

# A 12 YEARS BRAZILIAN SPACE EDUCATION ACTIVITY EXPERIENCE

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## 1-Introduction

After an year of studies, the members of “SPACE”(Sistema de Pesquisa Aeroespacial Científica Educativa) of UNOPAR (Universidade Norte do Paraná) launched on July, 21 of 2001, the first Experimental Rocket of our University. The rocket is called “STAR” (Sistema de Transporte Aeroespacial Recuperável), and its main objective was to fly, open the chutes, and come back on the ground no damaged. For being a very complex project, including different specific areas, the SPACE was divided in groups, each one was in charge of a part of the rocket: one of the structure, one of the engine, one of the altimeter, one of the accelerometer, and one group was in charge of GSP (Global Positioning System). Each group presented seminars to inform to the other members how the project is, this way, every one has knowledge about every part of the project.



## 2-Structure

The structure was developed with a PVC tube and parts of iron, aluminum, and other materials.

Using a PVC tube, with 1600 mm of length and 150 mm of diameter.

We got three openings on the tube, two of that was to the chutes, and the another one was to access the electronics components of the rocket.

By side in picture 1 we have a tube's photograph.

The rocket none one has a tangent shape and 730mm of length and 150mm of diameter on base, it was built of fiberglass, and was done from a wood cast. As in the photo below.



An iron skirt was done with 74 of length and 165mm of diameter to encase the engine and to fix the wings. See picture bellow .



<b>Nose</b>	Glass fiber	0,750
<b>Pyrotechnic</b>	Bin	1,130
<b>Skirt</b>	Iron	1,455
<b>Pin/ Stream</b>	Iron	0,555
<b>Fuel</b>	Solid	11,200
<b>Engine</b>	Iron	9,700

To fix the nose on the PVC tube and to fix the tube on the skirt was done two flange .

To fix the tube with the nose, was done connector called superior flange and another one, called inferior flange, was done to fix the tube with the iron skirt. The inferior flange is in charge of link engine and the chutes through a pin

The pin was done of iron, and on the base it got a thread M10, the engine was fixed through a screw on the rocket.

And in the other end, the pin got a stream to be laced for the chutes' string.

Between the flanges was put three aluminum plates to fix the electronics components and also to give to the tube more hardness.

The chute doors and the electronic door was also done with PVC tube.

To eject the chutes was used pyrotechnic charges that will be explained in another chapter.

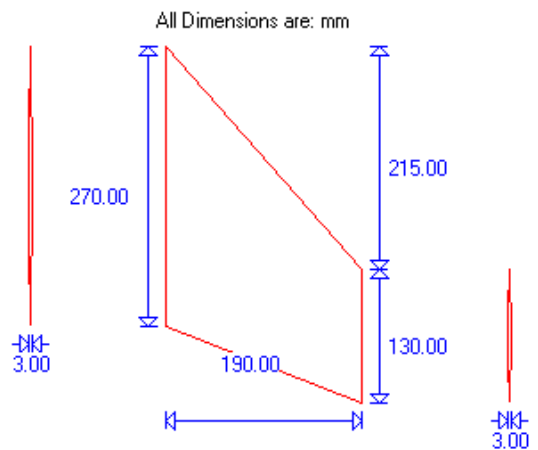
The STAR has a mass of 32,8kg with the solid fuel. On the next table we have the mass of the parts used on the rocket.

<b>PARTS</b>	<b>MATERIAL</b>	<b>MASS (Kg)</b>
<b>Finns</b>	Aluminum	1,440
<b>Plates</b>	Aluminum	0,570
<b>Flange 1</b>	Aluminum	0,615
<b>Flange 2</b>	Aluminum	0,850
<b>Tube</b>	PVC Tube	3,695
<b>Doors</b>	PVC Tube	0,810

### 3-Finns

The finns was projected from Barrowman method 1, through AEROLAB 2 software. A static margin of 230mm. For successive approximations was defined the finns sizes.

An aluminum plate was used to get four

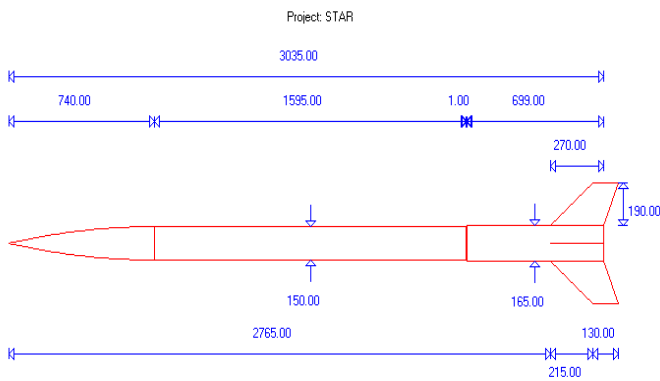


wings as shown in picture below.

The stabilizer wings was done of Aluminum with 2,4mm of thick, it's format was defined after a lot of computer's simulations using a software named Aerolab, It was filled the datas of the rocket like: type and size of the nose, tube diameter, and others, we projected a imagine wing, added the numbers of wings used, its size and the position where it will be, after that we done the simulation.

Then we find the pressure center. We changed the wings format until the pressure center stays far 1,5 diameter from Gravity center, to get the rocket stability.

Look below the final format and the draw of the rocket project with the Pressure Center.



#### 4-Pyrotechnic

The pyrotechnic system that we used in our project was developed by our group, teacher and students working together.

Its main objective is eject the doors to open the chutes, the signal to turn it on comes from the altimeter or the accelerometer.

The doors are locked by a pin with a little plate with a hole of 9,5mm.

This pivot is fixed on the pyrotechnic charge for a pin that goes through the hole on the plate, when exploded, the charge breaks up the pin leaving the chute door. To be sure that it will work properly, springs help to throw the doors away.

Look below the pyrotechnic pictures.



#### 5-Chutes

The STAR has two chutes, the *drog* and the *main*, and they work like shown below:

When the rocket gets the drogue, it opens the little chute(drog), this chute reduce the

acceleration of the rocket, and when the rocket gets 200m of altitude the second chute opens and make sure that the rocket won't touch the ground damaged.

Both chutes are composed of five rectangles drawing a cross. The rectangles are different sized for each chute. The little one(drog) is 0,43 x 0,43m and the main is 0,86 X 0,86m.

#### 6-Assembly Software Development for a microcontroled altimeter

##### 6.1-Brief

The experimental rocket development demands several characteristics treatment, for example, parachute controls, rocket positioning and trajectory information recording. This characteristics must be related separately, to the final project reach success. At Universidade Norte do Paraná, the Computer Engineering and Eletronic/Telecommunication Engineering students work with a lot of integration, there is task divisions to develop the rocket. The SAAM team (Software em Assembly para Altímetro Microcontrolado) was responsible to develop the altimeter, making the software to aquire the analog data generated by a pressure sensor, converting this data to digital signal that could be used by microcontroler. The software as programmed using the Assembler language, and the simulation test where executed with the microcontroler Kit.

##### 6.2- The Project

As we know, the altitude is inversely proportional to the pressure. So, the first flight session data (50 - 3000 m high), are recorded with a regressive way, because the pressure slows down gradually. At second session (3000 m - start point) the data are progressively recorded. The data are generated by the pressure sensor with tension format, witch make the memory recording easier, trough the hexadecimal conversion, maintaining the trajectory history information. This kind of resource is called analog to digital conversion. To analyze the data recorded at memory the reverse engineering is used, trough the digital to analog converter. For higher data precision, the software

will begin the data recording process at 50 m high, which guarantees that any rocket state variation is treated as being its launching. Initiating the launching, the counting loops till there is reading of the same altitude position twice, which represents the beginning of fall and, the top of trajectory. When the 300 m high is reached the system opens the parachute feature.

The sensor used is the MPX4100A from Motorola. Through the instructions at MPX4100A datasheet, the tension generator was correctly connected to pressure sensor. A tension output was connected to get the tension generated by sensor, and another connection was necessary for ground stuff.

### 6.3-Results

- Practice Results obtained till the moment
- Results Analyze
- Conclusion prevision

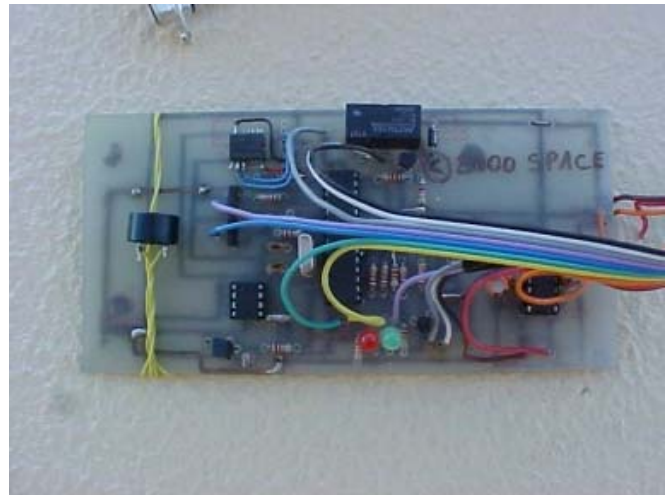
## 7- Rocket on board Microcontroller

### 7.1- Introduction

The system that will be present was developed based on a Microship PIC microcontroller, and its function is control some events in experimental rockets, such as: acceleration acquisition for parachute open feature, engine ignition checkup, photographic engine controls (optional), engine starter state signaling, acceleration sensor state signaling and photographic engine presence.

The prototype is on final phase testing, and must be test at real condition in the next Star rocket flight. The system capability of acceleration data acquisition, and at simulated form, commands the auxiliary parachute open system will be tested on next flight, because a commercial system will be working as master system, till the project qualification.

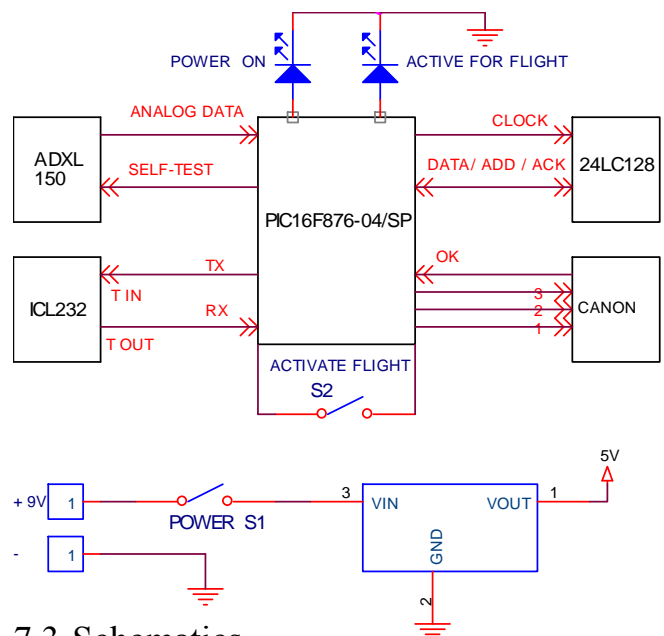
The PIC16F876 microcontroller was used as being the circuit central component, and the accelerometer ADXL150, EPROM memory microshio 24LC128 and MAX232 for computer communications still belongs to this circuit. The prototype could be viewed in the picture showed below.



### 7.2- The Hardware

The prototype was mounted over a double faced fiberglass board, with all conventional components, any SMD components was used in this prototype. Picture number 2 shows the block schematics.

The 16F876 microcontroller works with 4 MHz clock, an instruction without skip is executed in 1  $\mu$ S. In this prototype a microcontroller with a commercial temperature range was used, but will be replaced by an industrial temperature range, between -10 to +85 °C.



### 7.3-Schematics

The reason for use the 16F876 Chip in this circuit is that it has the necessary peripheral components for interfacing it with other project chips. The principal peripheral components is: USART, Bus I2C and ADC.

The acceleration sensor that was qualified for use in this project, the MMA1201P, was replaced by ADXL150 from Analog devices due to the difficulties to find it. The ADXL150 is a great sensor for 50g, with the advantage that it could be configured to 25 g, so, increasing the output resolution.

The acceleration sensor is directly connected to microcontroller internal ADC, the 8 bits ADC allows 0,5 g ou 0,25 g resolution when the sensor is configured to 25g max.

And EPROM serial memory is used with I2C bus witch uses a minor numbers of controller pins.

This memory has a 128 Kbits capability, so with the controller working with 16 8 bit acceleration data acquisitions per second, we can record acceleration data during 16 minutes.

The communication Integrated Circuit used for communication with microcomputers is the Harris ICL232, totally compatible with MAX232. This chip is responsible to generate the necessary tensions for the RS232 communication as EIA/TIA232 specification.

All this system uses in flight operation 60 mA, with PC communication it uses 90 mA, this way, we can use only one 9V battery, just using in this case a linear 5V Tension regulator to feed all this circuit.

### 7.4-The Firmware

The firmware was created in according to Microship assembler configuration, and has at all 740 code lines, the .HEX file generated has 2,8 Kb.

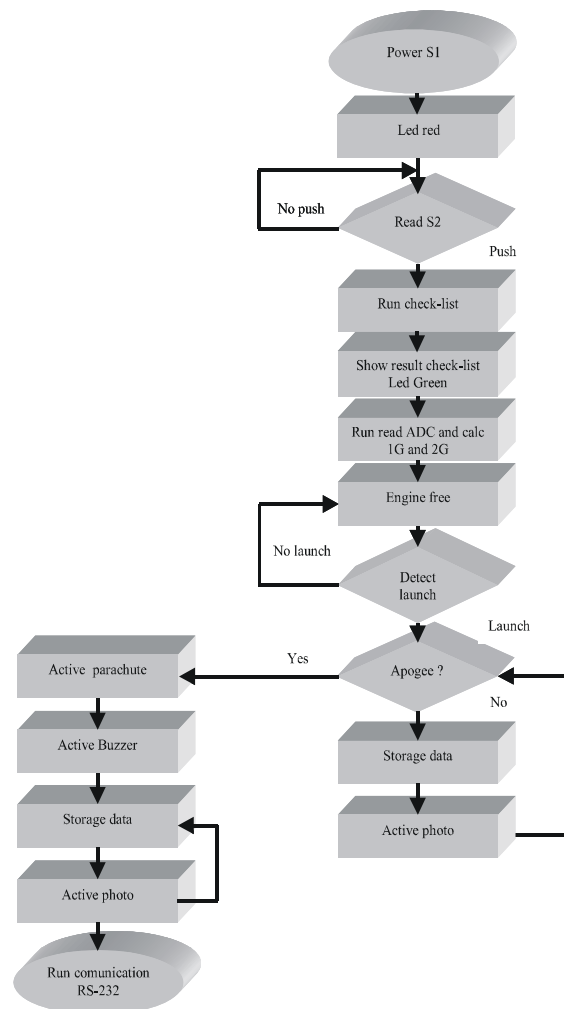
The greatest features of firmware are the checkup when S2 switch (Launch Switch) is turned on, and apogee detection routine. Picture 3, show us the block schematics.

The checkup routine first turns on the accelerometer self-test and reads its return, in case of the accelerometer be ok, it returns high level signal to microcontroller, after this, the engine starter continuity is tested, and finally the photograph engine presence is tested. In the second step, the firmware calculates local 1g, and from this data, calculates 2g, this data is used to detect the rocket launch, so the firmware sets free the engine starter.

The apogee detection routine when the launch is confirmed by another sub-routine that consists on get acceleration data, subtract 1g, and record this data on EPROM and add with previous result, the microcontroller understands as being apogee when this result is zero.

When the apogee is detected, the system saturates a transistor that turns the parachute open system, in STAR case, this is the auxiliary parachute.

That was the most difficult routine to be written, because the data add operation, even subtracting 1g, overflows the 255 decimal register limit., so 2 registers is necessary to use to record this add operation, and 2 registers to compare the 0 (zero), turning the routine into a complex operation.



The memory data reading could be done through MS-Windows Hyper Terminal, and the 1g value, 2g value, each reading from ADC (16 per seconds) will be listed. The data reading will be

improved if Delphi software, for example, be made for this function.

### 7.5-Conclusion

This system was projected to attend an specifically necessity, so, some functions found in commercial systems are not found in this prototype, the pressure sensor is used as an example to command the parachute opening. The prototype is on development phase, and a lot of changes and better improves could be made.

### 8- Ready to Fly

On July 20, the Star was ready to fly and the Printed was presented local. So in the next day the Star was launched in a near Farm.

Now we can see below in the pictures of the Star ready to Fly, before the launch.



The Star rocket was launched for the first time in July, 21th 2001, at a farm near Londrina, with the press presence.

This first flight was considered a great success, for all, since the first experimental rocket project, we get the rocket recovering.. In the picture showed below, we have the Star launch moment.



The flight hold out 35s , 13 s where used for reach the apogee, when the principal parachute was opened. After 8 seconds the second parachute was opened, at approximately 200 Feet high. In the picture showed below we can see the rocket with the parachute in action.



6. The Flight

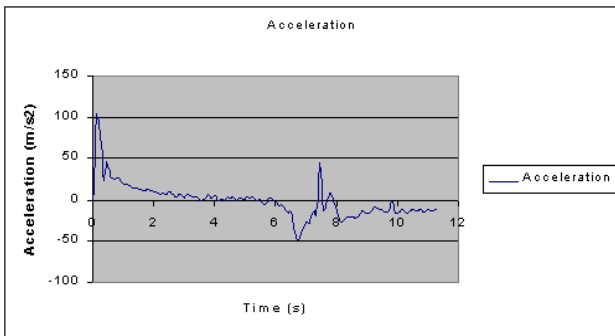


The rocket reach 520 meters high in its apogee. The biggest velocity was 73 m/s at  $t=6$  .

And the biggest acceleration reach 15g at launch moment.

All this data was recorded at a memory, and could be read by a computer so we can plot graphs as showed below.

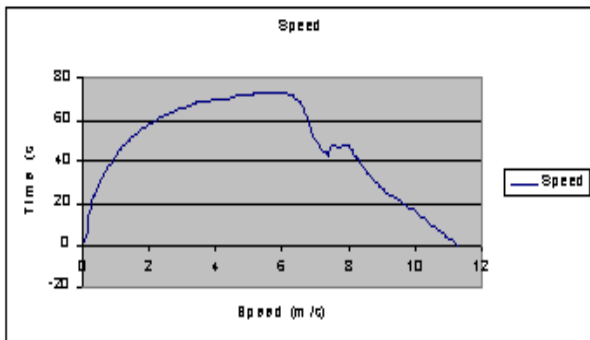
The first graph show us the acceleration. Analyzing it we can see that the rocket had an increasing acceleration till  $t=6$ , when it makes a loop in the air, in this instant the acceleration fastly increases down.



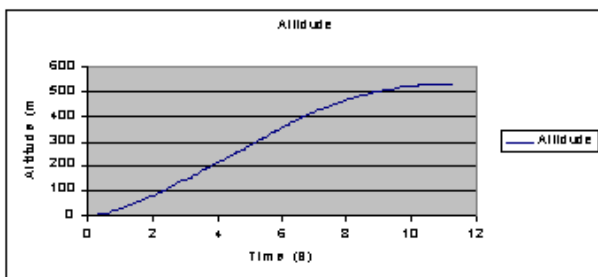
After the first loop the rocket return to accelerate and unfortunately lost one of it's wings witch makes a second loop at  $t=7,5s$ .

So, the acceleration increases down till the rocket reaches it's apogee at  $t=12s$ .

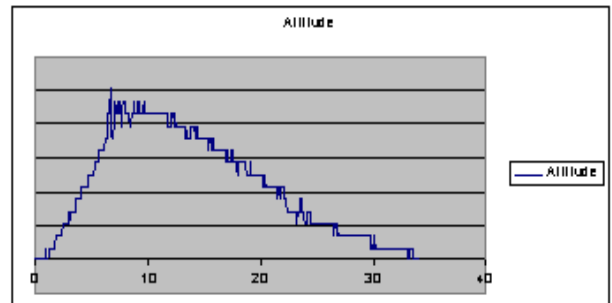
Integrating the graph showed above, we can get the velocity graph that we show in the picture below.



The third graph, shows the rocket position at a specifically time instant. We got this graph integrating the velocity graph.



The fourth graph relates the rocket position with the time instant, but it was plotted with the pressure sensor data, so, the position showed in this 4<sup>th</sup> graph is in pressure function.



With the graph showed above, we can see the total flight time and calculate the decay time.

In spite of the flight was considered a great success, some problems occurs in this project.

Some problems are listed below:

- The engine fuel did not work properly;
- Problems with the Wings;
- Tube Heating after the flight, softening it.

The Team is working to resolve this problems, but the first one is totally resolved. The tube will be replaced by other Inox - Tube.

To fix the wings, the team are projecting a most security system.

The STAR Rocket will be launch one more time this semester.