Alsat-1: First Results of Multispectral Imager

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ThS 3: Small Satellite for Earth Observation

KEY WORDS: Small/micro satellites, Observations, Camera, Imagery, Sensor, Pushbroom

ABSTRACT:

In November 2002, the 28th, at 06:07am GMT, was launched the 1st Algerian satellite from the cosmodrome of Plesetsk in Russia into a 700 km sun synchronous orbit. Alsat-1 is an enhanced earth observation microsatellite (<100kg), stabilised in 3 axes for image acquisition mode. It was designed for disaster monitoring and is part of the international constellation dedicated to Disaster Monitoring (DMC),

Alsat-1 payload is a multispectral imager, with two banks of 3 channels. Each bank works in a push broom mode and covers half of the whole image size with 5% overlap. The total swath width is 600 km and images are taken at 32m GSD, on three spectral bands (Green, Red, NIR), identical to those of Landsat-TM. A windowing mode was implemented to add more flexibility to the system and to prevent the saturation of the three storage units: Two adding up Solid State Data Recorder (SSDR) totalising 1Gbytes data and one redundant unit of 128MBytes. The image data are sent to the ground station thanks to the high rate transmitters working in S-band at 8Mbps.

Since Alsat-1 launch, the imager has taken more than 300 images. Their first evaluation showed a comparable quality to those from the similar satellites (Landsat-TM). The paper presents an overview of the Alsat-1 characteristics and shows the first results of the multispectral imager.

1. ALSAT-1 MISSION

Alsat-1 is an earth observation satellite which evolves in a sun-synchronous retrograde circular orbit. Designed to be part of a constellation for daily disaster monitoring, Alsat-1 is equipped with two banks of cameras giving a total of 600km field of view at 32 meters ground sampling distance in three spectral bands: Red, Green and Near Infra-Red. This field of view allows the constellation to cover the whole earth within 24 hours. In absence of disaster, Alsat-1 is dedicated for Algerian purposes: mainly for remote sensing applications

2. SATELLITE DESCRIPTION

Alsat-1 has a three axis stabilization in imaging mode and evolves in a BBQ mode out of imaging time. The attitude determination and control subsystem gives a good attitude pitch/roll/yaw stability during imaging (=5 m°/s) and the Orbit filter provides a maximum track error of the scene position of 5km (GPS On during one orbit a day).

The imaging system allows windowing and it is supported by a total storage capacity of two 0.5Gbytes of data which could be downloaded to a ground station at 8 Mbps (within 10min/SSDR). The downlink and the uplink, both operate in S band at 8 Mbps in normal operation and 38.4 / 9.6 kbps during commissioning for the downlink and uplink respectively.

Most of the Alsat-1 subsystems were designed with no single point failure to be highly resilient to non-nominal situation. Therefore, most of the critical subsystems for the mission are redundant, such as:

- 2 x receivers/transmitters to communicate with the spacecraft.
- 2 x Power Supply Modules (PCM) and one Power Distribution Module (PDM) providing two redundant power lines from each single switch.
- 2 x On Board Computers (OBC) manage the satellites tasks (OBC-386 as primary & OBC-186 as secondary).
- 3 x Image Data Storage Memory (2x0.5 Gbytes SSDRs and one 128 Mbytes SA1100).
- 2 x ADCS modules. Each controls one magnetometer, two sun-sensors, and three coils of the three magnetorquers.
- 2 x boom controllers to insure the pyro-firing for boom deployment.

Alsat-1 as part of the constellation is equipped with a propulsion system with 50mN thrust and two tanks with a capacity of 2.5 litres each. The propulsion system is needed to assure:

- The circularization of the constellation satellites is maintained so the sun-synchronicity of the mission too.
- The station acquisition which allows the satellites to equally separate from each other so the daily global coverage is respected.
- The station keeping of the satellites to avoid them to deviate from their original orbit under drag effect and keep the daily global coverage.

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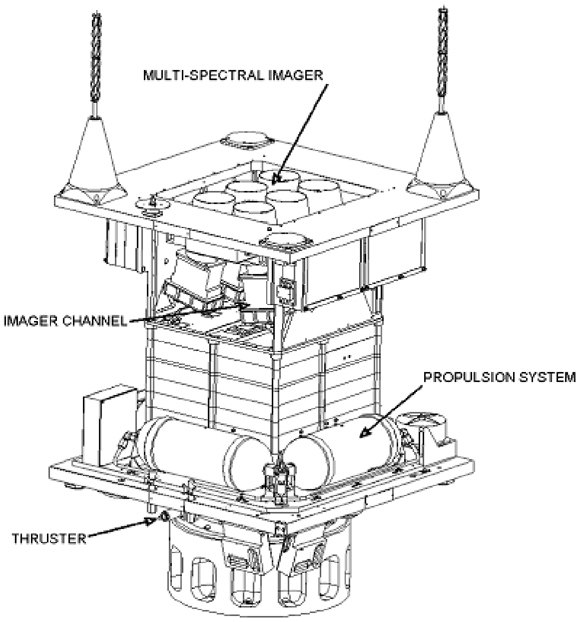


Figure 1: Alsat-1 structure

Alsat-1 structure is mainly Aluminium. The solar panels, the Earth and Space Facing Panels are honeycomb structure. The satellite size is 600x600x600 mm with a mass of 98Kg.

2.1 Payload description

The Alsat-1 payload is a multispectral camera which works in a push-broom mode (forward scan is provided by the spacecraft motion). It is in fact a couple of two imagers (of three channels each) which work separately or both together. This adds flexibility to program images (satellite operations).
For each spectral band (green, red, near-infrared), two channels (from both banks) provide a 600 km swath with (5% overlap between them) from its 686km altitude.

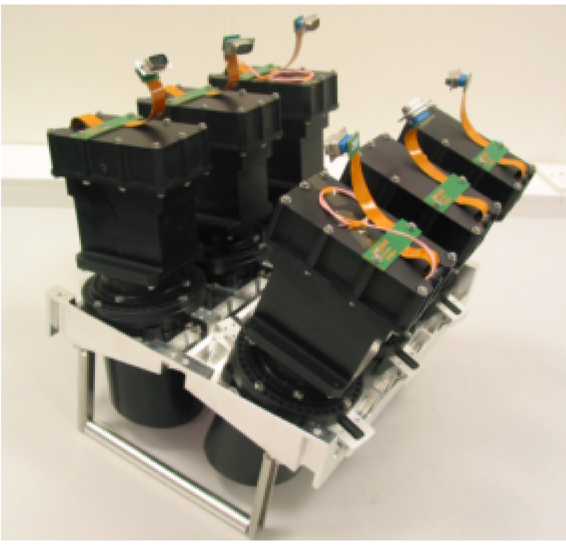


Figure 2: Alsat-1 Imager

2.2 Camera

It is a line scan camera system designed to provide medium resolution (32m GSD), high dynamic range and low noise imagery from orbit. It consists of 6 channels split into two banks and fixed on a V plate.
Due to the extremely wide swath, each bank acquires half of the scene (with 5% overlap).

2.3 Channel

Each channel is in fact an independent camera and contains a complete optic-system plus a PCB supporting the sensor & linked to the main PCB board in the stack (one main board per bank) thanks to a flexi-rigid PCB cable.

Sensor: It is a KLI-10203 linear CCD sensor, designed for color scanning applications. This is an RGB, 3 channels, 10k pixels. Due to the mission requirements, this COTS element was requested from Kodak without the RGB organic dye filters (applied to the light sensitive areas) but with a multilayer AR coated cover glass.

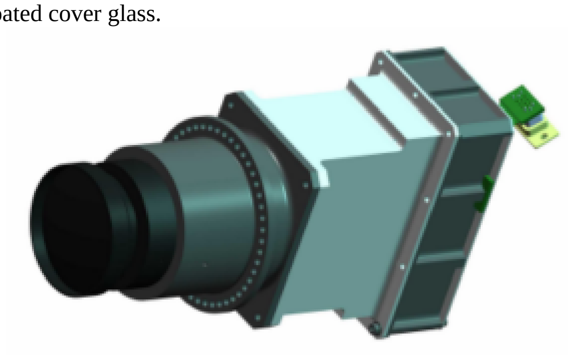


Figure 3: Camera head

Optics: The lens is a Schneider Apo-Componon HM 150mm FL (aperture f/4). It's a flight proven lens (flown onboard Tsinghua-1 satellite in 2000). This commercial lens has been subject to a set of test prior to use.

Filters: They are high quality dichroïc filters in the optical assembly provided by BARR Associates Inc.. Due to the mission requirement, the spectral band is red [523-605nm], Green [629-690nm] and Near Infrared [774-900nm]. The spectral characteristics are identical to the Landsat ETM+ bands (2, 3 and 4)

Electronic modules: Two boards shares the same PCB module (one for each bank of three channels).
Each board are fully independent and drives the three channels (red, green, infrared). It encloses:

- An FPGA circuit which is the heart of the module as it plays the main role: receives imaging parameters and generates signals for CCD sensor, LVDS, ADC…etc.
- Three programmable ADC which convert the image signal into digital value and send the data via an LVDS to the storage modules.
- A local microcontroller interfaces the board with the OBC via a CAN node.

Each module can be operated individually or synchronised together to work in a full 6 channels mode.

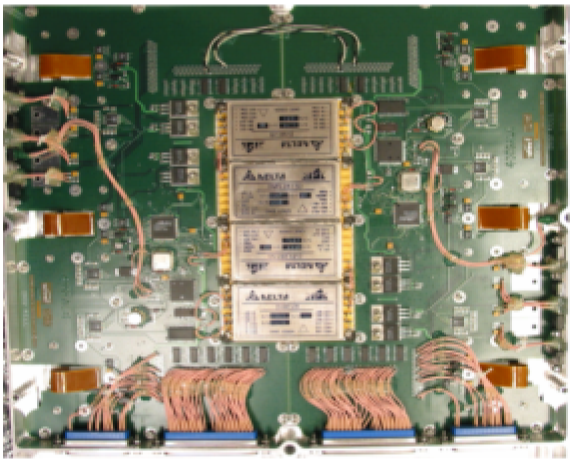


Figure 4: Camera electronics

Storage: Thanks to two adding up Solid State Data Recorder (SSDR) based on Power-PC processor and totalising 1Gbytes data and one redundant unit of 128Mbytes based on StrongARM (SA1100) and acting as a backup unit.
Each bank is linked to the three storage units via a synchronous serial input streams at nominal 20Mbit/s allowing a flexible satellite operation.

3. QUALIFICATION TESTS

For Alsat-1 mission, the storage units and the camera represent new modules (except SA1100 which was flown onboard a SNAP nanosatellite). Therefore, they follow all, several qualification tests (vibration, environmental test, thermal vacuum test, electromagnetic compatibility, etc.).

3.1 Imager Alignment tests

Because of their relative complexity with its six independents channels, the imager on Alsat-1 was the critical subsystem. It has a high demand on the optical and opto-mechanical alignment accuracies. Hence, two types of alignment were applied:

Interchannel alignment: The central channel of the bank (red filter) was selected as reference then two by two alignments carried out with the two other channels. The goal was to have the three lines sensor parallels within an acceptable margin. A complex mechanical adjustment was done.

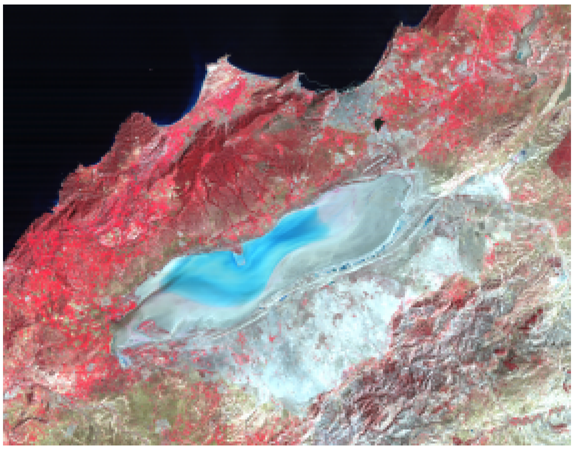
Interbank Alignment: the same central channel was selected for both bank then an interbank alignment was achieved so the two same channels (i.e.: red) will have their sensor line aligned in continuity to achieve a double line sensor (within an acceptable margin).

4. ALSAT-1 FIRST RESULTS

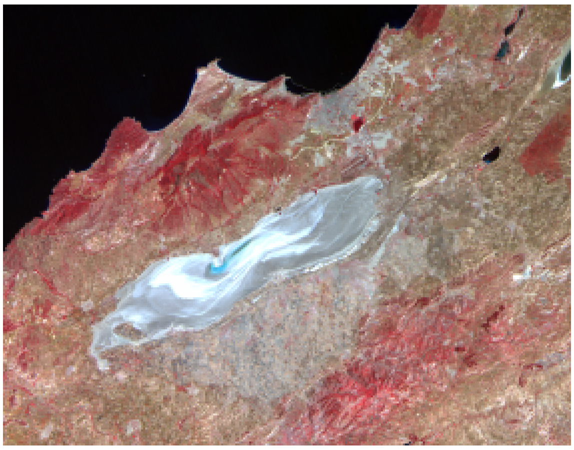
We began the commissioning phase just after the launch. The camera and the SSDR showed their characteristics close to the nominal values.

The first successful image of the Algiers bay was obtained a week after the beginning of the imaging tests because of the bad meteorological conditions (it was winter in Algeria).
A first commissioning review one month later showed that the equipments were reliable (no electric breakdown until now) but the orbit required a correction (due to a slight injection error of the satellite). This was achieved throughout six weeks (over March & April 2003) to pass from the elliptic orbit [684-745 km] to a circular one with a 686km altitude. It did not affect in a visible way the images quality.

The examination of the 300 images taken during the first year showed qualities close to those of Landsat. The spectral characteristics are almost identical on the other hand the images of Alsat-1 are geometrically less fine (in urban zones) as shown on the photo 5.



Landsat-5 TM image on region of Oran taken on 15 Mar. 1993
© LANDSAT data



Alsat-1 image on region of Oran taken on 28 May 2003
© CNTS 2003

Figure 5: Alsat-1 vs. Landsat images

The images also showed the other distortions more classic like:
The visible “vignettage” effects (unequal optical transmission factor between the centre and the edge of the optics) due to the exceptional wide swath width. This effect identified during the pre-flight tests was easily corrected.

The visible "stripping" effects on both bank (more visible on bank0). This effect is created by the CCD sensor. It would result from bad "Reset" for pixels pairs (some electrons remains in the output stage increasing by a constant value the grey levels of pixels pairs). This error also identified during pre-flight tests was easily corrected

5. ALSAT-1 CARACTERISTICS

Alsat-1 has three major characteristics, which distinguish it from the other microsatellites. We tried during this first year of satellite operations to put them in evidence.

5.1 Wide swath width

The main characteristic of Alsa-1 is to achieve a daily revisit in conjunction with the other satellite of the constellation. Hence, a large FOV was implemented. Several full size images were taken as this one taken on September 2003, the 28th, in the North-East of Algeria. It shows the exceptional big size allowing to cover 33.6 million hectares. This shows the importance of the area that can be covered: 10 images are enough to cover the hole of Algeria with its 2381741km^2.

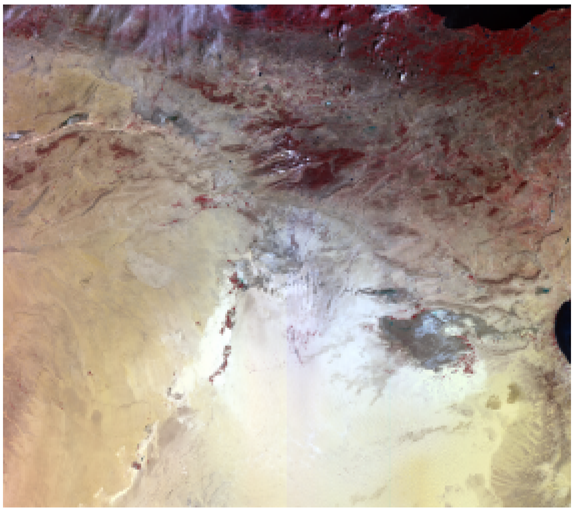


Figure 6: Alsat-1 image of Chott Merghir (Algeria) taken on 28 Sep. 2003 © CNTS 2003

5.2 Windowing

This function was added during the design of the satellite to avoid a saturation of the storage units and add more flexibility during the satellite operation. Alsat-1 being an experimental satellite, this function should allow us to image various types of area (around the world). This characteristic was able to be exploited to take images of an exceptional size.
We can see on the photo 7 the example of an image taken with bank1 (half Alsat-1 capacity) on the entire Nile River in one pass (from the Nasser lake to the mouth of the Nile on the Mediterranean Sea): a total image size of 160x1088 km. We could double the swath using both banks simultaneously.

5.3 Short Revisit time

The exceptional swath width of Alsat-1 allows obtaining a particularly short pseudo period (for a satellite not equipped with an Off-Pointing capability). This possibility was exploited during the fire monitoring campaign during summer, 2003 to quickly react during the start of a fire.

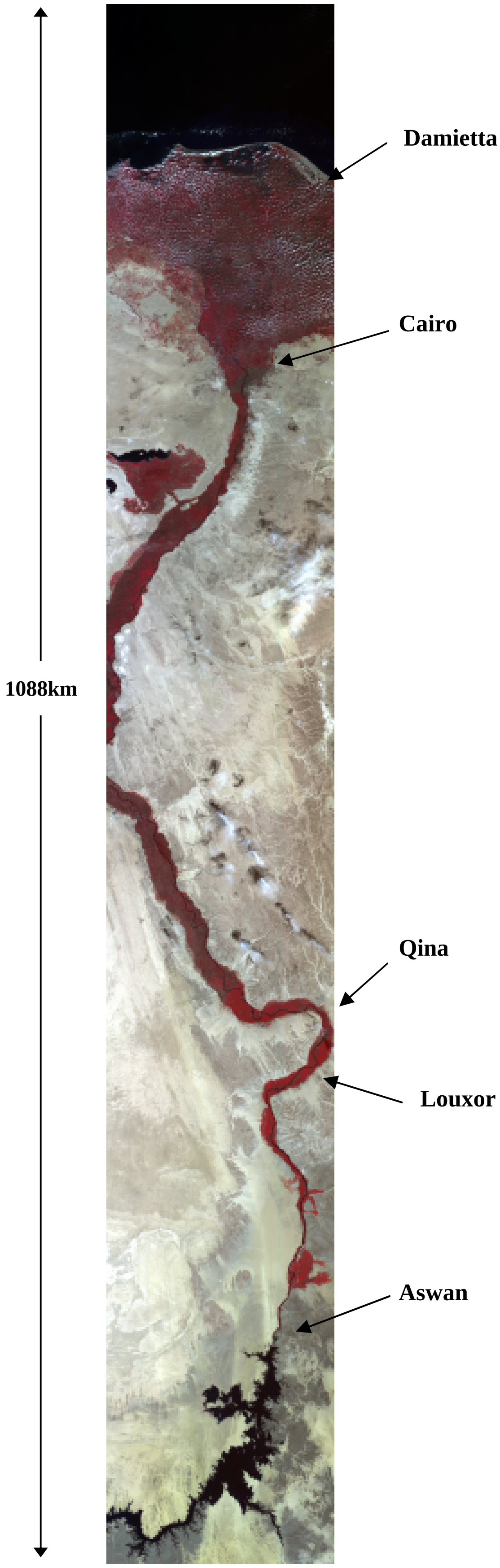


Figure 7: Alsat-1 image of the Nil River (Egypt) taken on 19 Oct 2003 © CNTS 2003

Photo 8 shows a starting of fire in the Monchique Bio-Park in Portugal, taken on August 2003, the 11th at the very beginning of the fire. A zoom of the image allows to identify the number of fire breaks and so to concentrate the means of intervention there to avoid a fatal progress as on photo 9 taken on the same area one week later on the19th.

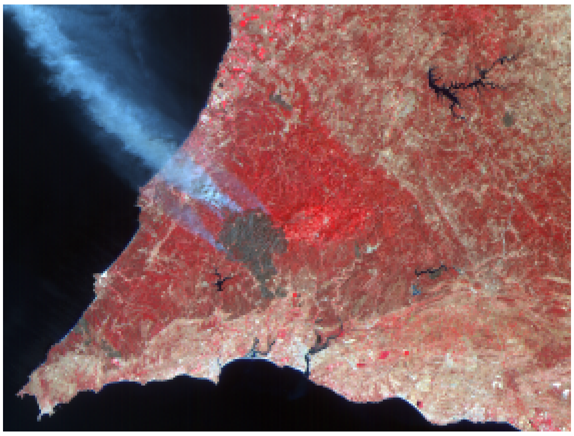


Figure 8: Alsat-1 image of Monchique Park (Portugal) taken on 12 Aug. 2003 © CNTS 2003

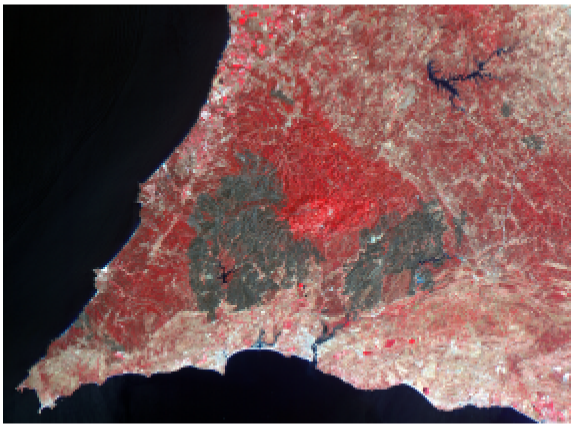


Figure 9: Alsat-1 image of Monchique Park (Portugal) taken on 18 Aug. 2003 © CNTS 2003

6. CONCLUSION

The first tests showed satisfying results. The image quality is good. The artefacts were easily corrected.

The specifications of the satellite are adapted to the mission (national needs in remote sensing and specific needs for the constellation) and the operation is quite flexible.

We have more to do on radiometric calibration but that is another story.

REFERENCES

Curiel A. & all., 2003, First Steps in the Disaster Monitoring Constellation, 4th IAA Symposium on Small Satellites for Earth Observation, Berlin, Germany.

Bekhti M. & all., 2002, AlSAT-1: The first step into Space for Algeria, Proceedings of the 53rd IAC and World Space Congress, Houston, TX, IAC-02-UN/IAA.3 rd.01.

Sweeting M.N., Chen F.Y., 1996, Network of low cost small satellite for monitoring & mitigation of natural disasters, 47th International Astronautical Congress, Beijing, IAF-96-C.1.09

Rachedi A., 2002, Utilisation de l'Outil Spatial pour le Suivi des Catastrophes Naturelles - Cas de la DMC, 3^{e} Forum des Assurances, El Aurassi – Algiers.

Chu V.Y. & all., 2000, Disaster Monitoring Constellation, IAA-00-IAA.11.4.03, Proceedings of the 51st IAF.

Tarel J. P., 1995, Calibration Radiométrique de Caméra, Rapport de recherche N°2509, INRIA.