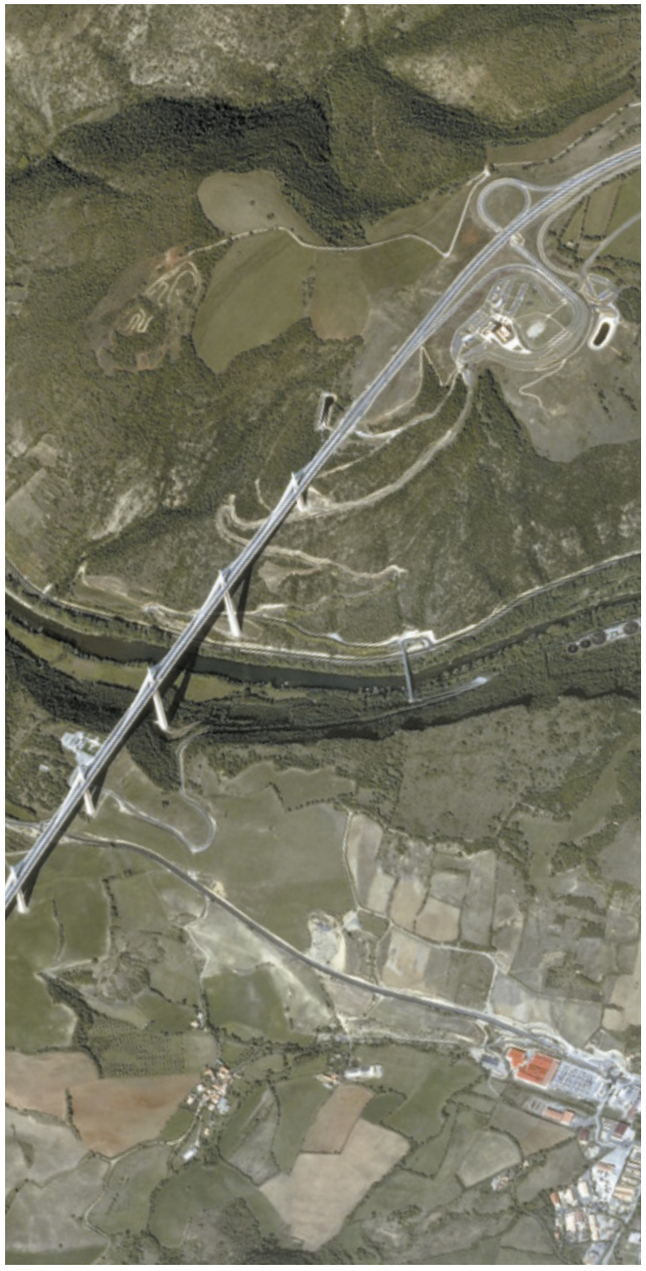
WEB FEATURE

Satellite imagery: Earth seen from space
cnes.fr/cnesmag67-imagerie-spatiale

Set in train by France in 1977, SPOT—for Satellites Pour l'Observation de la Terre—was the first European programme dedicated to Earth observation. From 1986 to 2002, it launched five satellites from Europe's spaceport in Kourou. When it lifted off in 1986, "*SPOT 1 was launching into uncharted territory*," recalls Eric Boussarie, CNES's deputy director of science and imaging payloads. "*It was based on no specific user requirement or order, and entirely 'home-built' in technology-push mode! But from the outset, its designers sought to make it an operational tool and we had the innovative technologies to do that. SPOT 1 gave us the opportunity to apply them and gain an edge in a potential market just waiting to be discovered.*" Engineers at IGN, France's national mapping and survey agency, contributed their skills and experience in deciphering aerial imagery. SPOT 2 and SPOT 3 subsequently confirmed the maturity of the technologies and strengthened ties with Belgium and Sweden, the programme's historic partners. "*CNES now began to transfer more and more responsibility to industry prime contractors*," notes Christophe Valorge, CNES's deputy director of orbital projects. In all, some 50 Belgian and Swedish contractors would work on the programme with the big names in France's space industry, Matra—now Airbus Defence & Space—and Aerospatiale/Satellites—now Thales Alenia Space.

REACHING FOR THE STARS

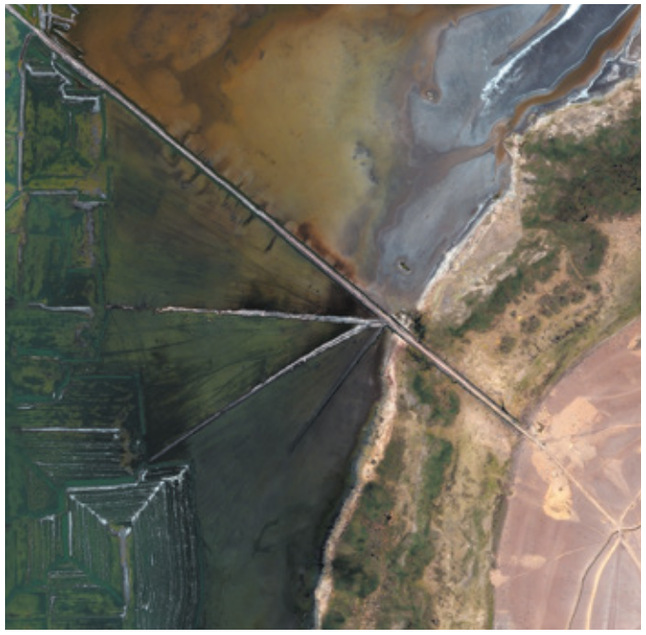
Now well and truly at cruising speed, Earth imaging received fresh impetus with the launch of SPOT 4. Flash memories paved the way for the replacement of venerable magnetic video tapes and the DORIS instrument, combined with the autonomous DIODE navigator, upped the location accuracy of imagery. SPOT 4 also brought changes in the programme's industrial organization, with Matra, Alcatel, Dassault and Thomson as prime contractors for the spacecraft bus, payload and telemetry system. At the same time, marketing efforts were stepped up a gear through Spot Image, the private firm formed by CNES, IGN and the space industry in 1982 to distribute SPOT data products. Mirroring these Earth remote-sensing technologies, Helios 1, France's first military reconnaissance satellite, was developed to exploit efficiencies with SPOT 4. Using the stars rather than pointing at the centre of Earth to achieve attitude control, it was also the first truly agile satellite. Helios 1 thus contributed to assuring France's strategic independence.



Pleiades-1A tracked construction of the Millau viaduc step by step.

THE HIGH-RES REVOLUTION

While SPOT 5 shared the same configuration as its predecessor's, its higher resolution revolutionized image quality. The satellite's High Resolution Geometric (HRG) instrument was a jewel of technology, opening up export markets with its 2.5-metre resolution. This niche of the market would soon wean itself off reliance on government support, with funding for SPOT 6 and its successors coming entirely from industry. Having first served



Santa Lucia de Salinas, Peru.

IMAGE PROCESSING

PIXEL-SCALE PRECISION

A satellite image is never perfect, affected as it is by the satellite's motion, viewing geometry, detector response, 'noise' and weather conditions. This all leads to distortion, striping and tonal imbalances. Such imperfections can be measured in orbit against calibrated parameters (see p.24) and image-processing algorithms can then correct them. This is the job of the engineers in CNES's Image Quality department. Using their intimate knowledge of the precise physical configuration of the imaging system, they define models that turn a raw image into a final corrected image. The first step is radiometric correction to remove striping, raise contrast and filter out noise. The second step then corrects the geometry, using location models to register the different colours, remove internal distortion due to the instrument and perspective effects, and geocode each ground pixel to match the user's requirements. The final image contains corrected pixels as well as metadata—viewing conditions, calibration coefficients, location models, quality masks and so on—that plugs automatically into users' software.

THR-NG simulation of Marseille.

70 cm

Optical imaging
is one of the fields where performance has most improved. Image resolution with SPOT 1 was 10 m, then 2.5 m with SPOT 5 and 70 cm with Pleiades.

increasingly sophisticated applications for the scientific community and institutional users, high-resolution satellite imagery was now set to energize the wider economy. Marketing of imagery is today no longer overseen by government, as in 2008 CNES sold its shares in Spot Image, since merged into Airbus Defence & Space (see p.7).
Since SPOT 5, optical space remote sensing has undergone various shifts. In 2012, Pleiades, the first dual-use civil/military satellite, brought with it a number of technology advances, not least in agility. One of Pleiades many pluses is the gyroscopic actuator that lets the satellite be steered at will to acquire imagery from multiple angles and enable frequent revisits, while also supporting production of 3D imagery much in demand from a growing range of applications. 2015 saw the launch of Sentinel-2, the first optical Earth-observation satellite of the European Copernicus environmental monitoring and security programme initiated by the European Union and the European Space Agency (ESA). Offering 10-metre resolution combined with a very wide imaging swath (300 km) and frequent revisit capability, Sentinel-2 is set to open up a whole new field of satellite imagery applications. With such ever-higher resolutions, you might think Earth remote sensing has hit its limit, but you would be wrong, for CSO[1] and OTOS are already waiting in the wings to take us to the next stage of the high-res revolution.

1. Composante spatiale optique.

WORK PLAN

TASK AND SHOOT

To obtain imagery, you obviously first have to task the satellite. This is the job of CNES's Mission Guidance and Tasking department. Satellite tasking is a complex process that begins by collecting users' requests. "*We then calculate the optimal imaging sequence for the satellite over a given area of interest to fulfil those requests,*" explains the department's head Paola Van Troostenberghe. This sequence, or tasking plan, depends on the number, geographic location and priority of requests and is constrained by the viewable corridor along the satellite's ground track and the sensors' ability to perform successive acquisitions. The amount of memory occupied by each image stored on board the satellite depends on the data compression rate chosen for a given level of image quality. The tasking plan factors in available storage space, as well as the number of receiving stations, onboard power consumption, cloud cover over the area to be imaged and image transmission throughput.

Artist's view of the OTOS demonstrator.

SPOT, PLEIADES
HOW HIGH CAN RESOLUTION GO?

To maintain its edge in the Earth-observation satellite market, France is gearing up to face growing competition.

+ 100%

With respect
to Pléiades, THR-NG is expected to increase coverage by a factor of 2 or more.

30 cm

THR-NG
will offer 30-cm resolution.

Optical technologies now in development are set to take imaging resolution to the next level. The THR-NG satellite currently at the feasibility study stage will incorporate 'super'-resolution optics. CNES will be the prime contractor responsible for building this dual-use civil/military system under the roadmap established jointly with DGA, the French defence procurement agency.
"*We'll be able to increase resolution by a factor of two, taking it to 25-30 centimetres,*" says Gilles Chalon, head of CNES's military imaging department. "*But the key thing for us to maintain our edge is to have an end-to-end strategy to build quicker, produce better and sell cheaper.*"
Conceived as the optical very-high-resolution Earth-imaging system of the future, THR-NG will use technologies derived from both Pleiades satellites, but it will also take them a

step further. Through the OTOS[1] ground technology demonstrator now in development, the new satellite intends to show that we can keep pushing the limits of technology and lay the foundation for this new-generation very-high-resolution system.

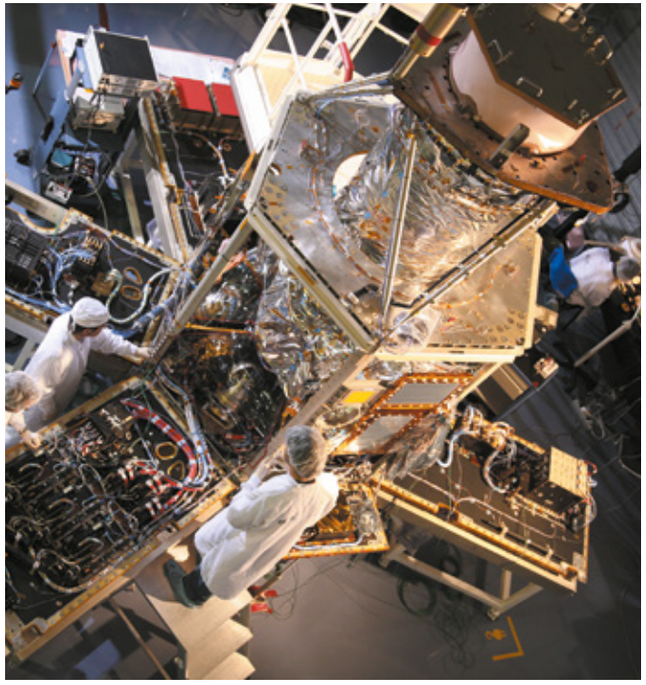
EXACTING TASK

OTOS's secret is its active optics. The accuracy of an Earth-imaging satellite depends to a certain extent on the telescopes' mirrors. Fabricating these telescopes is a long, costly and very exacting task. An active optics system uses a compensating mirror (see Materials p.27) to correct the imperfections of the primary mirrors. This process already traditionally used in astronomy could be adapted in space to enable industrial-scale production and thus shorten lead times and reduce costs. Active optics could also be used to build very-large-diameter space telescopes affording ultra-high-resolution. To this end, THR-NG will serve as a demonstrator of the future generation of optical military reconnaissance satellites.

THR-NG is also looking to increase sensitivity with new detectors. When viewing features really close up, we gain geometric resolution but lose light received, which affects image quality. The new generation of detectors is being designed with a view to overcoming this obstacle.

Lastly, THR-NG is expected to increase the coverage offered by Pleiades by a factor of two or three and its image acquisition and downlinking capacity will be improved accordingly. Efforts are also focusing on optimizing the overall architecture of the future THR-NG to make it smaller and lighter. *"The ultimate aim is to be able to orbit the satellite on the smaller and cheaper Vega launcher,"* says Gilles Chalon, and at the same time stay ahead in the fiercely competitive global market.

1. Observation de la Terre Optique Super résolue.



The Pleiades satellite undergoes integration at Astrium.

CALIBRATION

MORE TO READING IMAGERY THAN MEETS THE EYE

Without a frame of reference, a raw satellite image cannot be overlaid on a map and pixel brightness values cannot be compared with those from other sensors or with the amount of light reflected off the surface. We therefore need a known value from reference points on land, at sea or in the celestial sphere, chosen because they contain landmark features, or we can use artificial test patterns. The raw image of a reference point lets us see any imperfections in fine detail and we can then readjust the viewing angles with respect to landmark features. For Pleiades, calibration moved up a notch by using the stars to measure resolution and geometric stability more precisely.

VIDEO

Multi-use imagery: CNES's small digital works
cnes.fr/cnesmag67-applications

APPLICATIONS
KEEPING US SAFE AND BOOSTING BUSINESS

High-resolution optical imagery is a cutting-edge technology that is also spawning many industry applications.

Subscene of Pleiades image of 27 April 2015 over Kathmandu (48 hours after the earthquake) showing the collapsed Dharahara Tower (bottom left) and emergency tents in the park.

Pleiades has earned itself a fine reputation in emergency-response circles. With Copernicus, the European Union is deploying a global system to keep watch over the planet and this would be impossible without satellite imagery. In this programme, Pleiades complements the fleet of Sentinel satellites, providing its very high resolution, daily revisit capability, fine detail and real-time data transmission for certain highly demanding services. It is therefore no surprise to learn that the Pleiades system is perfectly suited to emergency response and a key contributor to the International Charter on Space and Major Disasters (see Roundup p.8). These days, analysis of pre- and post-disaster imagery is increasingly employed during the recovery phase. In 2013, Pleiades also found an unexpected application in insurance when French public reassurance firm Caisse Centrale de Réassurance (CCR) partnered with the SERTIT[1] regional image processing and remote sensing department at Strasbourg University. CCR uses Pleiades data to model and better understand disasters like flooding (see Q&A p.13). But Pleiades is also proving of great value to other sectors of the global economy, for example in the mining and oil industries. While its 70-centimetre resolution has attracted many private firms and urban planners worldwide, uptake by French ministries, agencies and local government is lagging and needs to be stepped up to reap the potential benefits for urban/land planning and environmental management.

76%

Percentage of activations

for the International Charter on Space and Major Disasters to which Pleiades has contributed. In 2015, Pleiades was called on for 29 out of 38 activations.

NEW MARKET OPPORTUNITIES

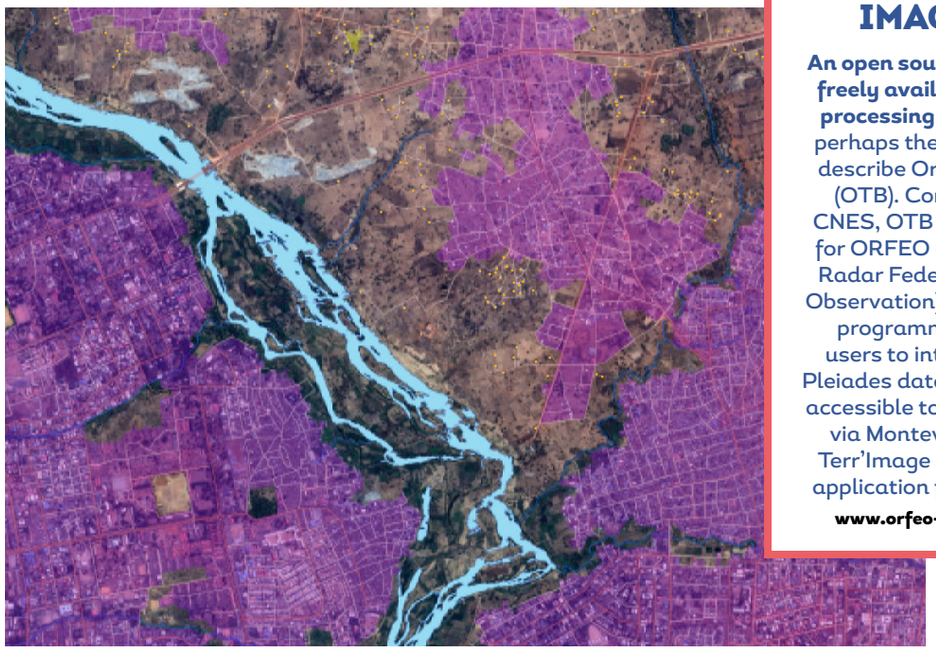
Optical high-resolution imagery can also aid important causes, for example in healthcare. The fight to eradicate polio is a case in point. In Nigeria, where the disease is endemic, Pleiades has been used to precisely map a vast area covering 100,000 sq.km in record time. Automatic transmission of data such as numbers of children vaccinated and village names has enabled field teams to keep a check on vaccination campaigns in real time and determine priority zones.

ORFEO TOOLBOX

— OPEN SOURCE — SATELLITE IMAGERY

An open source library of freely available image-processing software is perhaps the best way to describe Orfeo ToolBox (OTB). Conceived by CNES, OTB was devised for ORFEO (Optical and Radar Federated Earth Observation), the support programme helping users to interpret new Pleiades data. OTB is also accessible to non-experts via Monteverdi or the Terr'Image educational application for teachers.

www.orfeo-toolbox.org



Map of urban areas (mauve), villages (yellow) and remote dwellings (beige) as well as road and river networks used to plan and track polio vaccination campaigns.

One of the most singular cases illustrative of the market opportunities now emerging comes from the United States, where RS Metric supplies investors and corporations with exclusive data and analytics on shopping-mall car parks. Pleiades images are analysed weekly to calculate shop footfall from car park occupancy, thus providing an indirect measure of sales activity to inform investors' decisions. *"In the three years it has been operating, Pleiades has exceeded all of its technical and commercial goals, and there's more to come. We can expect to see new applications developing, notably through 3D data,"* notes Hélène de Boissezon at CNES's Image Analysis and Products department.

5%

Pleiades
is a dual-use civil/military system. The quota of images delivered daily to military users is 5%.

Besides its technologies, Pleiades' other asset is that it was conceived from the outset as a system. In other words, CNES worked up front to establish a user support programme and a lot of effort has gone into making standard, turnkey products delivered under an open sub-licence available to a wider institutional user base.

1. Service Régional de Traitement d'Image et de Télédétection

BOOSTING PERFORMANCE WITH ACTIVE OPTICS

OVER THE YEARS, CNES HAS INCREASED THE RESOLUTION OF ITS OPTICAL INSTRUMENTS from 10 metres to just 70 centimetres. In the future, applications are set to employ even higher resolutions of up to 30 centimetres, calling for bigger, heavier and therefore more costly mirrors. To overcome this weight and size obstacle, CNES is working on major innovations in active optics. The idea is simple: sensors are placed inside the telescope to gauge its optical quality and correct it where necessary at any time using a deformable mirror and a mobile mirror. This radically new approach means that the instrument's performance needs to be closely controlled, on the ground and in orbit. CNES is pursuing these new technologies through the OTOS programme, with the aim of sustaining development of very large instruments and making them twice as compact while assuring that the satellite can still be accommodated by a small launcher.

SPOT

1986

SPOT 1
THE ANCESTOR

SPOT 1 was the first European optical pushbroom Earth-observation satellite (see In Pictures, p.16). Conceived and built by CNES with industry partners Matra (now Airbus Defence & Space) and Aerospatiale (now Thales Alenia Space), it offered a resolution of 10 metres. SPOT 2, 3 and 4 would subsequently take performance to new heights. The French, Belgian and Swedish governments funded the programme together from the outset and Spot Image was formed in 1988 to market SPOT data. SPOT 4 and Helios 1, France's first military reconnaissance satellite, were developed together to exploit efficiencies.

2002

SPOT 5
THE GAME CHANGER

SPOT 5 marked a turning point, using its Supermode resampling techniques to achieve high-resolution imaging (2.5 metres). The satellite carried the first High Resolution Stereoscopic (HRS) instrument and enabled large-area digital elevation models (DEMs) of Earth's surface to be generated. The mode of funding also changed, based on a public-private model. Later, SPOT 6 and SPOT 7 would be built entirely from private funds and the private sector was tasked with marketing data products.

BEFORE THE DAYS OF HIGH RESOLUTION, SPOT 1 WAS ALREADY REVOLUTIONIZING EARTH IMAGING. FROM SPOT 1, THE ANCESTOR, TO THR-NG, ITS SUCCESSOR NOW IN DEVELOPMENT, SATELLITE REMOTE SENSING HAS CHANGED HOW WE SEE THE WORLD AND NURTURED NEW FIELDS OF EXPERTISE.

2012

PLEIADES
THE PARADIGM SHIFT

With their gimballed gyroscopic actuators, VHR imaging instruments and high-throughput image telemetry, the Pleiades satellites' innovative technologies give them exceptional agility and precision to revisit any point on the globe every day. Offering a resolution of 70 centimetres, their geometric accuracy paved the way for very-high-quality 3D products. Pleiades are the first dual-use Earth-imaging satellites serving both civil and military applications.

2020

THR-NG
A NEW ERA

This programme now underway to develop the first satellite offering very high spatial resolution will be packed with innovative technologies, including a promising active optics concept (see Materials p.27). Miniaturized components and a compact satellite are expected to largely reduce costs. No longer solely a matter of technology but also of economics, Earth observation is today driving a new revolution.

JEAN-PAUL GACHELIN

Founder of SIRS.

"I'm expecting a huge surge in demand in the next 10 years..."

Local and regional authorities in Europe now have free access to maps of 600 European cities. Jean-Paul Gachelin is the founder of SIRS, a company based near Lille in northern France and specializing in the production of geographic data from satellite imagery. A geophysicist by training, he was a student when SPOT 1 was launched. **He studied remote sensing at a young age and takes a keen interest in the imagery market.** When the European Environment Agency wanted satellite maps of all European cities with populations over 50,000, SIRS responded enthusiastically, offering the services needed to build the new Urban Atlas.

Covering 1 million square kilometres, the Urban Atlas delivered a first set of images in 2008. It was updated in 2012, using imagery acquired by the SPOT and Pleiades satellites. The European Commission's regional representations provide the data that planners need to analyse urban areas, their evolution and growth, evaluate potential sites for redevelopment and compare indicators with other cities. ***"We're currently working at a resolution of 2.5 metres, i.e. between high and very high resolution,"*** says Gachelin. He's tracking the market carefully: *"I'm expecting a huge surge in demand in the next 10 years,"* he adds. *"Between now and 2020, there'll be a major market shift towards environmental monitoring on a local, regional and global scale. Plus,* ***the arrival of high-resolution open data and the increasing amount of imagery available, including remote areas, will spawn new and affordable applications."*** With all the optimism of a start-up entrepreneur, Jean-Paul Gachelin founded SIRS in 1989 at the age of 26. Today, it has 40 employees, 20% of its budget is invested in R&D and 50% of its sales are generated outside France.

CAROLINE LAURENT

Director of Strategy at the French defence procurement agency DGA.

"Improvements in processing speed and agility have enabled us to move from strategic use of imagery to tactical applications..."

When it comes to SPOT or Pleiades, Caroline Laurent knows her stuff. Space has figured prominently throughout her career. After engineering studies at the École Polytechnique, she began her career at DGA's Missile and Space department. In 1995, she worked on shaping France's space policy. Then from 2011, she managed the Space and Operational Information Systems unit before being appointed DGA's Director of Strategy on 1 December 2014, where she is in charge of innovation and preparing the future. **But for Caroline, space isn't just a recurring theme in her career. It's a passion.** *"Even before Helios was developed, the military was using SPOT imagery,"* she says. *"CNES and DGA have been working together for 30 years. Helios 1 and 2 then Pleiades, with its speed and agility, are vital tools of France's sovereignty."* The imagery they deliver gives French forces a clearer picture of the terrain and enables them to plan more effectively: *"VHR imagery is a key element of the knowledge and anticipation function, which is one of the pillars of the White Paper."* Published in 2013, the White Paper on defence and national security is an important document for the French defence community. *"Daily satellite tasking over the theatre enables us to locate targets and assess the results of strikes. Improvements in processing speed and agility have enabled us to move from strategic use of imagery to tactical applications."* And it's a capability with a future, for ***"France really excels at Earth observation, both for civil and military applications".*** DGA and CNES plan to build on this excellence by partnering on the next-generation VHR system.

MOHAMED HAKIM KHARROU

Responsible for promoting irrigation techniques at ORMVAH, the Al Haouz region agricultural development board in Marrakesh, Morocco.

"High-resolution satellite imagery is helping farmers make better use of water..."

Mohamed Hakim Kharrou is a Moroccan agricultural engineer. He completed his PhD at Cadi Ayyad University in Marrakesh, specializing in the "contribution of remote sensing to irrigation system performance analysis in semi-arid zones", with the support of IRD/CESBIO and the TREMA[1] joint international research laboratory. **In 1994, he joined ORMVAH, where he's responsible for promoting water-saving irrigation techniques and developing decision-support tools.** "*The agricultural landscape around Marrakesh is changing*," he says. "*The plains are greener and more diversified: as well as the palm groves, farmers are now growing olives, citrus fruit, apricots, cereals and fodder crops.*" **He's upbeat about space: "*high-resolution imagery in the visible and near-infrared is helping farmers make better use of water, according to the needs of each crop*".** Close to the Atlas Mountains, the Al Haouz region is irrigated by dams, wells and wadis, which are often dry. Rainfall levels are low and irregular. The French-Moroccan team set up an experiment on a local farm, with four hectares irrigated conventionally and another four with the aid of satellite imagery. The results are impressive and the team is now introducing satellite technologies on a wider scale. Mohamed Hakim Kharrou divides his time between managing projects and visiting sites in the region. **He's also looking forward to the Sentinel-2 satellite, which promises to transform farming practices.** "*With the web, farmers will have access to soil moisture data at individual field level via their phones, so they'll know exactly when to irrigate.*" They'll also be trained how to use IT tools and read satellite maps, which are set to become a vital ally in the quest for water efficiency.

1. Télédétection et Ressources en Eau en Méditerranée semi-Aride (remote sensing and water sources in semi-arid Mediterranean environments).

Jacques Arnould, science historian and theologian, CNES ethics officer.

ETHICS CORNER

JACQUES **ARNOULD**

REVOLUTIONS

The SPOT satellites have enabled earthlings to see their planet in a new light. More broadly, more freely and more responsibly, too. And by being more aware, we can better prepare for the future.

Revolution. For the ancients, the stars and their unvarying orbits were evidence of the world's stability and part of what makes it so beautiful.

Revolution. In more modern times, the word came to mean 'abrupt change' or 'upheaval'. This was perhaps the fault of Copernicus, Galileo and company, who changed forever how we observe the cosmos, interpret our place in it and forecast the fate of our planet and its populations.

Revolutions. When SPOT 1 entered orbit, it epitomized these rich layers of meaning, inaugurating the ceaseless circular cycle of a family of satellites dedicated to Earth observation, keeping watch over the revolutions affecting our planet, its environments and its inhabitants. At times, it even became a factor or actor in affairs on the ground: it was the first to offer photographic evidence of the Chernobyl disaster in April 1986.

More revolutions when, with the web, the use of satellite imagery entered daily life and the realm of economics. The dream of the soldiers and spies of the past is the reality of consumers today: anyone can have a seat in the world's upper gallery and get the best view of its most remote corners and habitations.

REVOLUTIONS TO COME

Some fear what will come around next. After all, do these revolutions not threaten our very values and privacy? Undoubtedly, but the heaviest toll imposed by our orbiting companions is that we ourselves set these sentinels in the sky, like the eye following Cain in the Victor Hugo poem, which he could never escape because it was his own superego. The combination of spacecraft and computers has brought unexpected immediacy to the ancient injunction on fratricide: "*Where is Abel thy brother?*" No problem, say those who take the 1967 Outer Space Treaty seriously and want to make this fresh new realm a 'common heritage of humanity'. Set up quietly and without fuss, the International Charter on Space and Major Disasters is no less revolutionary: who in the early days of spy satellites would have thought that images from space would be made public?

We all know that a revolution or even repeated revolutions never stops the forward march of history. And we know we can never go back, that observation of the Blue Planet by SPOT and its accomplices and successors has changed our lives forever. So by being more aware, we can better prepare for the revolutions to come.

COFFEE TABLE BOOK

SPACE TOMORROW

All aboard for a futuristic voyage in this book that offers not only amazing views of space and our planet, but also invites readers to reflect on the (r)evolutions accomplished or to be imagined by the space sector. The aim: help humans better inhabit the Earth and unveil the secrets of the Universe.

Demain l'espace by Jacques Arnould – Published by Cherche Midi – 2016 – Foreword by Jean-Yves Le Gall – Preface by Irina Bokova – 155 pages – €29

BEHIND THE SCENES OF SPACE OBSERVATION

Written by space professionals, this book immerses readers in the technical advances and policy decisions that have enabled France and Europe to achieve excellence in satellite imagery. An account from those pioneers without whom SPOT, Pleiades and Copernicus would never have happened.

Observation spatiale de la Terre optique et radar – Institut Français d'Histoire de l'Espace – Published by Tessier et Ashpool – €49.50

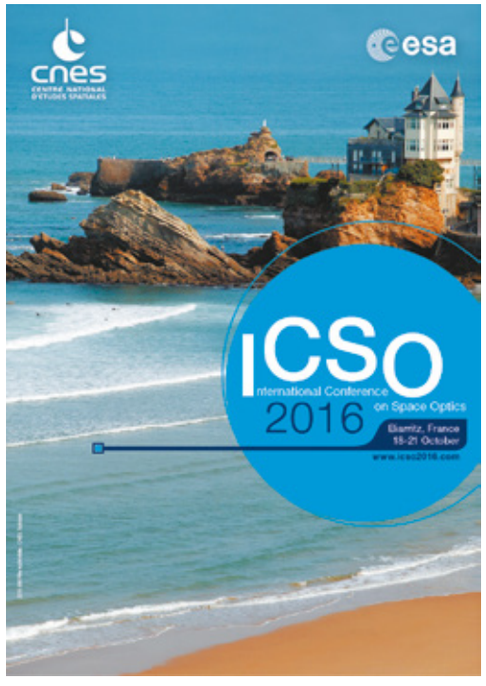
EDUCATION

SPACE FOR THE CLASSROOM

CNES rounded out its range of schools resources in 2014 when Terr'Image, designed to encourage the use of satellite imagery in the classroom, was made available for secondary schools. The associated TerreImage software offers a simplified method for processing and interpreting Pleiades data. The package includes materials directly related to school curricula and the option for teachers to download satellite data free of charge. Through one-off courses or CNES's space education summer school in July, teachers can learn the basics of remote sensing and then pass on their knowledge to pupils.

SYMPOSIUM

INTERNATIONAL CONFERENCE ON SPACE OPTICS



ICSO 2016 is dedicated to technological developments in optics and optronics for space missions. It also covers developments in instruments (images, spectrometers, lidars, etc.) for Earth observation and space sciences as well as lessons learned from missions.

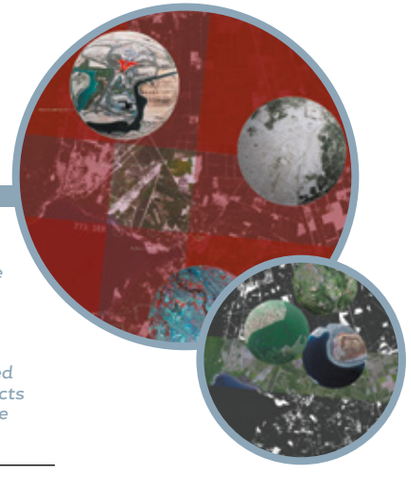
EVENT

SPOT TURNS 30

From SPOT 1 to SPOT 5, the spacefaring siblings keep a vital watch over the world today. By way of celebration, the Cité de l'Espace theme park in Toulouse is putting on an exhibition on 22 February dedicated to 30 years of SPOT observations. Images chosen from three decades of archives focus on historic events, technological developments and shifting landscapes. Components, detectors and other hardware from the SPOT and Pleiades missions will also be on display, reflecting the extraordinary advances made. With an eye on the future, the anniversary is also a tribute to the entire French industry and its leadership in Earth observation. Alongside the exhibition, a series of talks will look at the challenges ahead for the sector.

DIGITAL ART

When an artist is confronted with SPOT satellite technology, the result is something bristling with originality. Described as 'generative art' by former engineer Charles Giulioli, the work—reflecting the new modes of expression made possible by digital tools—will be previewed on a giant screen at the event. *"What interested me most was how images are created, rather than the end product,"* says Giulioli. *"It's also known as algorithmic art, because it uses algorithms to generate artwork autonomously. The software chooses a number of predetermined elements and reconstructs them randomly to create a unique piece."*



DIARY

22–24 FEBRUARY
Exhibition: "30 years of Earth observation"
Cité de l'Espace, Toulouse

24 FEBRUARY – 6:30 P.M.
Special evening: "1986-2016: 30 years of high-level Earth observation"
Cité de l'Espace, Toulouse

18–21 OCTOBER
International Conference on Space Optics (ICSO)
Biarritz
ww.icso2016.com

MAY 2018
Spaceops
Marseille

VIDEO

Report from a dentist's surgery
cnes.fr/cnesmag67-condorscan

DENTISTS TURN TO 3D IMAGERY

Derived directly from satellite imaging technologies, the CondorScan camera designed to take dental impressions in 3D is set to enter the commercial market in the first quarter of this year.

We sometimes see surprising applications developed from satellite technologies," says Didier Lapierre, in charge of spinoff at CNES. This is certainly the case with CondorScan, a camera that takes a patient's dental impression in 3D for prosthesis. CondorScan is the brainchild of Professor François Duret, odontologist and CEO of Aabam, a biotechnology R&D firm based in the Aude region of Southwest France, who decided one day to investigate whether space technologies might be able to spur innovations in this field.

To build a 3D model of Earth's surface, a satellite like Pleiades has to acquire at least two images of an area from two different viewing angles. Relief is then mapped by combining landmark features from the two images. This operation becomes trickier when the surface is virtually uniform, for example when the landscape is covered in snow, or likewise for white, smooth teeth.

CNES engineers Gwendoline Blanchet and Jean-Marc Delvit specialize in image-processing algorithms. They devised a solution for Aabam using a wavelength capable of revealing details that can then be merged. CondorScan thus makes it possible to obtain enough images to assure redundancy of the information obtained. The correlation algorithm and the methodology used in stereoscopic image processing to extract relief that form the basis for this revolutionary tool are derived directly from satellite imagery. Barely larger than a toothbrush, the camera took six years to develop and will enter the commercial market in the first half of this year.

1,000

Pre-sales of CondorScan cameras
already booked by Aabam.