

# τετραφάρμακος : Vegetation, atmosphere and flight parameters monitoring

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## Abstract

The τετραφάρμακος<sup>1</sup> is a Cansat project of the *Proton-thérapeutes* team for the second participation of the Institut d'Optique Graduate School to the C'Space competition co-organized by Planète-Sciences and the CNES.

This space probe as a homemade embedded module to detect chlorophyll. It will also make an atmospheric sounding and position tracking during its fall.

We hope these complementary studies could help to determine the chance of life on an Earth-like exoplanet.

## 1 INTRODUCTION

First of all, we need to precise that a Cansat is not really a satellite contained in a can. Indeed it will only fall instead of enter in any orbit. Then it is actually a space probe.

We are making the τετραφάρμακος in order to participate to the competition a Cansat competition co-organized by Planète-Sciences and the CNES : the C'Space 2012. It have to fulfill 2 missions, one of which is free. For the imposed mission, we decided to do an atmospheric sounding. And our Fourier Optics professor Jean Taboury suggested us to make an NDVI measurement for the free mission.

In addition to these 2 missions, another aspect of our work is to build a whole system. That means a probe that can be contained in 33 cL, fast enough to acquire a lot of informations, electrically autonomous, entirely automatic during the flight and finally resistant to a 200m fall — using a parachute, of course.

## 2 Context of development

### 2.1 Club

The *Proton-thérapeutes* team is composed of 3 first-year MSc students at the Institut d'Optique Graduate School. The first time our school participated to the Cansat competition was in 2011. This project has been initiated by Jean-Marie Feybesse, IT professor at Paris XI. But unfortunately, this team<sup>2</sup> didn't reached the last step of competition because of logistic issues.

As the previous team, we are 3. This number is too little not to be aware of the work of the whole team. Each member has not a specific work. Nevertheless some leadings have emerged, then we can describe the team as the following list:

- Clément: mechanics and electronic circuits designer
- Denis: electronics and cameras implementation
- Zubair: sensors implementation and parachute design



Figure 1: *Proton-thérapeutes* team. From left to right : Clément, Zubair and Denis. A friend of ours is holding the imagery system

### 2.2 Work plan

The team has been formed in November, our first job was to find the best electronic parts for our applications and draw a quick draft of the τετραφάρμακος organisation. Then we tested all the components we received. These preliminary tests went right but they have been done on a breadboard.

In April we decided to face non-electronic issues while we were trying to minimize the hardware connections. In May we felt good with non-electronic parts, our main job is now to get cameras working as we want.

We have planned to have electronic unity with cameras and sensors in June, and input all the parts in plastic tube. Then we believe we will be ready in July to do our first test flight.

<sup>1</sup>pronounce tetrapharmakos

<sup>2</sup>Archimede, leaded by Sébastien Giudicelli

### 3 DEFINITION OF THE MISSIONS

#### 3.1 Proposed mission : Atmospheric sounding

We chose to measure the temperature, the humidity and the pressure during the fall of our cansat thanks to two electronic captors : the BMP085 that measures the temperature and the pressure, and the DHT22 that measures the temperature and the humidity.

Measurements are made every two seconds, which is the refreshment rate of the used captors, and the requirement of the mission.

#### 3.2 Free mission : chlorophyll detection

In this mission, we detect active chlorophyll by multispectral imagery.

##### Chlorophyll spectrum

Chlorophyll absorbs much red, and emits in near infrared, as we can see on Fig 2.

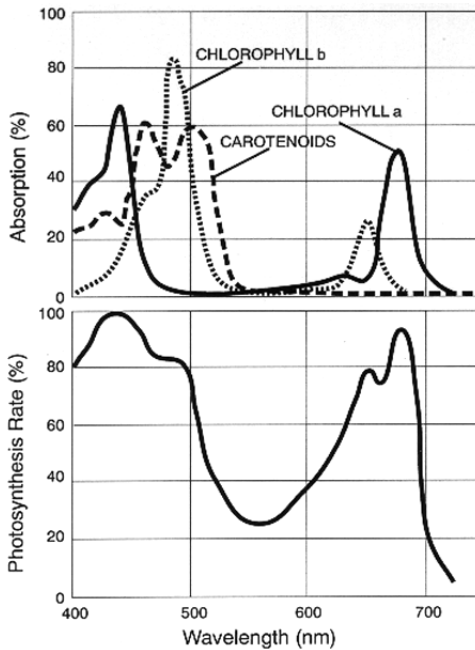


Figure 2: Absorption and fluorescence spectrum of chlorophyll

So we use this by taking two pictures of the same scene, one in a red spectral band, the other in a near infrared spectral band. We then calculate the Normalized Difference Vegetation Index (NDVI) with this formula :

$$NDVI = \frac{RED - NIR}{RED + NIR}$$

##### Detection system

The images in red and in NIR bands are taken by two CCD. In order to detect red on one CCD, and NIR on the other, we use

a cold mirror and filters. The hot mirror transmits most of visible light, and reflects most of infrared. Just like the chlorophyll its reflection and transmission spectrum cuts around 700nm.

Just before the CCD, we put filters because the hot mirror reflects a part of the visible light (by eye observation about as much as a regular glass, about 4 %) and it transmits all the visible light and not only the red part. The use of the hot mirror allows to keep a better part of the flux for both bands than a simple beam splitter, and allows to cut infrared for the red detector.

Before the hot mirror, we use a camera lens to form the image on both CCD, for instance we used a simple lens. The schematic of the optical system is given on Fig 3.

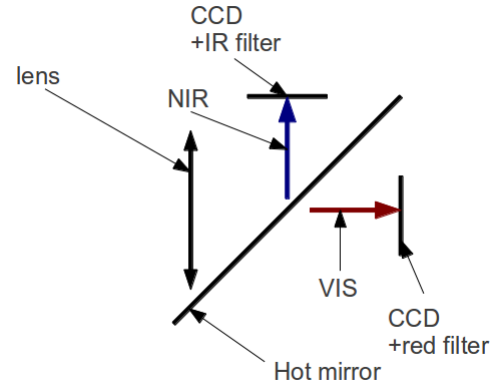


Figure 3: Schematic of the imagery system



Figure 4: Photograph of the assembled imagery system

#### 3.3 Additional measurements

We also track the position and the speed of the cansat thanks to an accelerometer and a GPS module. It will be useful to fit pressure measurements with a model.



Figure 5: A picture taken by our system in NIR

## 4 CANSAT ARCHITECTURE

### 4.1 Electrical architecture

The electrical architecture of the τετραφάρμακος is based on 2 Arduino Mini which load ATmega328 micro-controller. Because of an instable serial connection we found wiser to use each Arduino for a camera instead of putting the 2 cameras on the same. Then the architecture we decided is not the more elegant we would hope to have at first, it is described below:

- Arduino n° 1 (micro-controller)
  - $\mu$ CAM n° 1 (camera)
  - DHT22 (humidity, temperature sensor)
  - BMP085 (pressure, temperature sensor)
- Arduino n° 2 (micro-controller)
  - $\mu$ CAM n° 2 (camera)
  - ADXL335 (accelerometer)
  - GPS module
- Xbee Pro (radio communication module)

The cameras embedded are able to store an image in cache to send it on demand by a serial connection. We can use a software serial communication instead of a real hardware UART, which we do with the XBee and the GPS, but in the case of the camera, we did not manage to make the camera detect the highest baudrate (115200 bauds), so we preferred to use hardware UART for both cameras.

### 4.2 Mechanical parts

There are 3 main mechanical parts in the τετραφάρμακος : the cameras cube, the parachute and the tube.

The cameras we decided to use were shipped with their own lens. But this part was too large to be used in a cansat, especially when we need 2 cameras. Thus we have unmounted these parts to use a unique lens. We designed a cube to stabilize

the position of each part. By the way we put a place to set the hot mirror.

We will try to take the most photographs we can during the flight. We also made a parachute to limit the speed of the τετραφάρμακος to the *minimum* autorised by the rules. It has the shape of a cross, composed of 5 squares. To determine the total surface we compute

$$S = \frac{2mg}{\rho C_x V_L^2}$$

with the mass  $m = 0.3$  kg, the gravitational acceleration  $g = 9.8$  m/s<sup>-2</sup>, air density  $\rho = 1.2$  kg/m<sup>3</sup>, the drag coefficient  $C_x = 1$  and the speed we want  $V_L = 2$  m/s. We found a surface about  $S = 1.5$  m<sup>2</sup>

Last but not least, the tube in which we will put all the components is obviously an important mechanical part, but it is a simple part. The Archimede team has given us a plastic tube. We have also made some circle by cutting PCB. And we have found spindles in brass to organize the space inside the can.

### 4.3 Telemetry

Datas are sent all along the flight thank to the XBee. We use the XBee as a simple serial cable replacement.

During the flight, several type of data are to be transmitted. Datas collected from atmosphere captors, accelerometer and GPS are sent as plain text. Photographs are sent as binary packages. In order to manage all those datas, we use a header system. Plain text data packages are expected to be one line long and end by a carriage return. Binary package headers contain the length of the package.

Since there is two micro-controllers, and that each of them as datas to transmit, the XBee is shared by the two, and since most of the volume of datas are pictures, sharing of the XBee is cadenced by the pictures taken : when a picture is taken by both cameras, one of the Arduino begins to transmit the full picture (in several packages), then all its buffered text datas. Then the other Arduino does the same.

### 4.4 Flight algorithm

Cameras are powered off during until the beginning of the fall in order to spare batteries. When the beginning of flight signal is given, cameras are powered on and initialized and all captors begin to make measurements.

Atmosphere captors make measurement every two seconds, while accelerometer and GPS make measurement every seconds. The datas of Atmospheric captors, accelerometers and GPS are buffered until they are sent as described above. Picture are taken as fast as possible, that is as fast as pictures from both cameras can be taken simultaneously and both sent. Each camera can buffer one image, and so it can be kept until it is transmitted.

On landing, the program goes on as it did during the flight for several seconds, then cameras are powered off and all transmissions are stopped.

#### 4.5 Budgets

	Qty	Total (€)	Description
Arduino Mini V04	2	34,20	microcontrollers
Mini-USB adapter	1	15,00	
BMP085	1	18,50	pressure, temperature
RHT22	1	15,00	humidity, temperature
ADXL335	1	22,46	accelerometer
GPS	1	28,00	GPS
XBee Pro	2	71,52	data transmission
XBee Dongle USB	1	20,58	USB adapter
μCAM	2	112,42	camera
Mechanic		0,00	
Optic		0,00	
TOTAL		337,68	

Table 1: τετραπάρμαχος components prices

## 5 CONCLUSION

After learning about the difficulties that appears when we carry such a project, we have now finished the hardware electronic part, and have just to solder definitive electric connections here and there. The big part of the mechanical structure is now built (we have a tube and the supports are built).

We have yet to put all the components in it. We can test every electronic components except the cameras, with which we took picture on a computer with a program of our own, and made work almost everything on a Arduino, but we still only have obtained corrupted image files. Before the flight, we have to definitively assemble all the parts of the τετραπάρμαχος, figure out the problem with the camera, finish the programming and test it all.

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- Lionel, from Snootlab, that helped us to choose the right material for programming the arduino.

## Credits

- Fig 2 : John Whitmarsh and Govindjee CC-BY-SA-2.0.