Micro-electronic and Instrumentation Laboratory

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Title: ELYSSAT: A Nano Satellite for the desert remote-sensing.
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Need

Desert of Tunisia needs timely observation but Tunisia has not a satellite.

Mission Objectives

ELYSSAT objectives could be distinguished as humanitarian and Scientific objectives. Therefore, we would like to develop a Tunisian Nano-satellite for remote sensing which could be helpful for :

1. Control and management of actions to combat desertification based in the data sent via our future Nano-sat.
2. Locating missing person. Since it has no mobile network in the desert of Tunisia, this can be dangerous for people who make circuits (4x4 or camel) and hiking trips and competitors in the Rally of Tunisia. Satellite images provided by the constellation of the Nano-sat can help us locate missing persons.
3. Obtaining a series of images over the same scene can help us making digital elevation model (DEM).

Concept of Operations

There are four operation phase:

- Before nominal operation
    - This phase includes six steps: design, development, assembly, integration, testing and launch.
    - In this phase, we would like to practice our skills and knowledge to design our own Nano Sat. this phase continue until the launch.
    - Nanosatellites or cubesats are typically launched and deployed from a mechanism called a Poly-PicoSatellite Orbital Deployer (P-POD) mounted directly on a launch vehicle.
- Nominal Operation
    - This operation is most important it's consists of two modes (Figure 1):
        - The Control mode
        - The Data mode
    - In this operation the connection has two different models:
        - Standard connection model (Figure 1)
        - Alternative connection model (Figure 2)
- Contingency Operation
    - This operation start in the emergency mode though will only be active if something on the Nano Sat goes wrong.
- Replacement/Retirement Operation
    - Replacement operation is important for sustainable system, especially mission continuity is important for the daily observation of the evolution of the surface of the desert.

The satellite description will be discussed with details in next sections.

The Ground operation system will be a small ground station from ISIS. With its small satellite communication ground stations ISIS offers a solution that is specifically designed for small satellites in Low

Earth Orbit using radio amateur frequencies. The ISIS ground station is derived from the proven set up of the ground station of Delft University of Technology, which has been successfully used to provide support during small satellite missions and is the designated command ground station for the Delfi-C3 satellite mission. ISIS can provide a compact version of this ground station that contains everything a small ground station needs. This ground station provides a remote operation options, so It is possible to configure and control the ground station remotely through the internet. It costs 27 500 euros.

The images received by the ground station will be processed using the Erdas Imagine V9.1 software. Using a macro in this software we can obtain the image changes or the DEM automatically in few minutes.

Key Performance Parameters

1. Obtaining a big number of image for the same scene may help us to create a Digital Elevation Model (DEM) more accurate than the existing one.
2. Spatial resolution < 5m.
3. Our team has experience in the field of change detection for monitoring the surface areas (urban, green, water,...) using satellite imagery [1]. This advantage can allow us to apply the same techniques in order to monitor desertification.
4. Low power, mass, volume, cost components for earth observation.
5. Self-deployable solar panel for larger area to intercept sunlight.
6. No mechanical system

Space Segment Description

The system of ELYSSAT-1 consists of central unit and four subsystems such as the Communication subsystem; the Electrical Power subsystem; the Attitude Determination and Control subsystem and the Sensors subsystem. The system block diagram of our SAT is represented in Figure 3.

The general specs of ELYSSAT-1 are mentioned in the table below:

Table I. The general specs of ELYSSAT

Dimensions	3U : 30x10 cm Cube
Mass	3 Kg
Expected life time	2 years
Altitude	ELYSSAT-1 : 90km, ELYSSAT-2 : 270km, ELYSSAT-3 : 450km

The Power, mass, dimensions and prices of all components will be detailed in Table II. The connection between the central unit and the others electronics components will be an USB interface.

1. External Configuration

1. Structure : 3-Unit CubeSat Structure

The ISIS 3-Unit CubeSat structure is a developed as a generic, modular satellite structure based upon the CubeSat standard. The design created by ISIS allows for multiple mounting configuration, giving CubeSat developers maximum flexibility in their design process. It was tested and accepted in different test condition : Vibration, Mechanical Shock, Thermal Cycling, Thermal Vacuum.

2. Antenna System :Turnstile Configuration Deployable Antenna System

The ISIS deployable antenna system contains up to four tape spring antennas of up to 55 cm length. The system can accommodate up to for monopole antennas, which deploy from the system after orbit insertion.

3. Solar panels: 5 x NanoPower Solar 100

The NanoPower Solar 100 is an integrated side panel solution for CubeSat satellites on a single PCB only 2mm thick. The solar cells are space qualified triple junction cells from AzurSpace giving an effeciency of 28% or more. Two cells are reflow soldered to the panel and connected in series to achieve an output voltage of appr. 4.6V suitable for the NanoPower P-series power supply systems from GomSpace.

We plan to make the 4 solar panels self-deployable to increase the surface facing the sun. (without a mechanical system).

4. ADCS components : CubeSat Magnetorquer

Magnetorquers offer a method of controlling the attitude of a spacecraft. This can be achieved either directly, by interacting with the local Earth's magnetic field, or in combination with reaction wheels where they allow a method of dumping excess momentum in the wheels without the need for a complex propulsion system.

2. Internal Configuration

1. Power System : NanoPower P10U Power Supply

This system can interface to up to 6 solar arrays; one per spacecraft facet. Is compatible with USB battery charger and with dead launch via separation switches.

2. Communication System : FM - VHF downlink / UHF uplink Full Duplex Transceiver

It adds telemetry, remote control and beacon capability to the mission in a single board. Available with 9600 bps downlink data rate, and AFSK or Manchester FSK uplink. It include the AX.25 protocol and other protocols.

3. Sensors

The camera will be a 18 MP Digital Camera with 6x Optical Image Stabilized Zoom with an autofocus, Picture stabilization in action and SDK to be commanded from the central unit. The battery of this camera can be recharged using the USB cable connected to the motherboard. We estimate getting between 1 and 5 pixels/m spatial resolution. A Telephoto Zoom Lens will be added to the camera with a 200 mm of focal length. For the dimension constraint we can't replace the 200 mm Telephoto Zoom Lens by the 800 mm one. But if we will decide to increase the size of the Cubesat it will be possible to enhance the current image resolution.

The GPS receiver will be connected to the mainboard using an USB cable. It will be used to determine the exact position of ELYSSAT in the orbit.

Temperature, Accelerometer and Sun sensors.

4. Central unit

Pico-ITX is a PC motherboard form factor announced by VIA Technologies. The Pico-ITX form factor specifications call for the board to be 10 x 7.2cm. The integrated processor can be a VIA C7, a VIA Eden V4, or a VIA Nano 1.5 GHz, with 128KB L1 & L2 caches. It uses DDR2 400/533 SO-DIMM memory, with support for up to 1GB. It has been demonstrated running Microsoft Windows XP and Windows Vista. Modern versions of major Linux distributions.

Table II. List of components

Components	Power	Dimensions : l x w x h	Mass	Price
Structure		Outside Envelope : 100 x 100 x 340.5mm Inside Envelope : 98.4 x 98.4 x 98.4mm	580g	€ 3,800.00

Antenna System	Electrical power: < 50 mW RF power: <= 4W	98 mm x 98 mm x 7 mm	<100g	€ 5,500.00
ADCS components	200mW	70 mm x 08 mm x 8 mm	30g	€ 1,150.00
Solar panels		82.5mm x 98 mm x 2.1mm	5 x 7g	€ 2,000.00
EPS		96mm x 90mm x 26 mm	262g	€ 2,500.89
Communication	<1.7W (transmitter on), <0.2W (receiver only)	96mm x 90mm x 26 mm	85g	€ 7,500.00
Mainboard VIA Pico-ITX	<1 W	100mm x 72mm x 20 mm	100g	€ 272.00
Canon EOS 60D		144.5 x 105.8 x 78.6mm	755g	€ 1,300.00
Telephoto Zoom Lens		199 x 88.8 x 89mm	1490g	€ 1,500.00
Rikaline GPS-6010		50mm x 59mm x 20mm	20g	€ 30.00

Table III: Captured image resolution

Sat with Altitude	Area covered in one image	Spatial resolution	Number of image to cover all the Tunisian desert
ELYSSAT-1 at 90km	10125m X 6750m	3.8 m /pixel	838
ELYSSAT-2 at 270km	30375m X 27000m	34 m / pixel	70
ELYSSAT-3 at 450km	50625m X 33750m	95 m /pixel	34

3. Mission Objectives

We have three objectives: the first and the third are based on images captured and sent by ELYSSAT and processed by the operator in the ground station using the Erdas Imagine v9.1 software.

The second objective is realized using A transmitter. This small device sends out a signal in the form of radio waves containing the GPS information such as the transmitter used in Tracking an animal by radio. The satellites using a receiver track the transmitter's path as it moves. Finally the satellite send this path to the ground station.

Orbit/Constellation Description

To have an interesting time resolution and to cover all the Tunisian desert area we will schedule the launch of three ELYSSSAT. Those satellites can communicate with each other and with the ground station as in figure 2. The data exchanged between the satellites and between one satellite and the ground station will be encrypted before the transmission. Those three satellites will be ejected in 3 different altitudes : 90km , 270km and 450km to provide 3 different image space resolutions (Table III).

Implementation Plan

Combating desertification is a priority project in Tunisia. The Sahara Desert covers an area of between 33% and 40% of the territory (163 610 km^2) as we define it according to its aridity or as landscape features.
ELYSSAT project study has started since October 2010 in the Micro-electronic and Instrumentation Laboratory. A 60 m^2 area equipped with instruments and computers.
The time estimated for developing and testing ELYSSAT is about 2 years.
The top-level project schedule is as follow:

1. Prototype Design (about 4 mo)

Design the details of the instruments for the satellite based on the preliminary design.

2. Development (about 4 mo)

Develop the software part allowing us to control and command Cubesat with computer.

3. Assembly (about 1 mo)

Assembly all the component of the Cubesat.

4. Integration (about 2 mo)

Integration of the hardware and software together and centralize the on board computer data exchange.

5. Manufacture and testing of Engineering Model (EM) (about 6 mo)

Build EM. Conduct testing in harsh environments (extreme temperature, vacuum, vibration, etc.) to confirm that the EM can survive in space.

6. Manufacture and testing of Flight Model (FM) (about 6 mo)

Tests with a high altitude balloon system.
Receive feedback from the EM tests, build FM, and conduct space environment tests.

7. Launch (about 1 mo)

8. Initial Operation (about 1 mo)

After successful launch, check the status of the satellite in space.

References

[1] Rochdi Bouchiha, Kamel Besbes, ***Apport de deux méthodes de suivi d'évolution de la zone urbaine par imagerie Landsat***, Revue Française de Photogrammétrie et de Télédétection (SFPT), n°190, pp.40-48, 2010. http://runners.ritsumei.ac.jp/cgi-bin/swets/hold-query-e?idxno=30851133

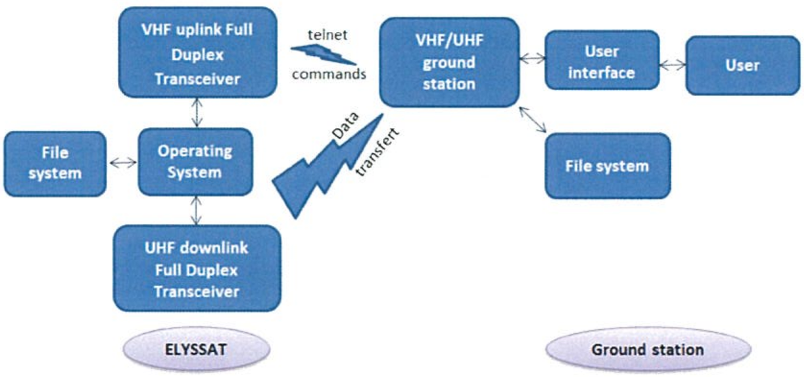

Figure 1: Standard connection model

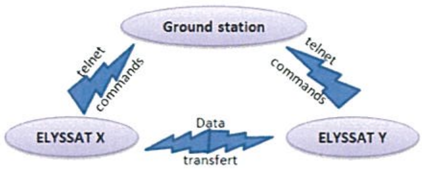

Figure 2: Alternative connection model

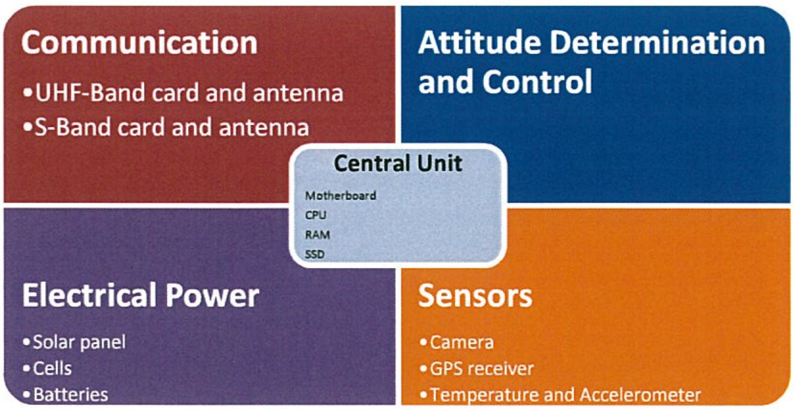

Figure 3 : ELYSSAT-1 subsytems