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TÍTOL DEL TFC: **High altitude balloon mission design and implementation for a mini-launcher**

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Resumen

Durante muchos años, las sondas estratosféricas han sido usadas para experimentos atmosféricos. Los nuevos globos de LATEX de bajo coste permiten poner hasta 4 kilogramos de carga de pago en el espacio cercano. Típicamente, los globos estratosféricos alcanzan hasta 37 km y son llenados de helio.

Esta plataforma es adecuada para probar componentes COTS (*Commercial off-the-shelf*) en espacio cercano. De esta manera es muy barato validar nuevos componentes para el espacio, hace más barato ir al espacio. Antes de tener esta plataforma, la única manera de validar componentes era lanzando un cohete real en el espacio o a cuestas (*piggyback*) de otro lanzamiento real.

En este trabajo final de carrera (TFC) se diseña y lanza una misión basada en una sonda estratosférica para probar la segunda etapa de una mini-lanzadera que está programada en unos meses.

Este trabajo es realizado en paralelo con otros TFCs. El estudiante tiene que sincronizar la carga de trabajo con otros temas como la preparación del grano, la construcción de la tobera y el sistema de control de actitud. Otros subsistemas fueron probados en lanzamientos de sondas estratosféricas de la EPSC previos. Un sistema de seguimiento de la posición, basado en una radio VHF, será instalada para seguir toda la trayectoria, no solo para el vuelo del globo si no también de la segunda etapa hasta que sea tirado al mar. En este sentido, un tubo de lanzamiento será instalado en el globo de forma que asegure un mínimo ángulo y rumbo antes del lanzamiento.

Este trabajo será realizado en colaboración con algún organismo espacial como el INTA. El lanzamiento será llevado a cabo bajo la supervisión de la autoridad de aeronavegación como la DGAC y el estado mayor. Usaremos para tal fin alguna base de lanzamiento como puede ser "El arenosillo" (España).

Palabras clave: High altitude balloon, Mini-launcher, Helium, N-Prize, Low cost, Latex

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Overview

For many years, high altitude balloons were used for atmospheric experiments. The new generation of low-cost LATEX balloons makes feasible to put up to 4 kilogram payload in the near space with a single balloon. Typically, high altitude balloons reach up to 37 km and are filled with helium.

This platform is suitable for test COTS (Commercial off-the-shelf) components in near space. That way it is very cheap to validate new components for space and make cheaper to reach the space. Before having this platform, the only way to validate a component was to launch a real rocket in the space or as a piggyback.

In this final bachelor work (TFC) a high altitude balloon mission is designed and launched in order to test a second stage of a mini-launcher that is scheduled in few months.

This work is done in parallel with other TFCs. The student has to synchronize the workload with other subjects such as grain preparation, nozzle construction and attitude control system. Other subsystems where tested in previous EPSC high altitude balloon launches. A tracking system, based on a VHF radio, will be installed to track the entire trajectory, not only the balloon flight but also the second stage trajectory until it is disposed in the sea. In this sense, a launch tube will be installed in the balloon that ensures a minimum angle and heading before the launch.

This work will be done in collaboration with any space organism like INTA. The launch will be done under airworthiness authority supervision like the DGAC and the Major State. We will use any launch base such as "El arenosillo" (Spain).

Keywords: High altitude balloon, Mini-launcher, Helium, N-Prize, Low cost, Latex

Als meus pares, per tot i més.
A la Montse, per confiar i ensenyar-me el camí.
A en Miquel, per ser-hi sempre.
A la Caro i l'Oscar per acollir-me.
A la tia Mari Angela i a en Xevi.

INDEX

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

To date, reaching space for any purpose is very expensive and can only be allowed by a select group of people with a lot of money. Why is so expensive to reach space? The blame lies with the gravity and the Earth's atmosphere, against the first one we can do nothing, the laws of physics (until proven otherwise) are unavoidable, but we can do that, somehow, acting on our behalf (as the case of satellites orbiting the earth) and even they are unavoidable, we could do something so that their actions were less "strong", and with the atmosphere we can also do something to avoid it a little, enough to cheapen a mission until it can be made affordable for anyone.

Let's think of the atmosphere, this is a great mass of gas that extends several thousand kilometers above us and is vital for life. This is not homogenous and is divided into layers and about 75% of this is in the first 11 km, that means that it is precisely the most dense layer, so not hard to imagine that is what makes most expensive a space mission, while being gaseous, provides an enormous resistance (or Drag), this augment as the speed of the object that crosses augment and how bigger the object is, greater resistance.

Every day hundreds of scientists and engineers working for smaller and lighter payloads, so that the space launcher can be smaller and therefore this offers less resistance to the atmosphere (and do not forget, the gravity) does not take much to imagine how much this costs as well, even so, the payloads are still very heavy and transport therefore, immense and expensive.

That is why we have reached a few conclusions, first of all need a dwarf payload of tens of grams at most, then we have this lleba shuttle payload to an altitude high enough to avoid the first kilometer of atmosphere, and here comes another question: Is this possible?

Yes, it is possible, we have payload, the WikiSat, a satellite that is less than 20 grams which is now in its fourth evolution and is capable of communicating with ground stations and several data sending photos. The way to carry this payload with launcher up high enough to avoid the densest part of the atmosphere is through a high altitude LATEX balloon; these balloons made of LATEX are capable to reach the 37 km high.

In this project we will demonstrate that it is possible, starting from scratch, using simulations first and then designing and manufacturing all we need to do a mission like this, from the launch pad through the launcher, tracking system, recovery system, etc., and not only that, we will lay the groundwork for such missions, to do in the near future releases quickly and efficiently.

Acknowledgements

I want be grateful to all the Wikisat group members specially mention by Joshua Tristancho for his patience and dedication, Victor Kravchenko, Juan Martínez and Ernest Arias.

Finally I want to thank our sponsors and collaborators:

Figure 1 WikiSat partners

ACRONYMS, ABBREVIATIONS AND DEFINITIONS

APCP	Ammonium Perchlorate Composite Propellant
APRS	Automatic Packet Reporting System
AX.25	Data link layer protocol derived from the X.25 suit and designed by amateur radio operators.
AWIP	Advanced Wireless Inertial Platform
BC	Before Christ (used to designate the years before death of Chist)
DGAC	Dirección General de Aviación Civil
EEPROM	Electronically Erased Programmable Read Only Memory
GPS	Global Positioning System
ITU-T	Internationa Telecommunication Union, Standarization sector
KML	Keyhole Markup Language
LEO	Low Earth Orbit
NMEA	National Marine Electronics Association
NOTAM	Notice to Airman
PVC	Polyvinyl chloride
SMD	Surface-Mount Technology
SRCF	Student-Run Computing Facility
X.25	ITU-T standard protocol suited for packed switchd wide area network (WAN) communication.
XML	eXtensible Markup Language
MIPS	Million of Instructions Per Second

CHAPTER 1. TECHNOLOGIES FOR LOW-COST SPACE MISSIONS

In this chapter few technologies for the low-cost space missions based in a High-altitude balloon are presented, these technologies will be used in following chapters, such as:

- High-altitude balloons.
- Low-cost mini launching platforms.
- Open source tools.
- Tracking systems.

1.1 High altitude balloons

The balloon was the first type of aircraft invented, it goes back to the second or third century BC where we find the Sky lantern, also known as Kongming Lantern, it was invented by the sage and military strategist Zhuge Liang and was used for military communications, it is considered the first hot air balloon and was made of rice paper, bamboo and a candle.

In 1783 occurs the first manned hot-air balloon, designed by the Montgolfier brothers, who take off from the Bois de Boulogne, Paris. This balloon was inflated with hot smoke, have 10 meters diameter and flew for a period of 20 minutes. From here the ballooning was evolving, the next step was use a gases lighter than the air, such as hydrogen, helium, etc. until the modern era where we can reach up to 50 km altitude.

Actually the altitude world record with a High-altitude balloon it has Japanese researchers[1], which did so 2003 reaching 53 km high. The balloon had a capacity of 60,000 m^3 and was made of a thin film for high altitude with a thickness of 3.4 micrometers, and it ascended about 300 meters per minute.

Today the high-altitude balloons are very often used for atmospheric sounding. Nowadays, METEO is a science very well developed and it needs to be updated in short periods of time.

1.1.1 High-altitude balloon materials

For amateur high-altitude balloons want them to have a specific properties, the most important property is that the material must be very elastic to hold the gases will expand as the balloon rises, but we must not forget that it is an amateur and low-cost mission and therefore, we search a cheap material. We find two materials with these properties, the LATEX and the Polycloroprene, which are a plastic very well known and used in the society.

[1] http://www.jaxa.jp/projects/sas/balloon/index_e.html

- The LATEX[2] is a vegetable product obtained from the Hevea brasiliensis tropical tree or rubber tree. It is used in high-altitude balloons by its high flexibility, so it can support the expansion experienced by helium (most common used gas) as the balloon rises.

- Polycloroprene[3] best known as NEOPRENE which is the trade name, it is a type of dipped latex product that is treated with a substance somewhat like household bleach after dipping to modify the LATEX and make it more environmentally resistive, It is a type of synthetic rubber. These balloons are more expensive but should be last longer inflated outside.

- Other materials are used for high altitude balloons; these are materials without elastic property but very light and stress properties. Then for this type of balloon, we put excess of material so the gas can expand, when it has covered all the space, the balloon still resist for kilometers thanks to its great capacity to withstand stress, this type of balloon can fly for days. But this practice is far more expensive than the previous mentioned.

1.1.2 *Gases*

A high-altitude balloon can be filled with various gases; the most widely used are the helium and the hydrogen.

- Hydrogen: It is the most abundant element in the universe, therefore, very easy to obtain. Hydrogen gas is the lightest gas in the earth but it is highly flammable and will burn in air at a very wide range of concentrations, this make hydrogen very dangerous to handle (remember the Hindenburg disaster in 1937)

- Helium: The second element of the periodic table is also the second most abundant element of the universe, more difficult to obtain than the hydrogen due to its low and constant presence. Hydrogen weights less than Helium but this is not so dangerous to handle, as it is a noble gas.

1.1.3 *Balloon parameters*

A high-altitude LATEX balloon has some parameters that would be interesting bear in mind like the measures, weights, etc.

- Measures: Neck diameter, neck length, flaccid body length, barely inflated diameter, diameter at burst.

- Weights: The average weight, payload, recommended free lift (it determines de rate of ascent), nozzle lift, gross lift.

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[2] http://www.flow-tronic.com/portal/downloads/PDF/Tec-Spec%20balloon%20TX.pdf
[3] http://www.iisrp.com/WebPolymers/04FinalPolychloropreneIISRP.pdf

- Others: Volume at Release, rate of ascent, diameter at burst, bursting altitude and bursting pressure.

We want our project to be as cheap as possible, which is why we will try as far as possible to launch our mission with a single balloon. Then we will have some important properties than others, and the most important properties for us are the bursting altitude and the payload well as price (of course) we will show later how we use these three parameters to obtain, in a specific manufacturer, the best "quality"/price balloon for our launch mission.

Bursting altitude: It tells us the maximum altitude can reach the balloon. It is very important because lower balloon altitude means lower Stage2[4] altitude due to the large augmentation of air friction, later we will see how significant is this.

Payload mass: It involves several parameters that are inevitably linked; they are the cost and the altitude. We will consider that for us any payload is "heavy" then we want to put up a "heavy " payload and we find two possibilities, high payload and big balloon to reach high altitude means expensive balloon, high payload and small balloon (cheaper) may mean lower altitude (lower bursting altitude) and this does not interest us. Then we have to find the equilibrium between the payload and the burst altitude to get the cheapest mission.

1.2 Low-cost mini launching platforms

A launch platform is a structure capable to subject a rocket or spacecraft so that they can take off, in our case the second stage of a hypothetical rocket, which will carry a warhead of femto-satellites.

These platforms are made with very cheap materials that can be easily found in hardware stores, have to be very simple to minimize costs. PVC[5], steel, aluminum, etc any material is good, provided that is cheap, if is possible light, and capable of withstanding a minimum temperature and pressure.

1.3 Open source & free ware tools

There are many open source tools in the World Wide Web that can be used; from text editors to track simulators and that our mission will become more economical (due to we will not have to buy specific software).

1.3.1 Track simulators

Before the definitive balloon launch we need to do all sorts of simulations and calculations of trajectories to help us get an idea of how to behave our balloon and Stage2, also from the administration (DGAC) they will demand us simulations to give the corresponding permission (ie NOTAM).

[4] Stage2: Stage two of the WikiLauncher (Launcher that will be used by the Wikisat group to put the WikiSat in orbit) that we use as a sounding rocket.
[5] PolyVinyl Chloride biologically and chemically resistant polimer very common used in pipes, doors and windows.

1.3.1.1 Moon2.0

Joshua Tristancho and Juan Martínez created the Moon2.0 simulator in august 2009 for the WikiSat project; it is an opened tool under construction but sufficiently updated to simulate any kind of trajectories. It can be used for example, to simulate the path that would make an Ariane rocket or a satellite on Earth, a trip to the moon or in our case the trajectory of a balloon and the subsequent Stage2 launch. You can found the last update of this track simulation software in the web page of the moon2.0 group[6].

1.3.1.2 Other track simulators

There are other applications in the World Wide Web that we can use, one of them is this trajectory simulator[7], it is developed by the department of atmospheric science of the University of Wyoming and it makes a 24 hours simulation divided in 5 fraction times of 6 hours. It generates a file that can be opened with Google Earth[8] and show us the simulation.

We also have a real-time satellite tracking and orbit predictor called Gpredict[9]. This program allows tracking any satellite, it displays the position and other useful data and even, it is able to predict the satellite passes with detailed information.

1.3.2 *Other useful free ware & open source tools*

Other useful open source tools that we can found and it's very useful is a burst altitude simulator[10], it is developed by SRCF (Student-Run Computing Facility) who provide useful, flexible computing and network services for University of Cambridge Staff and Students and that have very interesting opened applications.

Then we have to talk about Celestia[11], it is an open source space environment simulator project created by Chris Laurel in 2001; we could say that Celestia is like Google Earth but instead of focusing on Earth, focusing on space and allows you to explore our entire galaxy.

1.4 Tracking systems

To see which direction and behavior have or have had our system we must make use of a tracking system. We say "have or have had" because it can be "live" it means we receive the (in our case) GPS parameters via live broadcast or we can save these parameters in a memory, recover the system and then

[6] http://code.google.com/p/moon-20/
[7] http://weather.uwyo.edu/polar/balloon_traj.html
[8] http://www.google.es/intl/es/earth/index.html
[9] http://gpredict.oz9aec.net/
[10] http://www.srcf.ucam.org/~cuspaceflight/calc/
[11] http://www.shatters.net/celestia/

read the direction and behavior that our system "have had". Let's see the most common and cheapest tracking systems.

1.4.1 *APRS*

Their labels indicate APRS [1] is a system that can send "reports", ie data. It is based on amateur radio and is based in part on the AX.25 amateur protocol which is a data link layer protocol derived from X.25, this is very widespread in the United States and is primarily used to send position information but also can be used to send "messages" between users. With these digital data that can easily send us enter into a computer and easily paste this position information in a program such as Google Earth.

To create our APRS a GPS receiver is needed, a data converter that receives the data NMEA[12] from the GPS receiver, encoded data in APRS packets and generates the appropriate signal for an FM transmitter programmable for frequencies between 144 MHz and 148 MHz (amateur band) and Finally we need an antenna capable of transmitting between these frequencies as efficiently as possible.

So we receive this signal with a transceiver that is responsible for dealing with the received signal to obtain the "message" that contains, in our case we expect to obtain position, altitude, heading and speed.

It is a kind of "live" tracking systems and don't need to be recovered.

1.4.2 *GPS + Arduino*

If you connect a GPS to an Arduino, you can use this to save the frames that the GPS sends to the Arduino EEPROM for very short missions or other larger memory for longer missions. This system is very cheap and versatile as it is the only limitation is your imagination. We can for example only record the maximum altitude reached by the system and use the minimum memory EEPROM.

The only "disadvantage" of this system is that it is necessarily recoverable due to we need to "download" the self-stored information, and we have to design some kind of parachute or damping system. To found it then we will need a localizer or a beacon.

[12] NMEA is an association that creates standard protocols used by GPS receivers to transmit data.

CHAPTER 2. WIKISAT SPACE PROGRAM

This work is integrated into the Wikisat group to help him in his way to victory in the N-prize contest. The characteristic features of this group are, above all, teamwork, everything is made to be shared with everyone (open source) and affordable (low cost) as it is private melts. His main motivation is the N-prize competition, but also being able to bring space to people who until now could not afford.

2.1 The N-Prize contest

The N-Prize[13] challenge is a competition created by Google Company to motivate the creativity, originality and inventiveness in the face of severe odds and impossible financial restrictions. The rules of the contest are very simple, we have to put a satellite with a mass of between 9.99 and 19.99 grams, and to prove that it has completed at least 9 orbits around the Earth. The total cost of the mission cannot exceed in any case the £999.99.

There are two prizes of £9,999.99 each for the first entrant to complete the challenge using a non-reusable launch system and for the first entrant to complete the challenge using a partially or wholly reusable launch system.

Lots of teachers, students and collaboretors are working in a femto-satellite called WikiSat and his rocket, the WikiLauncher to participate in the N-prize.

2.2 WikiSat: The femto-satellite

The WikiSat space program consists of to implement a low cost satellite for the N-Prize.

The satellite WikiSat is a less than 20 gram femto-satellite[14] that will be the brain of our mission, is responsible of ignite the rocket, its control, to ignite the Stage2, etc. with this we save job and weight because we don't need a single control system for the rocket, our WikiSat is capable of doing these functions also.

Then the WikiSat is an essential part of the group and everything that makes the group has directly or indirectly with the femto satellite from the Satellite Heart (AWIP board) and the antenna, until his vehicle into orbit.

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13 http://www.n-prize.com/

14 whose weight is less than 100 gr

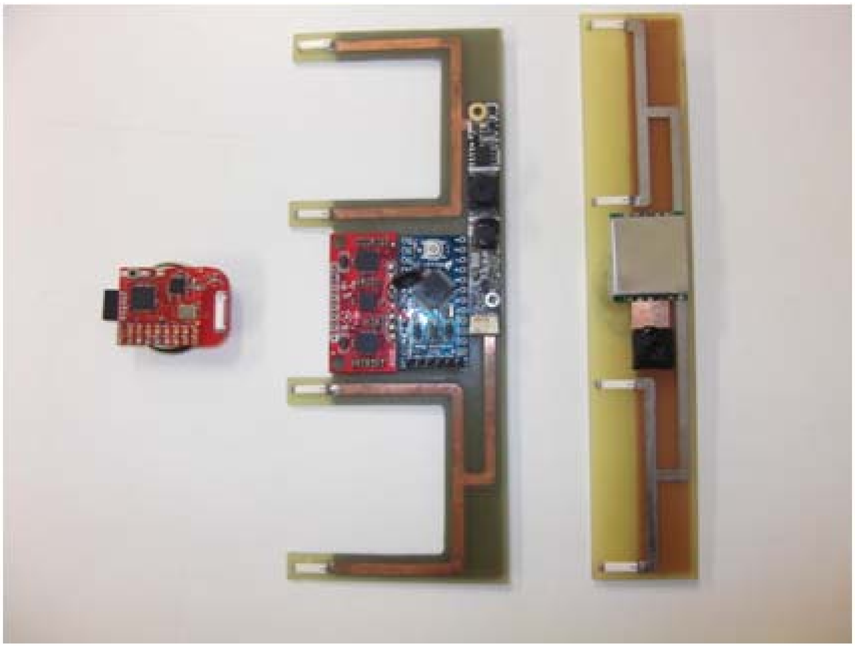

Figure 2 WikSat prototypes (1, 2, & 3)

2.2.1 WikiSat performances

Orbit: LEO 250 km
Communications range: 200 to 1,000 km
Time in orbit: 8 days
Mass: less than 20 grams
MIPS: 20

2.2.2 WikiSat subsystems

As can be supposed, for weight restrictions we cannot equip our satellite with a lot of subsystems. So it has the minimum required subsystems to accomplish its mission. These subsystems are:

- **Power Supply subsystem** consists of a LiPoly battery and few voltaje regulators. It is possible to turn on or turn off components for power saving. There is the possibility to install small solar cells for long missions.
- **Communication subsystem** is hable to transmitt the payload data to the ground station using a S-Band WiFi like. Also it is able to communicate with other satellite if they fly like swarm. Upload is also available to modify the mission parameters.
- **Structure subsystem** has a synergy the thermal control subsystem and the communication subsystem becuse the high gain antenna is mainly the structure and the external areas were selected properly to have a pasive equilibrium in such a way the heat flow guarantees a correct operative temperature range.
- **Attitude determination subsystem** is made by inertial means through three gyros and corrected by optic sensors which they work like Sun

tracker. The attitude determination is used during the launching phase to control the launcher stability and on orbit to point the High Gain Antenna or sensor towards the ground station or interest point.

- **Position determination subsystem** is made by inertial means through three accelerometers and corrected by the tracking subsystem during the launching phase and on orbit by almanac.
- **Attitude control subsystem** is done by two pairs of magnetorquers. During the lunching phase is the Stage2 of the launcher that follows the payload commands.
- **Tracking subsystem** provides absolute coordinates respect to the WGS84 reference frame but it is only used during the launching phase.
- **Payload subsystem** is any SMD detector like magnetic field sensor, optic sensor or other kind of SMD component to be validated in space.

2.3 WikiLauncher: The mini-launcher

The Wiki-Launcher space program is an scalable to the mission launcher design; it is to say, it may change the size depending on payload mass, altitude orbit, orbit inclination or launching place keeping the original design. The cost budget is always fitted in the N-Prize requirements.

2.3.1 WikiLauncher performances

To orbit our WikiSat, we are devising two types of launchers, one more "classic" and one more "innovative”. The "classic" one would be the typical rocket launched from the ground with two stages of about 1.5 meters long, the "innovative" one is the one that describes this work and consists of a rocket whose size is more or less the size of the Stage2 of the rocket used by "classic" method (between 30 and 40 cm) with two stage launched from an altitude of between 30 and 35 km, this gives us some advantages and substantial cost savings. In both cases the rocket fuel used is APCP.

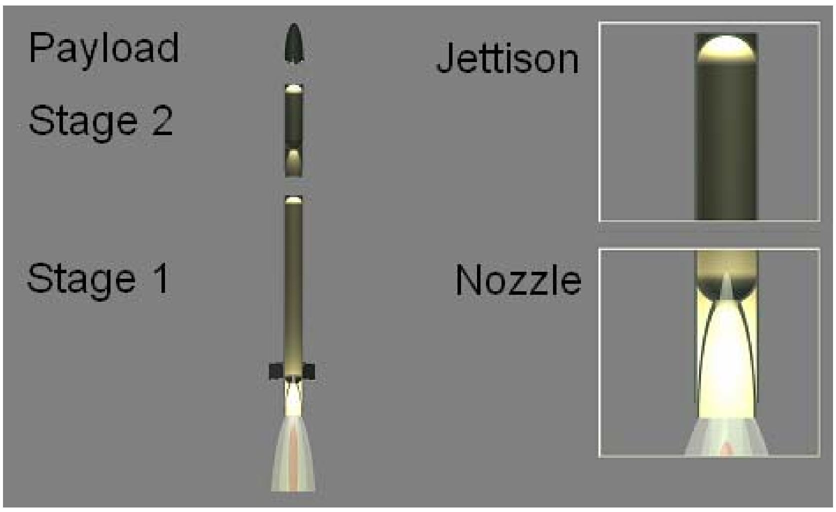

Figure 3 WikiLauncher

2.3.2 WikiLauncher subsystems

As it was said before, it changes the size without changing the original design and keeping the N-Prize cost budget. This is possible because the simplicity of the subsystems and because the larger the size, the greather the propellant capacity but not the complexity. This is valid only if payload is a femto-satellite. It can not be scaled everywhere; large launchers have huge impact by the atmsphere and a lost of efficiency. The subsystems are:

- **Safe launch and flight subsystem** is a method to stop by destroying the launcher when the first stage is burning and it don't follow a safe corridor. This subsystem is not required for a launch from a high altitude balloon because there are no people around it during the initial trajectory.
- **Propulsion subsystem** is in charge to apply a DeltaV or to increment the velocity. Due to the use of solid propellant there is no thrust control; it is what it is.
- **Thermal control subsystem** is able to absorb the excess of heat during the burn because there is no conductive path to the atmosphere in the vacuum. This control is made in the design, it is a passive one and it is done by ablative means[15].
- **Electrical power supply subsystem** is an independent electrical power source that is used to move servos or to ignite the stages.
- **Attitude determination and control subsystem** is able to know the attitude (Managed by the payload) and to control the launcher vector based on purge some pressure from the Stage2.
- **Position determination and navigation subsystem** is able to know the position relative to the trajectory managed by the payload.
- **Trajectory simulation subsystem** is able to know if the trajectory is correct and also adapts this trajectory to real needs, in example, when the apogee is reached; it calculates the required orbital speed.
- **Structure subsystem** is able to support the combustion pressure and at the same time the flight loads being very light.
- **Jettison subsystem** is a passive method that breaks when the second stage ignites. No pyrotechnic methods are used.

2.4 Balloon mission objectives

The main objectives for this mission are the following:

- To reach space with low-cost amateur technology both safe.
- To use a GPS to check that we have the space.
- To record flight with a camera.
- To test components as:
    - Stage2 launcher.

[15] By ablative means is the property of some materials to absorb heat burning itself

  - Space validation of the AWIP platform that goes into the satellite.
- Space validation of the components just valitated in near spaces: GPS, battery, camera.
- To learn the necessary procedures so that future missions can repeat this type: Validate amateurs components in space so as to reach space is cheap and fast in terms of months.
- To recover the payload using a localizer due to this mission is necessarily recoverable.

2.5 Design of a low-cost amateur mission to space

We define the space payload paradigm as the engineering process of designing a space mission around its payload and not around the space industry [2].

To achieve a spacial low-cost mission today may do so only if we follow certain rules or guidelines which are detailed below:

- Use amateur tecnology.
- Draw on open source programs.
- Knowing when something is better to buy than to produce it.
- Report everything that is done to the comunity.

Use amateur tecnology means that our mission will be a much smaller scale than those used today for the billion-dollar space missions (and therefore affordable only for a small privileged minority).

And this, even it seems impossible; it is not because the amateur technology we have on hand has evolved significantly in recent years. Platforms such as Arduino, and his sister developed by the wikisat group AWIP board allow us to do things years ago impossible for amateurs.

Just 20 years ago the "simple" calculation of a balloon trajectory had to be done by super computers the size of houses, today there are open source programs on the network that can be used free of charge and you can simulate anything you want, from a balloon and rocket flight, to a lunar mission. Increasing, the limit is your imagination because today, a ridiculous budget can do amazing things.

But make no mistake, make a low-cost mission using amateur technology does not mean have to manufacture everything you need, no, sometimes will be necessar manufactured products throwing, as its price and validation can save us time we can expend on more important things, things it have not been done before at amateur level (as it is the Stage2) and require a fresh start and a good dose of patience and time reviewing material to detect failures.

Another very important thing we have also to do is report all what we are doing, matter how amateur it is, it shouldn't be free of professionalism, then we must think of a reporting method, in our case is based on creating a blog[16] where we pointed every small progress that we make, however small it is written, there is nothing it makes a mission more expensive than having to repeat things already done and the repetition of errors, therefore everything we are doing we videotaped and photographed it for later study and report.

[16] http://missionlowcostspace.blogspot.com/, Wikisat group use a google application for groups seen in section 1.3.1.1

CHAPTER 3. LAUNCH CAMPAIGN

3.1 Launching platform

A launching platform [3] is a structure capable to protect against damage, transport, hold, guide and correctly launch a misile, rochet, space craft, etc.

3.1.1 Design

Peculiarity of this launching platform is that instead of being bolted to the floor or be carried by a tank or person, this has to be subject to a high altitude balloon.

To design a launch pad, we must first know what sounding rocket will have to carry. We already knew this in advance, our sounding rocket would be a soda can, appropriately amended, with its respective payload, nozzle, nose, and filled with its special fuel, but without exceeding its original size.

Knowing this was very easy to imagine how it could be our launching platform, like a bazooka or cannon, a cylindrical tube long enough for the sounding rocket is able to take right direction, designed to scale, with a meter long of tube we would have enough, this tube would have to have the property of being lightweight and resistant to extreme temperatures, hot and cold alike.

Then came up another question, how to hold the launching platform to our balloon? The first thing that came to mind was using cables, a couple of wires attached to the nozzle of the balloon, but this is a problem because the sounding rocket to leave the tube would meet with the entire balloon and this, even that fragile, it could divert the sounding rocket making our mission failure. The solution to this would be slightly tilting the tube so tha the sounding rocket leaves it with a certain angle, this is not very difficult to get, you only need to hook a cable from the other end of the tube to the balloon noozle. This is not quite like us because it complicates the sounding rocket launch sequence due to the sounding rocket could not be released until the tube not pointing the desired direction.

This problem will find a solution fast enough, we forget that cables and think on this mouthpiece of the balloon. The nozzles of high altitude latex are very strong so we thought that if the tube enters the noozle we would have the tube pointing upwards with no angle to control, and only a thin layer of latex to cross, ant that, at the launching height, it will be so the limit that will break it instantly without possibility of diverting our sounding rocket. But this gives another problem/s, how do we seal the balloon-tube system assembly so as not to loose the helium? How to introduce helium to it does not escape?

Bad thing, but easy to solve, yet we are quite complicated the pre-launch preparations. The theory is, we will put a lid with a fitting and seal it with a very strong adhesive, then through a hose to inflate the balloon. I say this complicates our pre-launch preparations because the sounding rocket will have to be inside the tube when sealing the other end with fitting lid, and here we have a point of no return and if we let ourselves be forgotten any step no longer able to remove the cap because it will be sealed with adhesive.

So we have designed our platform launch, and the materials are not hard to find, one meter of tube, in any large hardware store (Bauhaus, Leroy Merlin), or even if you ask in the hardware of your city / town is easy that the have a similar tube, we use PVC plumbing tube bought at Bauhaus hardware store in Gavá for a price about 10 €, the cap and the union are found in the same place at less price. The balloon will have to ask a specialized company, and in the next chapter, there are different types, we show how to choose one.

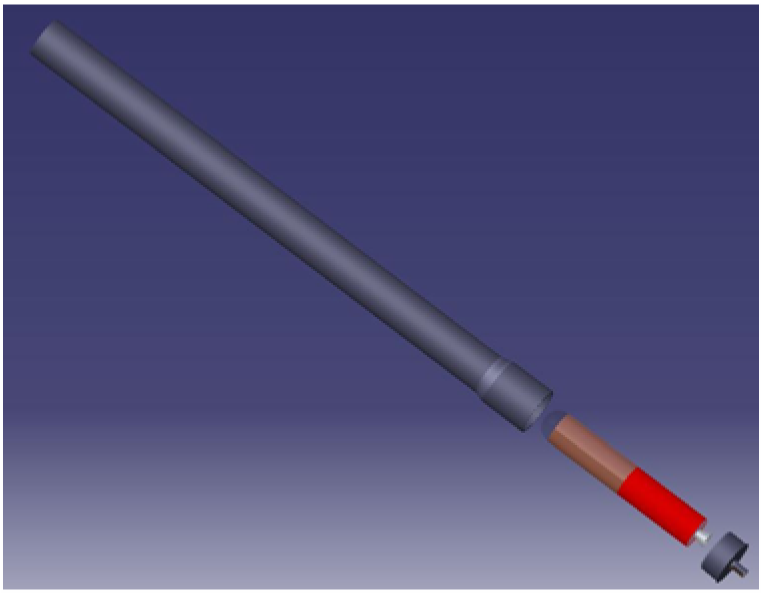

Figure 4 Launch pad with the sounding rocket modeled in CATIA (by Laia Molas)

3.1.2 *Manufacturing*

Making the launching platform is very "simple", you only need to enter the tube into the mouthpiece, only a step which in turn is very laborious and requires a minimum of 2 persons and a few shoehorns. Specifically, using 5, bought from the Chinese for 0.80 euros each. The steps are:

1. Introduce 4 shoehorns into the balloon mouthpiece.
2. To align the tube with the shoehorns, placing shims in pairs, one in front of another.
3. Place the tube vertically doing downward force with the shoehorns, we see that the mouthpiece widens.
    a. Very important keep the shoehorns well placed.
4. Put the fifth shoehorn when we see that there is enough space, distributing the shoehorns.
    a. We will always have to do downward force to prevent scape tube shoehorns.

5. Push down hard until the tube enters (not all, about 10 to 15 cm which is what measures the mouthpiece).
6. Remove Shoehorns.
    a. With enough strength and pulling down, one by one.
    b. In this process we must be careful not to twist the balloon and give us some instability and unwanted rolling on the flight.

Figure 5 Shoehorns & final result

3.1.3 Choosing balloon

Choosing the balloon may seem easy, but it is one of the most complex decisions, as the balloon manufacturer[17] gives us a very broad catalog. So knowing our minimum targets, we have a whole cast of balloons that would serve us, but everyone is different, with different payloads, balloon diameters, nozzle diameter (very important, as we have seen), free lift, heights and prices.

So we decided to provide a table showing the properties to take greater account and then draw the corresponding graphs. We do it with excel but we can use any other open source program like Calc (Open Office group program)[18].

Type	BURST Altitude	Cost	Balloon diameter	Apogee	
100gr	18,5 km	21,30 €	0,55 m	24,7 km	**100**
200gr	21,0 km	31,76 €	0,75 m	29,0 km	**200**
300gr	24,0 km	30,46 €	0,95 m	35,0 km	**300**
500gr	26,5 km	36,53 €	1,30 m	40,8 km	**500**
600gr	28,5 km	57,83 €	1,45 m	45,8 km	**600**
700gr	29,5 km	73,02 €	1,60 m	48,5 km	**700**
800gr	30,5 km	79,14 €	1,70 m	51,1 km	**800**
1000gr	32,5 km	91,27 €	1,80 m	56,3 km	**1000**
1200gr	33,5 km	152,09 €	2,00 m	58,8 km	**1200**
1500gr	35,0 km	182,55 €	2,20 m	62,3 km	**1500**
2000gr	37,0 km	304,21 €	2,50 m	66,8 km	**2000**
3000gr	39,0 km	608,45 €	2,95 m	70,8 km	**3000**

TABLE 3.1 BALLOON PROPERTIES

17 http://www.meteorologyshop.eu/Radiosonding_balloons/ENG_276_EUR_38_0__.html
18 http://www.openoffice.org/product/calc.html

	Apogee	Burst	Launcher	Balloon	Efficiency	Costly coeff.
100	24,7	18,5	0,195	0,474	0,092	0,089
200	29	21	0,252	0,538	0,135	0,128
300	35	24	0,346	0,615	0,213	0,202
500	40,8	26,5	0,450	0,679	0,306	0,287
600	45,8	28,5	0,544	0,731	0,398	0,360
700	48,5	29,5	0,597	0,756	0,452	0,398
800	51,1	30,5	0,648	0,782	0,507	0,441
1000	56,3	32,5	0,748	0,833	0,624	0,530
1200	58,8	33,5	0,796	0,859	0,683	0,513
1500	62,3	35	0,858	0,897	0,770	0,539
2000	66,8	37	0,937	0,949	0,889	0,445
3000	70,8	39	1,000	1,000	1,000	0,000

TABLE 3.2 BALLOON COEFFICIENTS 42

The first table is purely informative, on this we see the balloons types that the company offers, burst altitude, the cost, the balloon diameter and the apogee height, that is the sounding rocket height reached if it is launched from the balloon burst altitude, these have been found using a simulation done with the Moon2.0, the image which we see below in Figure 6.

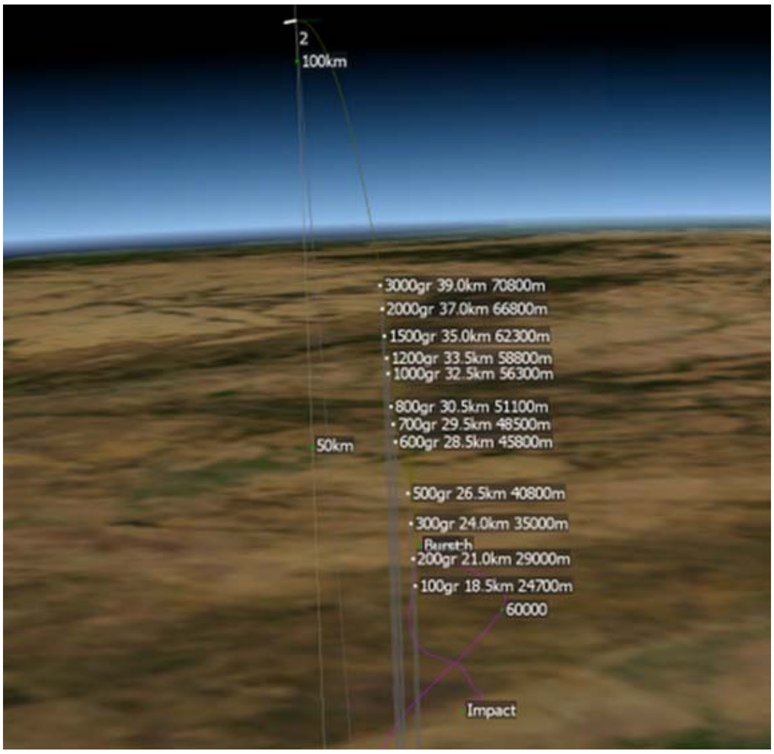

Figure 6 Stage2 apogee according balloon type

In the second table we have the apogee (which would come the sounding rocket launched from burst altitude) and the balloon burst altitude. Now we want to create some coefficients or indices so that they can be introduced into a graph and see how different is a balloon of another, if there is much improvement from one type to another, etc. The indices have separated into four columns that are launcher, balloon, efficiency and costly coefficient.

To get the Launcher column we subtract type and apogee column and divide this by subtraction burst and type of the larger type, ie 3000 gr (70.8 - 39 = 31.8).

Example: type 100 gr Launcher coefficient – (100 – 24.7) / 31.8 = **0.195**

To get the Balloon column we divide Burst with the larger Burst (ie. Type 3000gr – burst 39 km).

Example: 100 gr Balloon coefficient – 18.5 / 39 = **0.474**

To get the Efficiency column we multiply launcher with balloon.

Example: 100 gr Efficiency coefficient – 0.195 * 0.474 = **0.092**

And finally to get the costly coefficient we multiply the efficiency with the substract of the cost of the type and the cost of the expensive type and divide this with the cost of the expensive type (the cost of the expensive type is the 3000gr type and it is 608.45 €)

Example: 100 gr Costly coefficient – 0.092 * (21.3 – 608.45) / 608.45 = **0.089**

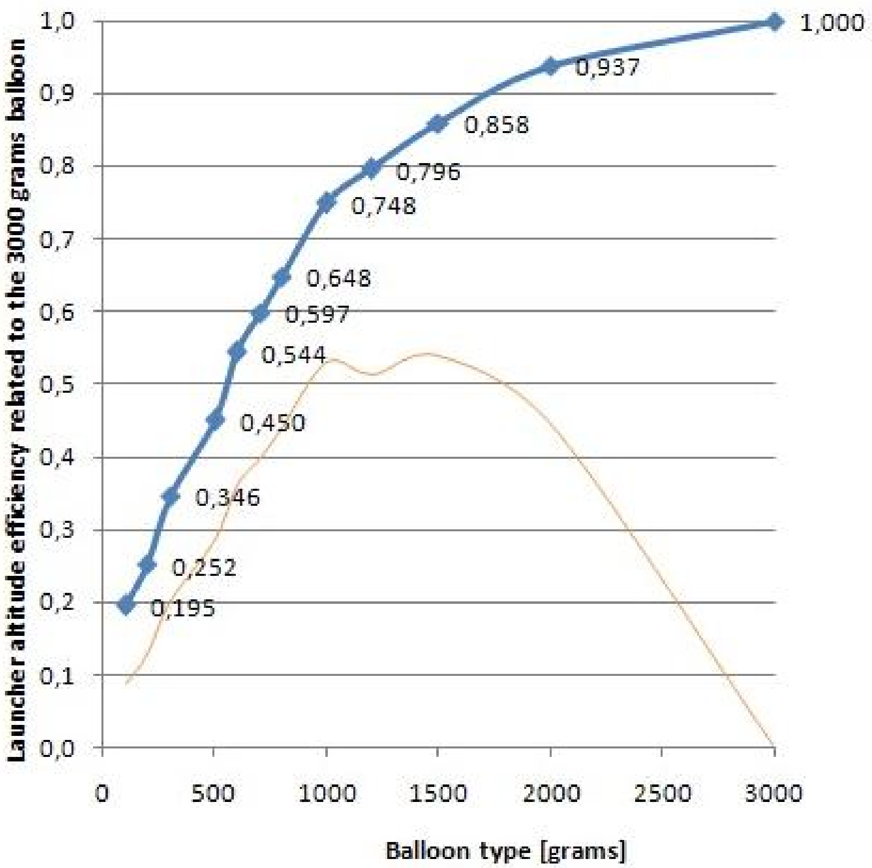

Figure 7 Apogee efficiency – ballon type (compared with a cost efficiency graph)

In this graph we can see how we won apogee height as the altitude of the balloon burst augment, if we had only consider these two parameters, we should choose the type 3000gr balloon type because it offers us a greater apogee thing that guarantees success mission, but as we are trying to design a low cost mission we must consider the cost of our materials and this is precisely what we do in the following graphs, we compare the Balloon and Efficiency coeficient in the figure 8 with a curve made with the Costly coefficient and that compare the cost with the efficiency of the balloon to show on your higher points the types who will make our mission cheap while efficient.

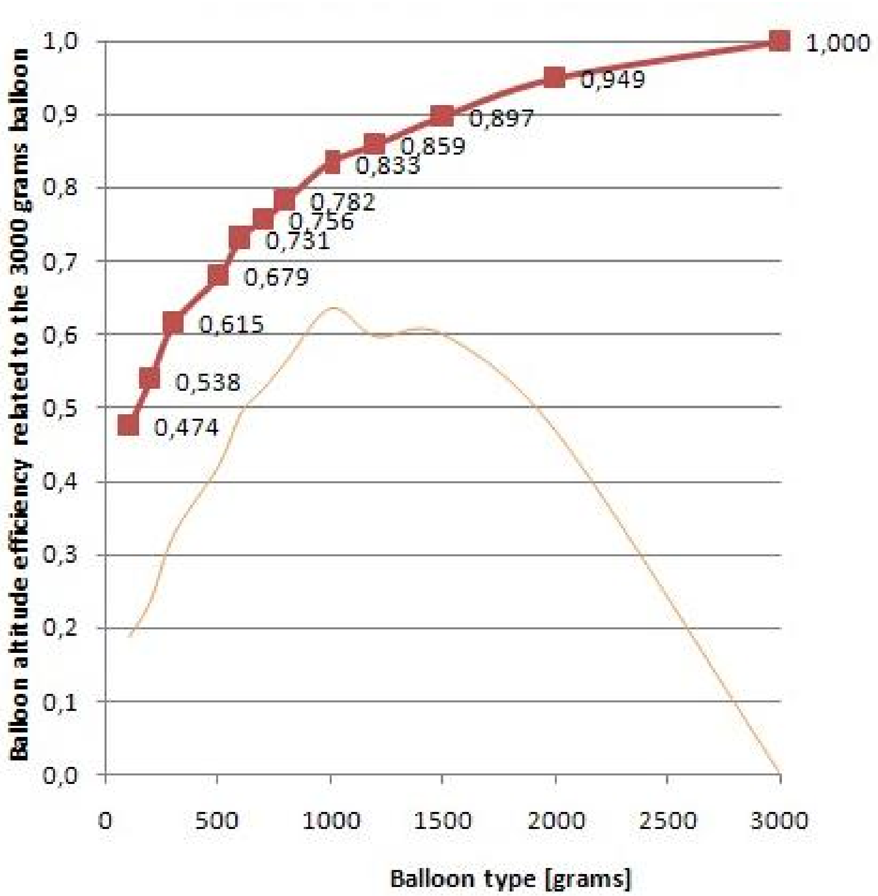

Figure 8 Balloon altitude efficiency – ballon type (compared with a cost efficiency graph)

And finaly as we can see, the types graced with the gift of cheap efficiency are the types 1000gr, 1200gr, 1500gr whose coefficients are 0.530, 0.513 and 0.539 respectively and will choose the type 1500gr because it is the highest coefficient and allow us to reach a burst altitude of 35 km with an estimate Stage2 apogee of 62.3 km.

Just out of curiosity, to see how much is gained launching from a height, launching with this balloon to 35 km we reach 62.3 km high, this gives us a flight for our sounding rocket (if all goes well) of 27.3 km, while on the ground the same type of sounding rocket will not reach either the 2 km altitude.

3.1.4 *Parachute*

The parachute of our launching platform is made with a material similar to that used for the heating, resistant wires attached with glue and duct tape through. The parachute is attached to the "mouth" of the launch pad at the junction with the balloon reinforced with duct tape. This is suspended as the balloon rises and acts only when the balloon burst and the tube begins to fall.

Figure 9 Balloon Parachute

3.1.5 *Tests*

For the launch platform we believed necessary to make 2 kinds of test, a tube - balloon union behavior and other only with the tube. These tests are essential for us to validate the system, if they fail the tests we will have to find where the fault is, fix it and try again until successfully pass the test. In all tests we have taken every precaution that the test require, have been used protective screens, eye and ear protection, gloves and remote triggers (Fire Box).

3.1.5.1 Tube-balloon

Our intention with this test is (being an "unknown" union or has not been used until now) first will see the union’s behavior, if it stands or not, if will leak, test ways of inflating the balloon and that once inflated is airtight, get an error that can only be detected with the balloon inflated, etc.

So join a tube with a balloon in the manner explained above, this time we will inflate the balloon with air. With this type of union will share the gas tube that carries the balloon, ie helium, so the tube-balloon system will have to be hermetic to prevent leaks that would seriously compromise our mission. we decided to inflate it using a "cap" with a fitting that only lets through the air in one direction, in the same place where we buy the tube, they sell its corresponding "cap", you had a hole this big enough to fit compressed air fitting (for the upcoming launch we will have to look is fitting that the "cap" is the same as that of the hose we use for helium), we put the connector into the hole and sealed it with glue and let it dry. Once dry the fitting-cap union, we put this cap into the tube and also sealed with adhesive.

For this test we need enough space, and then these balloons reach a long stretch. We subject the tube so that it is vertical position and with enough space for us to introduce the male fitting compressor hose and began to introduce air. When this has reached critical size, we proceed to stop inflation and inspect the system.

Figure 10 tube-balloon union behavior test

We look closely at audible leaks, the result is quite positive, the system remains tight, we decided to leave it overnight to see If by the morning has been deflated, but before we look at the junction of the tube with the balloon and we see that we put the mouthpiece of the balloon a little askew, as a result the balloon is forced, this may be a weak point, the conclusion is that we must be very careful when attaching the tube with the balloon and put it as straight as possible.

The next morning the balloon was unchanged, good news, we just introduce air to cause the balloon to break and see if the cap holds the pressure, it holds perfectly, but as we know it is another critical point of the system, the launch day we will not only sealed with adhesive but it also we will ensure it and the tube-balloon junction with tape.

3.1.5.2 Tube as a launcher

We passed to test tube as a launcher, for these tests we need Stage2 prototypes (of which we speak more deeply below). We have to do these tests to see that the Stage works out of the tube, see if it supports the temperature of the sounding rocket, in definitive behavior with a sounding rocket taking off from inside.

For this test we need an ignition system, ie, the igniter and a system that gives us a minimum of security. That is why we decided to create a Fire Box, in this there is the 9-volt battery that will give the necessary voltage to the igniter works but also has a redundant system that prevents accidental Stage2 ignition. All this is embedded in a metal box with three switches and two LEDs as shown in the picture (Figure 11).

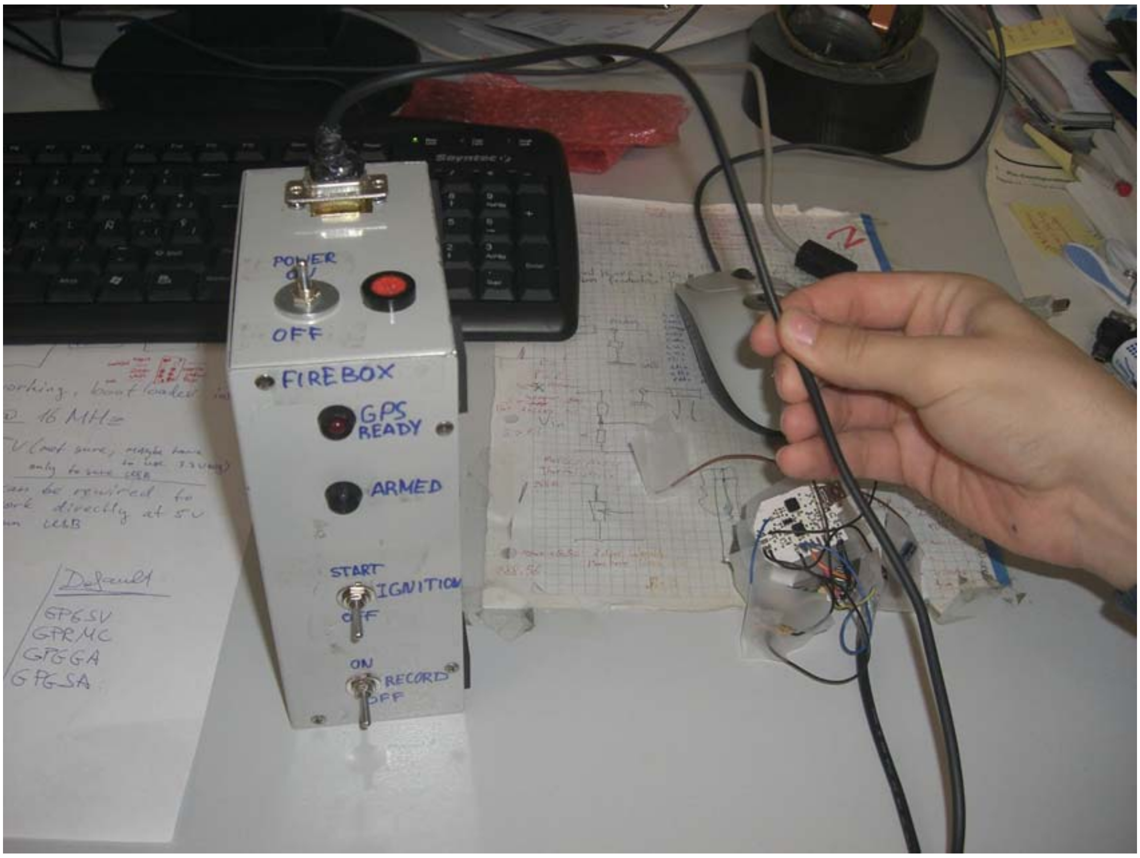

Figure 11 Fire Box

This even includes a system to turn on the GPS and can thus test it. The operation of the Fire Box is very simple, first of all, ensure that all switches are OFF before connecting the Fire Box with Stage2, it starts with the on / off button (putting it ON) and instantly turns on the ARMED LED, If we only would like to launch the Stage2, we have to throw the IGNITION switch from OFF to START, if we wanted to test the GPS too, would move the RECORD switch from OFF to ON so that blinks the GPS READY LED, that only stays fixed when it knows that GPS is aligned and then I could throw the IGNITION switch from OFF to START.

So we take the same tube used in the previous test (also with a cap to which we have made a hole to pass the ignition cable) and introduce a Stage2 inside, this goes without problems, only a few millimeters between the tube and the stage, then proceeds to launch the sounding rocket (connecting de igniter wire with the Fire Box).

We have done three ground launches with de tube and a Stage2 prototype and the results are very good, the tube and cap perfect holding the stage ignition and all the way into the tube where temperature was high enough.

Figure 12 Launch sequence

3.2 Igniter

An igniter is a device that typically contains pyrotechnic material (or flammable) and used to ignite other materials more difficult to ignite (ignite) or dangerous such as thermite (aluminum pyrotechnic composition and a metal oxide) gas generator or rocket solid fuel.

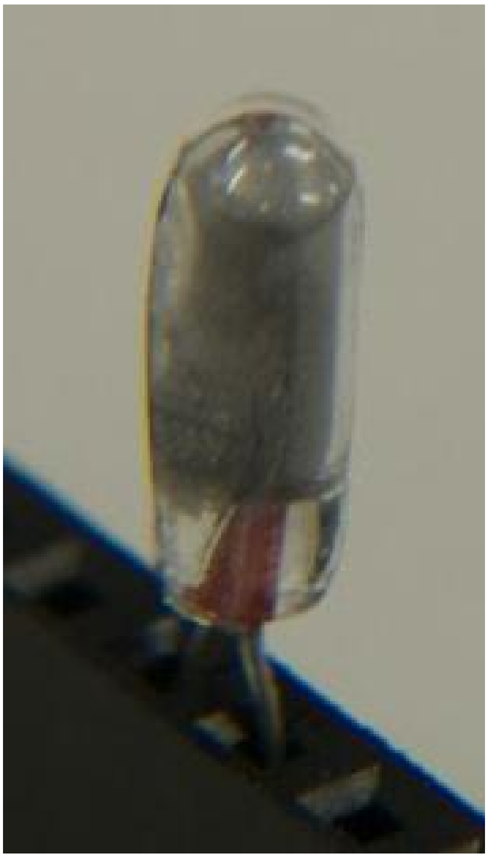

Figure 13 Igniter

3.2.1 *Fabrication & operation*

There are many types of igniters, Ernest Arias in his final bachelor work [4] has a most extended explanation abaut the igniter but, in a very short resume, the igniter we use is a light bulb which produces 1.5 volts. One side is cut and filled with blackpowder and covered with resin.

When short-circuit the battery, the igniter operates and increases the temperature by a few tenths of a second, heat + blackpowder result in a large flame enough to ignite our propellant.

3.2.2 *Tests*

The tests are the most simple, first of all we shorted about 3 igniters to see which way the blackpowder bulb explodes and to see what kind of battery would have to use, in the end we opted for a 9-volt battery.

Once we saw how it worked, we tested it in our Stage2 burn tests and thus be able to validate it on the ground, the launch day we validate it on near-space (as this will be ignite to a maximum height of 35 km).

3.3 Stage2 sounding rocket

To reach the Space from 35 km we need a sounding rocket as small and light enough to be transported to that point with the balloon, which is why we take this opportunity to evolve in the Stage2 knowledge and manufacture that would be used in a hypothetical sounding rocket launched from the ground and adapted quite well to our needs.

3.3.1 Design

As we are working to a low-cost level (ie amateur), we must look at materials and products used in everyday life, so to begin with the structure, we must think of something that is cylindrical, that its size is not too big and not too heavy, preferably made of some metalic material. We are many things on mind, pipes, broomsticks, spray cans, soda cans, etc. At first we decided to remove the pipes by weight and broomsticks for their small size, leaving us with spray cans and soda cans. We finally decided to opt for soda cans and especially for its abundance, which appreciate when we have to do test after test to find the best way of manufacture.

So our Stage2 will be a can with a propellant (very, very amateur), with a bulkhead, that will protect the payload located in the nose, and a nozzle to maximize the burning of this fuel, in figure 10 we can see the work made by Javier Sanchez who has a modelling of a Coca-Cola zero can, after used to resistance, preasure and aerodynamics computing tests.

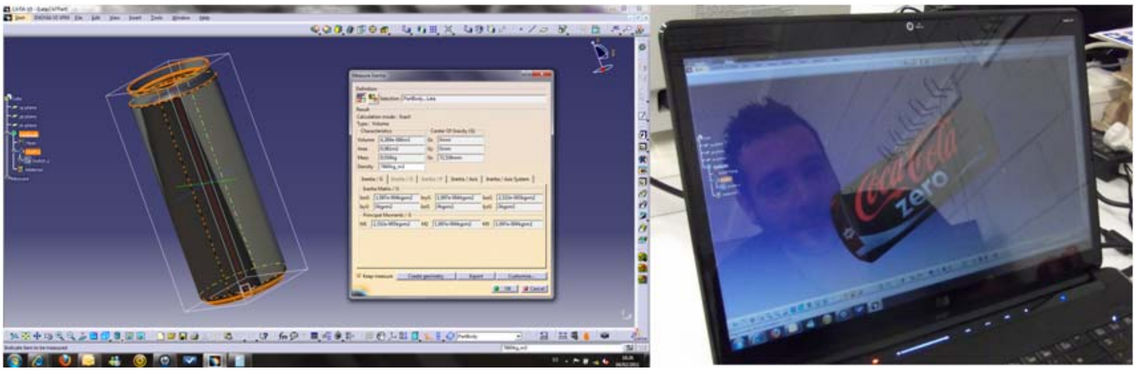

Figure 14 Coca-cola can modelling in CATIA (by Javier Sánchez)

Our intention is to make a prototype, test, analyze the data obtained from the test, see where the mistakes are and correct them.

3.3.2 Thrust system

We use as propellant for our Stage2 an amateur engine (made of blackpowder). It is very commonly used for fans of model rocket launch.

This cartridge or grain is formed by a nozzle, the propellant that is just a gunpowder and a retardant all this carton packing. We are interested in using the propellant because we already have a nozzle more suited to our needs. The study and design of this nozzle is responsible Ernest Arias in his final bachelor work [4] where he seeks the optimal parameters for a nozzle of theese characteristics (low-cost, ie, made with amateur materials.); we will use for this purpose aluminium, this is a materials that can not stand much higher temperatures but that is lightweight while cheap and easy to obtain, in addition, an estimated work time is not going to be very long and do not care if once completed his function nothing remains about the nozzle (less weight).

Figure 15 The Stage2 aluminium nozzle

It is important to note that use blackpowder as a propellant is a highly inefficient solution due to originally the nozzle parameters was calculated using as ACPC (Ammonium Perchlorate Composite Propellant), a propellant much more suitable but more dangerouse to handle and more difficult to achieve, but we need to acquire ACPC in the future if we would like to use this type of launch (sounding rocket launched from a balloon) to put a WikiSat in its orbit.

3.3.3 *Manufacturing*

Construction of the Stage2 is all components of the project one of the most delicate due to we work with materials that are very easily damaged and deformed, construction technique has been improved as we have been testing prototypes.

For the construction of the Stage2 we need a nozzle, two cans of soda that are made of steel, eight grains and epoxy resin. We will use the resin not only as an adhesive, but we will use it also as thermal insulator. One can will be the structure of the Stage2, we will use the bottom of the other one to do the union between the can and the nozzle more solid, and the body as a mold to buid the payload encapsulation. (There is a manufacturing tutorial in Annex C)

3.3.4 *Tests*

As mentioned, the manufacturing method has been closely linked to the tests, because we have basically 3 types of tests that we have been detecting and resolving problems then we had to solve the next generation of prototypes. For these tests we need, of course, the igniters and better if we have the Fire Box.

3.3.4.1 Preassure tests

In order first tested what pressure, the can and bukhead, is capable of withstand. This test is being introduced nitrogen pressure in the can until it gave way, then for this test we need a preasure nitrogen bottle with a manometer (we have a reductor), a pressure hose (capable to withstand high pressures) and a piece of aluminum (or any other material you have) that replaces the nozzle and having a fitting to attach to hose. These tests improve, overall, the union between the can and the nozzle. The bulkhead was never a problem, will hold.

Figure 16 Pressure test

3.3.4.2 Burn tests

In these tests are tested various configurations of grains (putting more or less grains one way or another), we put it and then we ignite it to see the effects and, of course, we report them. First, we realized we needed to put the resin layer to a better temperature withstand, then that we could not use aluminum cans, due to they do not support well the temperature as good as steel cans, which are deformed with heat, aluminum simply explode.

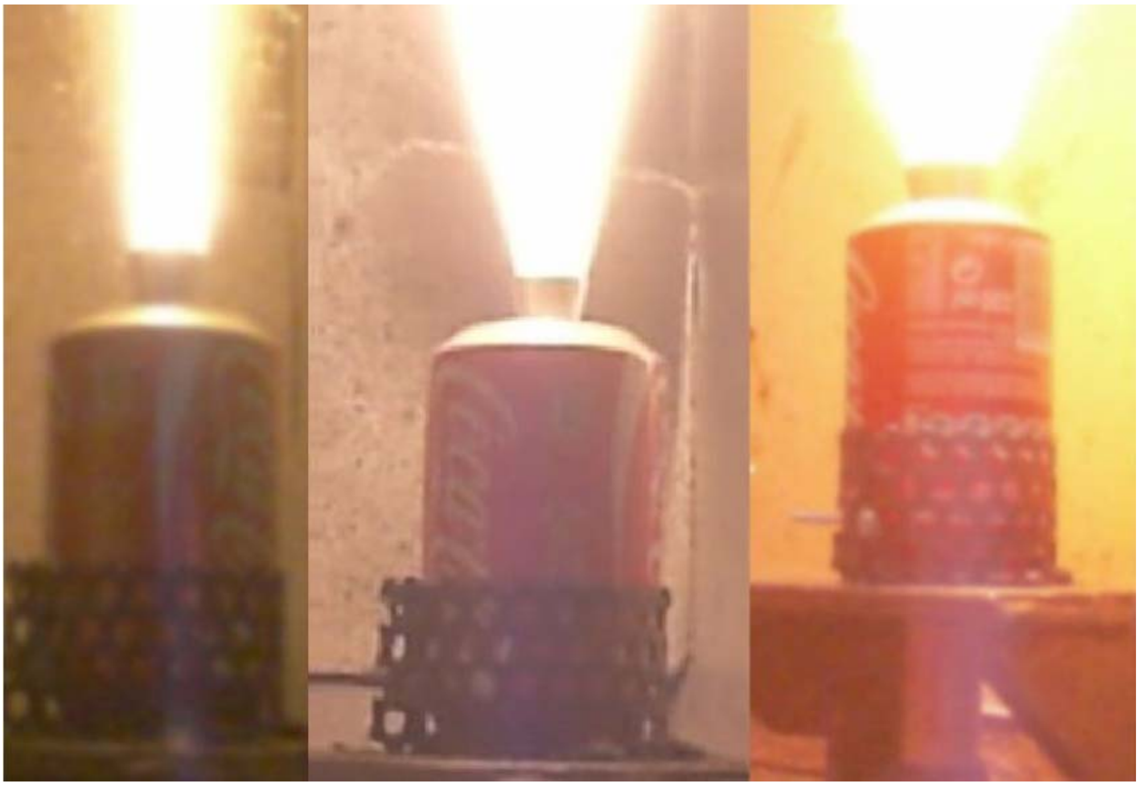

Figure 17 Three different burn tests

With these tests we also get (thanks to a bascule) to draw an estimated propulsion – time graph of a grain with our aluminum nozzle and with its “series” nozzle.

3.3.4.3 Behavior tests

We made three behavior launches, mostly to see the stage stability, the truth is that these tests have not been too successful but in the future (with a better propellant, ie APCP) it wil be more stable thanks to Roberto’s work [5] who is just working on a highly sophisticated control system through nozzles and micro servos using the pressure generated into the combustion chamber that will have the sounding rocket very stable. So basically in this launches we attempted to try to put the center of gravity as the nose closer to the Stage2 to be as stable as possible. We can see in picture picture x the vector control system with four nozzle, and four servos which each controls a nozzle.

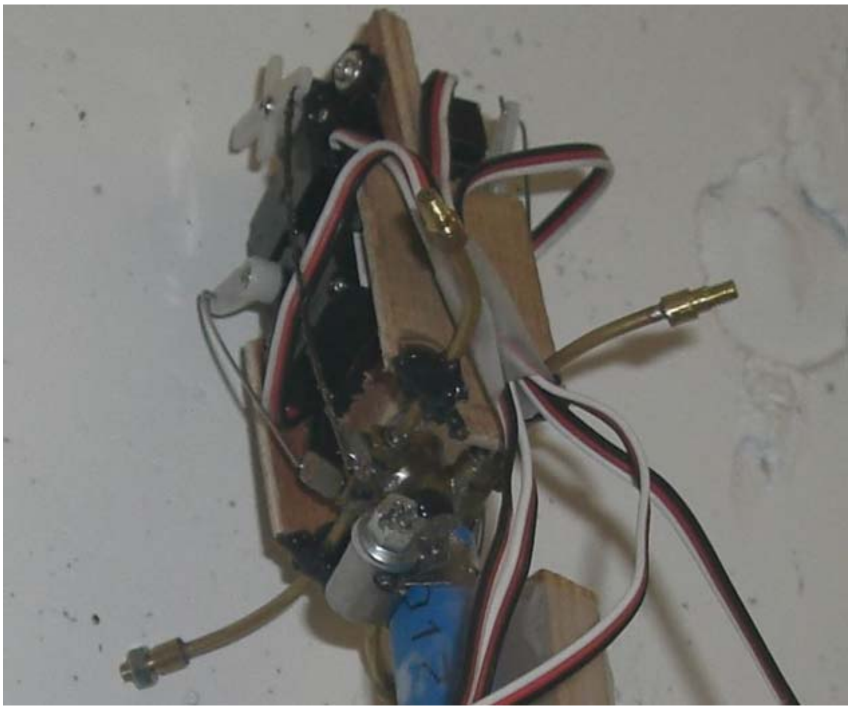

Figure 18 Vector control

3.4 Stage2 payload

Mainly this mission will be to test and validate components as close as possible of the space, and then we will explain the components that will be used commonly for these missions. All the payload componets will be contained in an epoxy-build encapsulation large enough to enter "any" extra component that the group wants to validate in space.

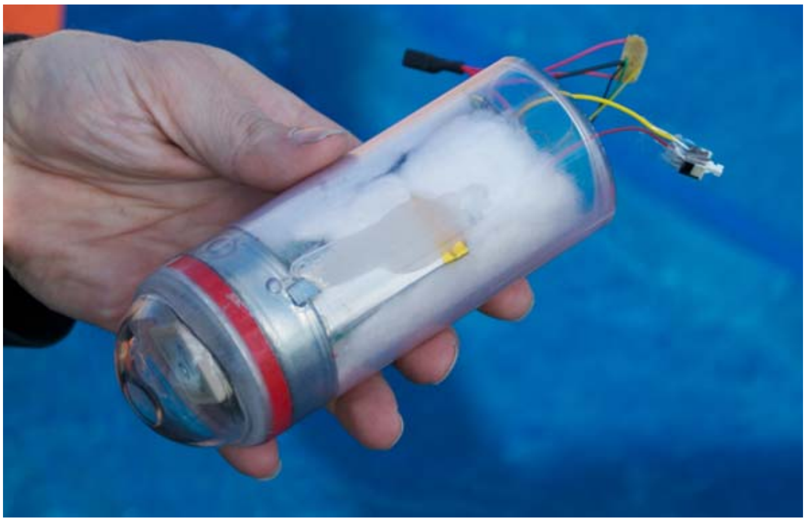

Figure 19 Payload encapsulation

3.4.1 Camera

Today there are a large variety of micro cameras on the market, has made a great leap in a few years on this issue and now you can find these kind of cameras with a performance more than acceptable at a ridiculous price. We have chosen, for our purpose, two different types, one is a camera that is integrated on a keychain and the other in a pen. In both cases what we do is remove them from your body (being careful not to damage them) and change the batteries with higher capacity and a micro SD memory card, allowing us enregistrer throughout the flight (To see the camera performances, see the Annex B).

Figure 20 The two kind of cameras: keychain camera and pen camera

3.4.2 *Battery*

There are several batteries, a 9-volt comercial battery that powers the GPS garmin and to short-circuit the igniter when the AWIP deems necessary (ie 35 km hight), and two LiPoly 400 mA battery, one to power the AWIP (or Arduino) board and the other one to supply the camera.

3.4.3 *GPS based systems*

For this mission the use of GPS is essential, and it is essential for two reasons, one is to know how high our sounding rocket has arrived, the other is linked to the fact that our mission is necessarily recoverable, as we will need a GPS to give us the position where the sounding rocket has fallen to retrieve it and thus to obtain the stored data.

3.4.3.1 Apogee detection

To determine whether or not we rached the space, we will use a GPS that works in Space (ie for altitudes above 100 km) and our AWIP platform, the operation is very simple, because we have not put any communication between the sounding rocket and the ground and we want to save having to put an extra memory to the payload, we decided to use the EEPROM memory of which has AWIP platform, the problem of these memories is that its size is really small to store many data, so our intention is to save only the highest altitude data to give us the GPS, so we know how far our sounding rocket has arrived (you can see the apogee detection code in Annex D).

3.4.3.2 Recovery system

To recover the sounding rocket we use a tracking system for vehicles, people and animals it we can locate it whenever you have phone coverage (and of course it is intact). This system is one of those it we decided it's better to buy it manufacture it by ourselves due it even it is not exactly cheap due it it costs around 200 € the unit has been decided by this method due it was the lightest and easier to integrate independent of the tracking system. Future missions will not be necesaro or recover the system or if you need to recover not need a specific system it we have monitored all the time the sounding rocket with the communications system will be integrated. To avoid that in the ground collision we don’t break the locator which will parachute talk before.

Figure 21 The two kinds of localizers (loc8tor & Chinese)

3.5 Regulation accomplishment

3.5.1 NOTAM requirement

So with our launch platform, Stage2, igniter and our exquisite technology (amateur) courtesy of the Wikisat group willing of space validation, we can proceed with the last step of our mission, asking Civil Aviation[19] (DGCA) to grant us a NOTAM. For this we have to meet certain requirements [6] (regulation JAR-101.7 applied to the free balloon launch[20], see on Annex E), certain information that we have to provide, and terms that we have to meet so that we can publish the NOTAM.

First of all we have to choose a place as close and "comfortable" as possible and that meets all requirements to facilitate us to provide the desired NOTAM. Then we have to do balloon trajectory simulation and see specially to keep it far away from any protected airspace (style military airfield or airport airspace). At the end we will list what will put in the balloon (payload) we will take the simulation and the launch location and was split into an e-mail we send to DGAC one month or more before launch.

3.5.2 Launch situation

Choosing the place is not easy thing because we have to take into account various factors. In the chapter “environmental impact” we will discuss what happens if something goes wrong during launch, now we believe we have choosen a well site, and then in subsequent chapters will show that this place is really good and acceptable to DGAC and to avoid any serious incidents.

The site is chosen for its "close", its easy to reach by car and your isolation, it is outside the town of Zuera (41.859N, 0.753W) in the Autonomous Community of Aragon, Zaragoza province, just about 20 km from Zaragoza city and bordering the desert of Los Monegros.

[19] Involving both the Department of Operations Coordination of Aena as the spanish Major State of Air
[20] http://www.eoss.org/pubs/far_annotated.htm

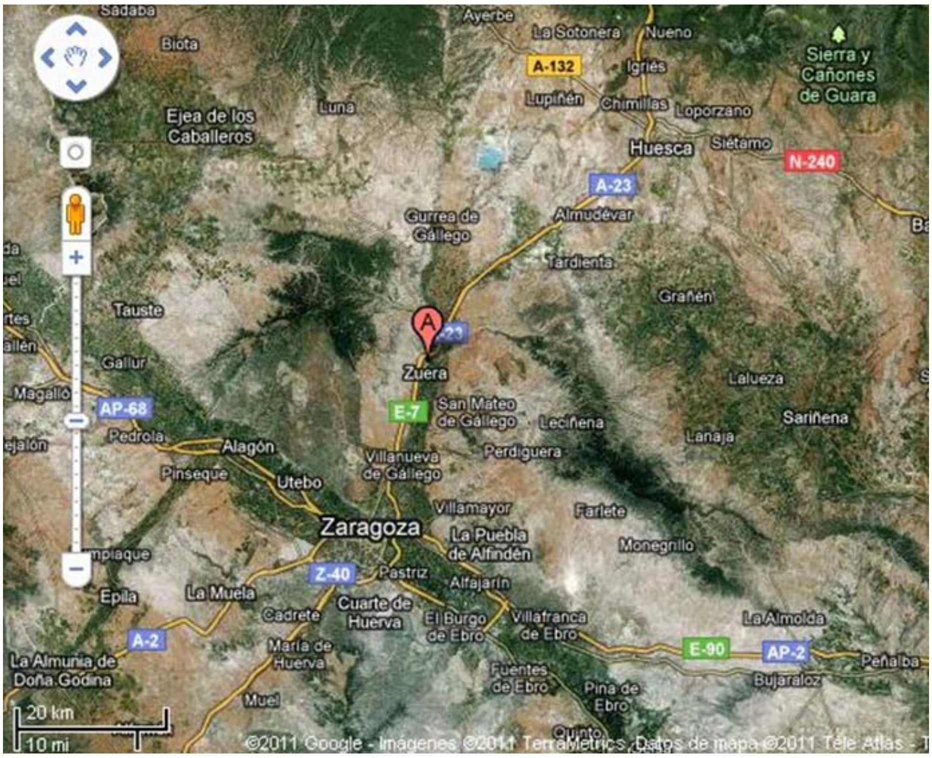

Figure 22 Zuera situation

3.5.3 *Launch simulations*

For the DGAC we will send a balloon trajectory simulation since it was launched until apogee, where it burst, to the landing. This can be done easily with the aforementioned moon2.0 simulator, but in this case (and without a precedent) we will use a web program also referred to in section 1.3.1.2, just to show how easy can be to create a simulation by a not know how the Moon2.0 works, only with the file created by the web and opened it with the free google earth program only with three easy steps.

This program gives us a 24 hour after simulation separate in 4 times both separates in 6 hours then we have simulations at 12 AM, 6 AM, 12 PM and 6PM. First of all we need the coordinates of the launch point, we put the coordinates in the respective boxes, the step two is to create the .KML[21] file able to be opened with Google Earth, and the third and last step is open this file with the Google Earth, to be more precisely we have done several simulations using all the times because, don't forget, it is a prevision and could not be quite good. Below in the picture 23 we can see the three only steps we have to follow to create a balloon trajectory, on the 1st step we have to introduce our data (Launch time, forecast period, the launch coordinates, the burst altitude and finally the output format) then it creates a .KML file, we have to open this file (2nd Step) and then see the virtual trajectory with Google Earth.

[21] is a XML schema for expressing geographic annotation and visualitation within Internet-based, two-dimensional maps and three-dimensional Earth browsers. KML was developed for use with Google Earth.

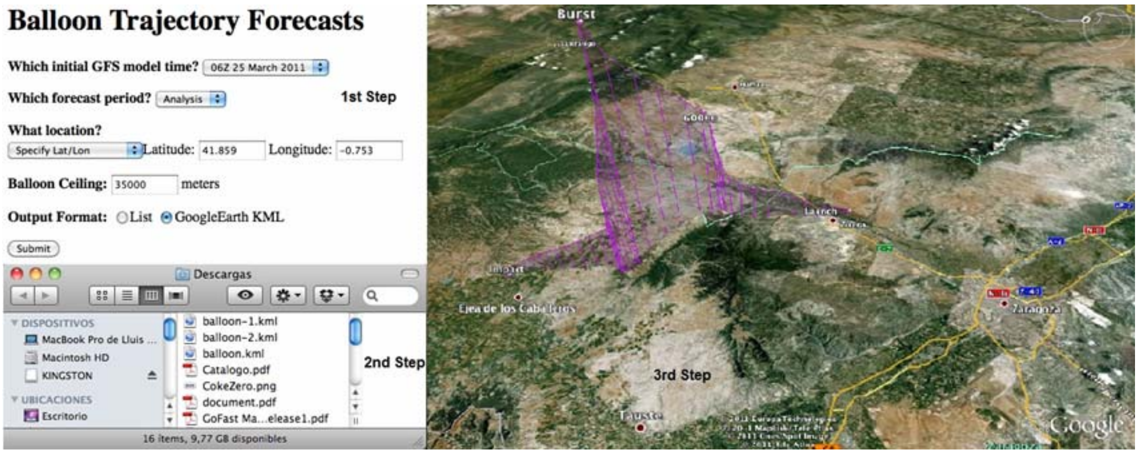

Figure 23 Balloon trajectory forecast creation

If we have several simulations we can see the results and choose the best time to launch, we can see the results below in picture 24.

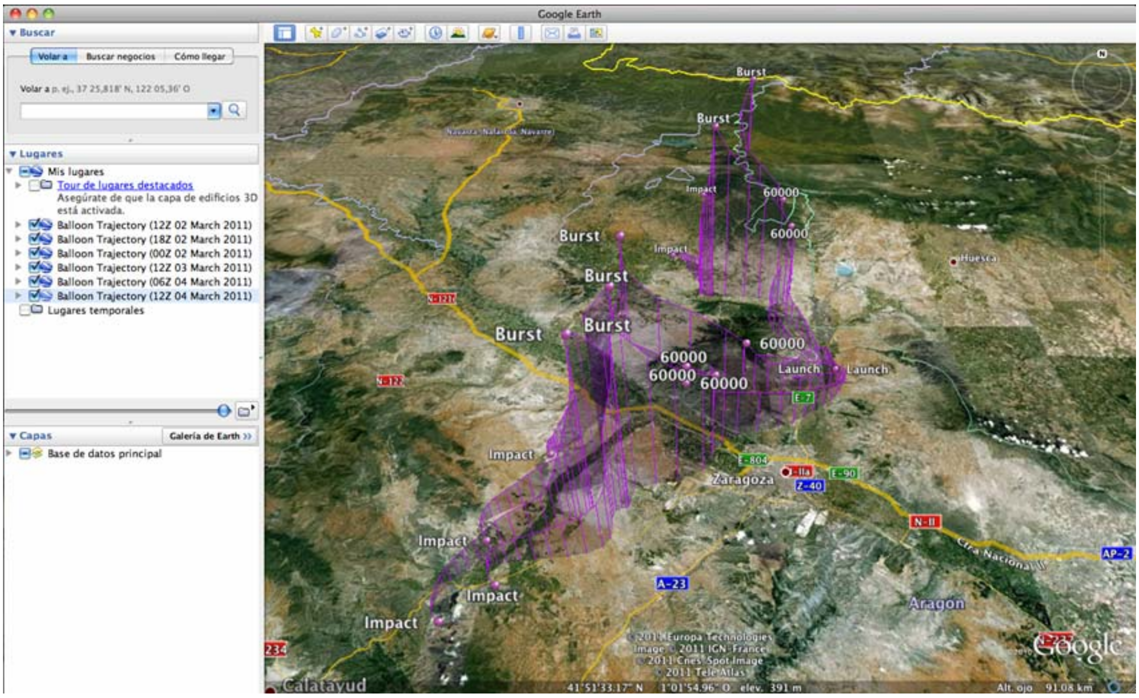

Figure 24 Several balloon trajectories forecast

3.5.4 NOTAM request

Below, the NOTAM request send by us to DGAC, with this e-mail we include a trajectory simulation (it is not strictly necessary but any extra usefull documentation helps):

Dear Sirs,

According to our procedure REF2009/10, we communicate with more than one month in advance of our intention to launch a balloon to generate the appropriate NOTAM. Two days before launch, we will update the forecast to have more accurate data path of the balloon.

This launch is part of a research project at the Polytechnic University of Catalonia (UPC) which we have done other releases previously under authorization. This project is important because it allows us to test small electronic components in near space of great value for the Spanish industry due it facilitates the use of new components in new satellite. The UPC has a long history of projects in collaboration with the European Space Agency (ESA) where they have put into orbit several satellites. The free balloon would be released from a point just outside the town of Zuera near Zaragoza ascending at a speed of 20 km/h. In 30 minutes I would have left the upper airspace. When the balloon reaches a height of approximately 30 kilometers, explodes and falls slowly with a parachute in the area indicated in the simulation of winds that we have attached. The payload was intended to carry a mobile phone with GPS to detect that reaches the ground send us a message with the coordinates and was subsequently recovered, usually in the mountains. In the later hour we have got problems with the sim card and we used some components like a GPS, a small computer, and a GSM locator that worked equally as the mobile phone. We made a study of the upper airways and never cross any of them; the green dot is where you get the balloon and is directed toward the northeast.

The release properties as well as my data as the project are summarized below:

Release Date: Day Month Number at Hour UTC
Coordinate Format: 41.859N, 0.753W
Release Location: Zuera (Zaragoza)
Maximum altitude: 30 km
Standard latex balloon (800 grams)
Diameter: 2 m
Color: White
Activity radius: 200 km
Flight time: 3 hours
Payload: Localizer, GPS with Arduino board and a camera (190 grams)
Parachute cord and plastic (20 grams)

NOTAM answer:

Consulta NOTAM

(D0333/11 NOTAMN
Q)LECM/QWLLW/IV/M /W /NAV/000/985/4152N00045W108
A)LECM B)1103051200 C)1103051500
E)RADIOSOUNDING. ASCENT OF FREE METEOROLOGICAL STRATOSPHERIC BALLOON
ON 415132N 0004511W
ZARAGOZA/ZUERA

BALLOON FEATURES
TYPE: SPHERICAL
COLOUR: WHITE
DIAMETER: 2M
WEIGHT: APROX. 1000GR INCLUDING SOUNDING
ASCENSIONAL SPEED: APROX. 5.6M/SEC
MAXIMUN ALTITUDE: APROX. 30000M AGL
MAXIMUM DEVIATION APROX. 200KM
F)SFC G)30000M AGL)

Figure 25 NOTAM

3.6 Pre-flight test

Before giving approval to a prototype for use in the validation space you have to do series of tests to ensure at least that works on land. In this project we have done all tests on everything from pressure tests and burned to cover evidence (in the case of localizers) to test temperature, all are recorded to report them. There are test more "sensitive" than others, tests that have to follow strict security measures that we will elaborate below:

3.6.1 Preassure tests

These tests consist on introducing a presure gas inside a hermetically sealed object until it subsides. The material used for these tests is of paramount importance, not just any hose or gauge, we must ensure that these materials will withstand the pressure that we will use, because the object that we will test will be well protected in a box but these other elements will go away.

For these tests will be essential to the use of hearing protection and gloves for those handling the bottle with the gas pressure.

3.6.2 Burn tests

The firing tests are essentially tests to test the performance and push the Stage2, this is above the handle, push the blackpowder used and the structure of the Stage2.

We've talked before how to do these tests and the manufacture and use of the Fire Box, this will be essential, as it allows the Stage2 IGNITION the safe distance to avoid being damaged, because the test can be destructive. Must be done outside or in rooms specifically designed for this function.

3.6.3 *Other tests*

The two previously mentioned types of tests are the most "sensitive" to make, then there are others that do not require any special security measures. These tests are usually those that are related to look if they work (normally or in extreme environment) electronic devices such as pagers, GPS, etc.

These are usually done outdoors (if we need to align with satellites) or in the laboratory. The materials needed to make these tests (if needed) are often testers, power supplies, batteries and a freezer (extremes of temperature tests).

3.7 Pre-flight check list

To help leaving anything important before the launch, it is advisable to make a check list of materials as well as procedures. This minimizes the mistakes we make due to an oversight and gives more guarantees of success for the mission.

3.7.1 *Check list of materials*

- Localizers:
  - Chinese.
  - Loc8tor.
- Launch pad parachute.
- Lid with fitting x 2.
- Compressed air hose.
- Heat gun with replacement.
- Adhesive for plastic.
- Lighter.
- Cutter.
- Several pliers.
- Scissors.
- Duct tape.
- Adhesive tape.
- Measuring tape.
- Datasheet.
- Flanges.
- Welder with tin.
- Welder support.
- Thermal blanket.
- Hearing protection.
- 9-Volt Battery.
- 9-Volt Battery Back up.
- USB wire with FTDI
- Several Screwdrivers.
- Pen.
- Cameras fot tube x 2.

- Record process cameras[22] x 2.
- Payload camera.
- DC to AC car converter.
- Laptop with charger, mouse and modem.
- Helium bottle.
- Plastic mat.
- Stage2.
- Payload encapsulation[23].
- Balloon joined with the launch pad.
- 5 kg scale with a clamp.
- 2 kg load.
- Electric cable.
- Tester.

3.7.2 Check list of procedure

- Report with pictures and videos from now until the end of the precedure.
- Extend the plastic mat on the floor.
- Plug the heat gun to the DC to AC car converter.
- Download from the car the helium bottle.
- Putting up of the plastic mat:
    - The launch pad with the balloon.
    - Lid with fitting.
    - Payload components (payload encapsulation, payload camera, 9-volt Battery, thermal blanket, loc8tor).
    - Stage2.
    - Chinese localizer.
    - Several Tapes.
    - Cutter.
    - Tester.
    - Compressed air hose.
    - 5 kg scale with a clamp and 2 kg load.
    - Adhesive for plastic.
- Prepare the launch pad:
    - Fix the parachute with duct tape.
    - Protect the cameras with thermal blanket and fix to the tube.
    - Checks the Chinese localizer protect it with thermal blanket and fix to the tube.
- Prepare the payload:
    - Check that the payload camera works doing a record test.
    - Turn on the payload camera.
    - Fix it into the payload encapsulation with thermic glue.
    - Cover it with thermal blanket.
    - Connect the 9-Volt Battery.
    - Cover with more thermal blanket.
    - Introduce the loc8tor[24].

[22] Commercial digital cameras to photograph and record the entire launch process.
[23] Epoxy resin cylinder, nose made with an IKEA ashtray and Garmin GPS and an Arduino board built-in.

    - Cover with more thermal blanket.
- Check the Stage2 igniter with the tester.
- Connect the igniter with the Arduino (See below, picture 27 for connector schematic).
- Turn on the Arduino board with the switch (See picture 26)
- Seal the union with duct tape.
- Enter the Stage2 into the launch pad.
- Put Adhesive for plastic all around the lid with the fitting.
- Introduce it quickly into the launch pad and seal with duct tape too.
- Connect the air pressure hose with the helium bottle and the launch pad.
- Open the helium bottle valve slowly[25].
- Check the free lift with the scale[26].
- Once the free lift is correct, let go off the launching platform.

You can see below in picture 26 & 27 a picture of the payload where we can see the Star/Stop Arduino switch and the igniter, Paras & battery connector with its schematics.

Figure 26 Star/Stop Arduino switck and connector

[24] You have to prove that the Loc8tor works during the trip to the launch zone also must have been bought position and SMS credits a few days before launch, enough for at least 7-8 hours of positions and a minimum of 50 SMS.

[25] Taking care that the Stage2 does not leave the tube.

[26] Put 2 kg weight on the scale and then grab the launch pad, the difference is the free lift.

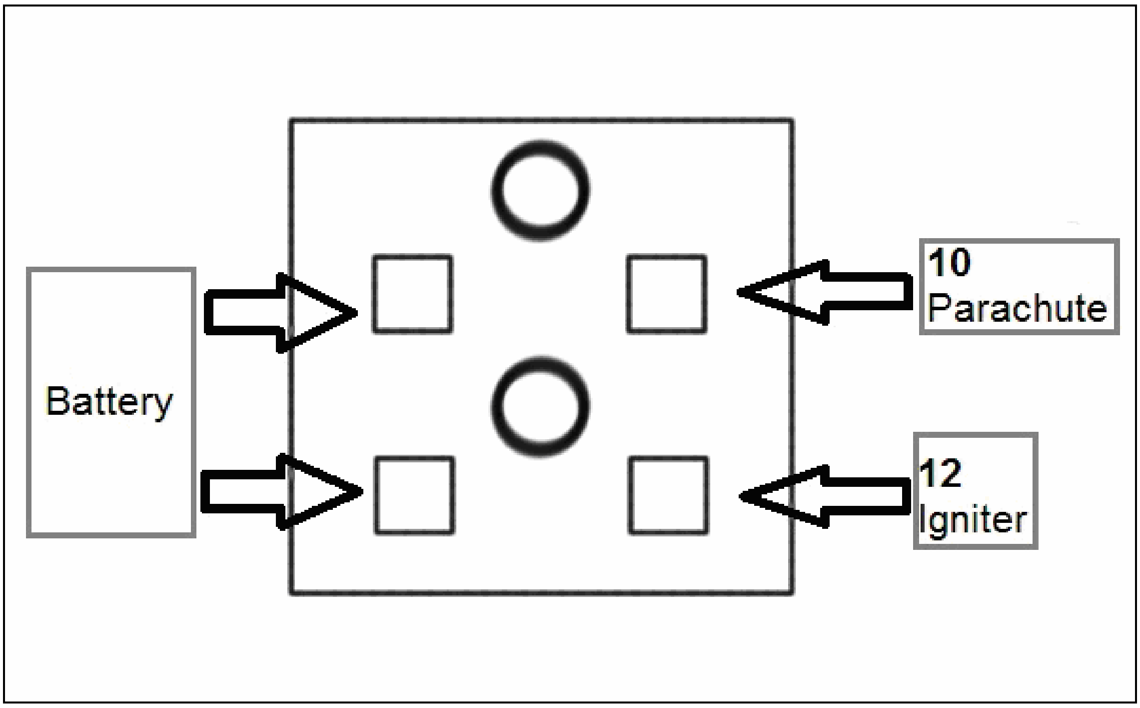

Figure 27 Schematics

CHAPTER 4. Environmental impact

Before executing a mission like this in that we work with unmanned vehicles and they are not remotely controlled, we have to do an exhaustive study of the failures that can cause a catastrophe[27].

Although this mission is, per se, very secure due its most dangerous step (ignition) occurs at a very high altitude (over 30 km) and we're talking about a very small sounding rocket, but in every balloon mission (either sounding or component testing) there are a couple of situations somewhat compromised, these are during the balloon ascent and (less important) the fall of the payload carried.

This study will serve both to validate the launch area, if we see that the simulations give us a remote or nule chance that has a disaster launching the sounding rocket from the chosen area, we will be given the green light to the area and may be used provided for this particular mission, if it fails the "tests" we had to choose another area and go through the simulations and calculations until we find a place that meets the highest security measures.

4.1 Study of hazardous trajectories

Let's see what's in the area we have chosen for the launch, on the ground (let's do a study of the terrain, population, etc) and in the air (let's see what airways may we cross).

4.1.1 Climb path

One of the most "sensitive" moments of the mission is when the balloon climbs and it could cross any airway that has been around, that's why we had to take into account the number of airways that pass near our launching area. You can mistakenly think that the danger is that an airplane could hit against the balloon, nothing is further from reality, the greatest danger is that a pilot could see the balloon and get scared. This is why we are requested NOTAM, it are published each month and inform pilots about casual events in certain aerial parts, such as launching a sounding balloon, a deviation in the path of a taxiway due to works, etc.

Thus in the worst case, we might encounter that a pilot sees our balloon and, still warned, he get panic and does a sudden movement to avoid it (thing really improved). Then we will study how many airways have about 50 km and which of them can be crossed by our balloon, and then let's look at which airports are and its relevance.

First of all we have to know that airspace is divided into lower airspace and upper airspace, so let's start with one and then do the other:

[27] When we talk about tragic and catastrophic, we mean that our mission can cause any kind of fire, destruction or damage to properties and most importantly, human damages.

4.1.1.1 Lower airspace

In the picture 28 we can see the lower airspace airways more or less 50 km away of the launching point (situated on the red point):

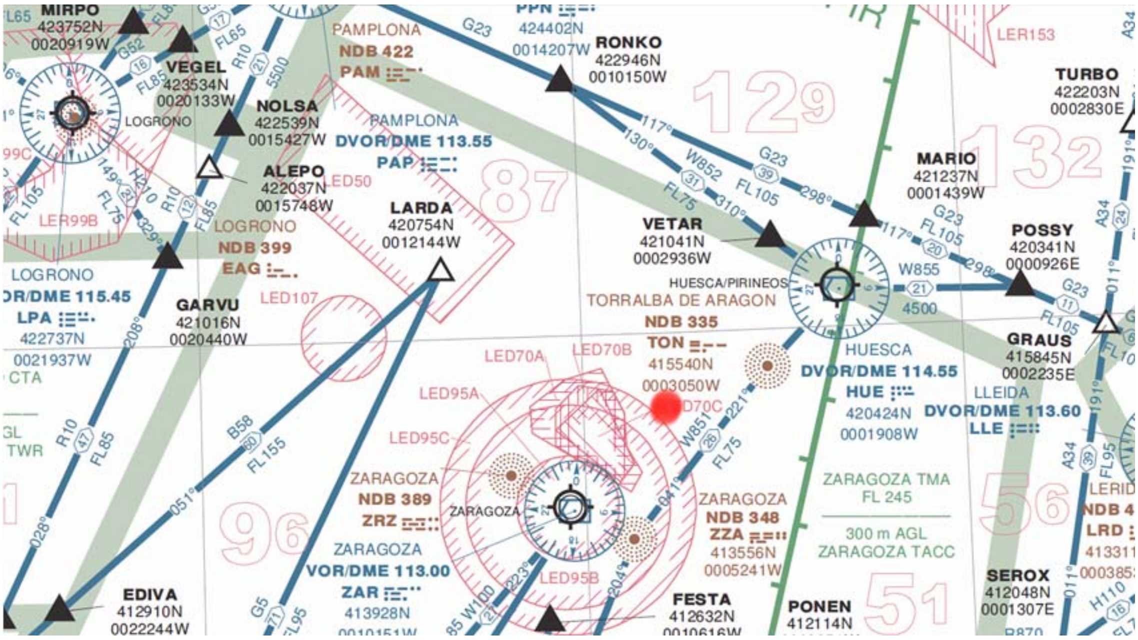

Figure 28 Lower airways

Airway	Minimum Flight Level
W855	4500 (1371 m)
W1	FL65 (1981 m)
W851	FL75 (2286 m)
W852	FL75
W100	FL85 (2590 m)
R10	FL85
A869	FL85
G5	FL95 (2895 m)
G23	FL105 (3200 m)
B58	FL155 (4724 m)

TABLE 4.1 NEAR LOWER AIRWAYS

Of these the most concerns us is the W851, the others still who are at a distance of about 50 km from the launch point is almost impossible that are crossed during the ascent, to give us an idea at the validation launch we just crossed this airway, the other airways as much could be crossed at the time of descent.

4.1.1.2 Upper airspace

In picture 29 we can see the aiways belonging to the upper airspace:

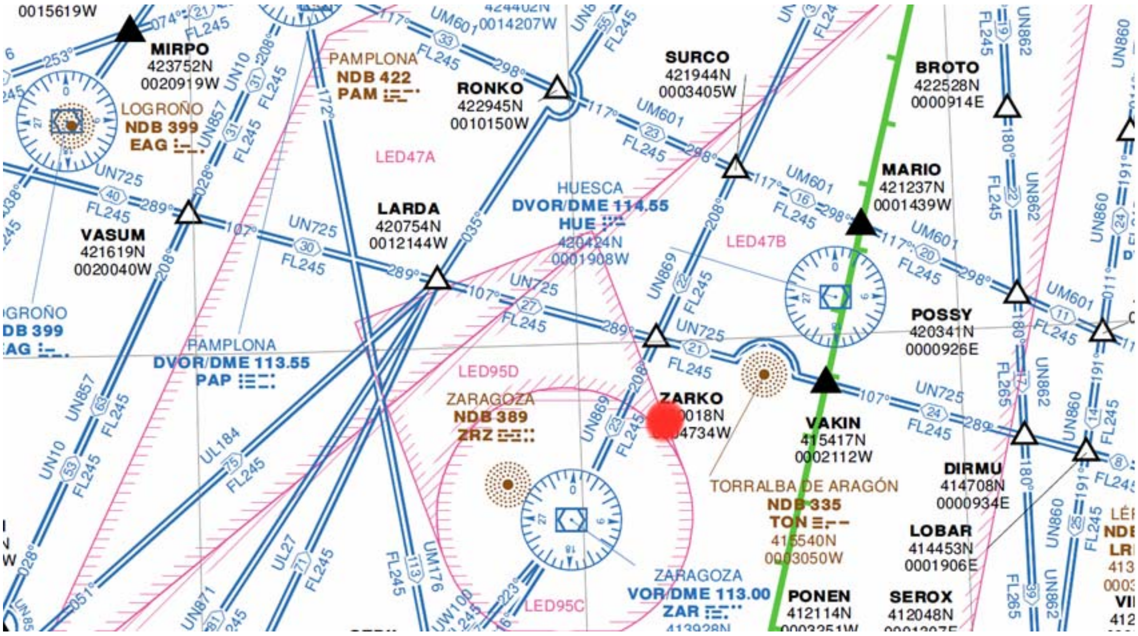

Figure 29 Upper airways

Airway	Minimum Flight Level
UM601	FL245 (7467 m)
UN725	FL245
UN869	FL245
UW100	FL245
UN869	FL245
UL27	FL245
UN871	FL245
UL184	FL245
UM176	FL245

TABLE 4.2 NEAR UPPER AIRWAYS

The only ones we have to worry about are the UN725 and UN869, the closest. In our launch just came across the UN725, as much in a launch would come across two (these two) the others still are relatively close, it would be very difficult (unless the wind that day in the lower layers was very strong) that never even crossed.

***4.1.2** Fall launching ramp*

Our launch pad, once it has left the sounding rocket and has broken the balloon, it begins to fall, if the parachute does not break, this is going to get soft and quietly to the ground, but let's see what happens if this breaks, first let's see about which area would fall and then the "damage" it would cause.

In picture 30 can see the landing zone population density, this covers 8259 km^2 of surface and a population[28] about 888837, you can see it detailed by municipality, see annex F below, the color code:

Color code	population/km^2
	1000
	100 to 999
	40 to 99
	20 to 39
	1 to 19

TABLE 4.3 COLOR CODE

Figure 30 Landing area population density

[28] Census and surface extracted from the Government of Aragon website http://www.comarcas.es/

As we see there is a large concentrated area where the majority of the population which is Zaragoza city and five other large concentrations of population such as Utebo, Huesca, Curate of Huerba, Puebla de Alfinden and Cadrete. Everything else could be considered almost deserted, with some occasional small town, most of which is no more than 1000 people. The geography is made up of small hills, the flora is made up basically of low brush throughout the area has no large extensions of forest.

Then we will calculate how hard could impact our launch pad in case the parachute brokes, for this we need to calculate the terminal velocity of the launch pad to calculate roughly the energy that would impact and see if this is very relevant:

$$V_t = \sqrt{\frac{2mg}{\rho A C_d}} \quad \textbf{(4.1)}$$

Where

V_t is the terminal velocity,
m is the mass of our launching pad, it is 1.2 kg,
g is the gravity acceleration, it is 9.8 m/s^2,
ρ is the air density[29], it is 1.22 kg/m^3,
A is the projected area of the launching pad, it is 0.00442 m^2.
C_d is the drag coefficient[30], it is 0.82.

With these values we have obtained, we have a terminal velocity of 73 m/s or 265 km/h. Then let's see the energy obtained with this terminal velocity at the ground impact time.

$$E_m = E_k + E_p \quad \textbf{(4.2)}$$

Where

E_m is the mechanical energy,
E_k is the Kinetic energy, see **(4.3)**
E_p is the Potential energy, see **(4.4)**

$$E_k = \frac{1}{2} m v^2 \quad \textbf{(4.3)}$$

Where

m is the mass of our launching pad, it is 1.2 kg,
v is the terminal velocity, it is 73 m/s

29 http://www.denysschen.com/catalogue/density.asp
30 http://www.aerospaceweb.org/question/aerodynamics/q0231.shtml

$$E_p = mgh \tag{4.4}$$

Where

h is the altitude, it is 0 m, then E_p will be 0.

Then the if we use our known values, we have an E_m of 3197.4 J, we did this for an idea, would be the energy that would make a 1000 kg car crashing to 9 km/h, to scare someone, but not to break anything.

So we conclude that the area is ideal due to the big extension without population and even taking a city about 20 km far, if for accident our launch pad fall on the city and it will break the parachute, the damage would be almost imperceptible.

CHAPTER 5. FINAL VALIDATION

5.1 Launch day

For the trip to the launch point on the outskirts of the town of Zuera we used a van, wide and comfortable to carry all the material we need for launch.

We loaded the van carefully, falcate helium bottle well so it does not move during the travel and putting delicate things in places where there couldn't be damaged. The journey took about 3 hours and there were no incidents. The weather was excellent, without wind and lots of sunshine. We checked the ground, a position is well separated from civilization only accessible by dirt roads, and then we came and began to prepare things.

Figure 31 Preparing the payload

We follow all the process indicated in the check list of procedure (before mentioned), even let us see through a balance and a two-kilos weight, the free lift that the system had, and this gave us about 400 grams, which is not bad. We can see below in picture 32 the time before launch.

Figure 32 At launch

5.1.1 Unexpected failures

But not all was as expected, there were several unexpected failures that made us change a little the mission and not allow us to validate some things, we list them below:

We were not able to run the chinese locator, it had to go on the launch pad and allow for recovery, recovering so the cameras that would show near-space images and the key moments of the mission such as the balloon burst and the output and first moments of the Stage2. Without this locator we had to remove the tube cameras, even they were not very expensive, we decided not to risk it and validate the next mission.

Another mistake was to put a wrong balloon, we had thought of using a “1500gr” balloon type with a maximum altitude of 35 km, instead of this, we used one of “800gr” that in the best case comes to 30.5 km, this "error" came given that the order of balloons did not arrive and we had to use one of the "old" that Joshua had. Although the balloon reached the altitude that the program has as launch altitude, the margin of error was very small and could not really sure that this reach really 30 km high.

5.1.2 Recovery time

The rocket locator was giving us the position data for a while, when he lost coverage, stopped sending data, but hour and a half after launch, returned to receive data and again stop, the last data we receive was standing at a point in the "desert ", the flight time was very small, but we believe that as the balloon was a little worn could be that this had exploded prematurely and we started to search it. At that time we realized that we had ceased to take an essential tool to find the locator, a GPS mapping. We seek an alternative, a mobile with GPS and Google Earth would be enough.

The method was as follows, be checking in different strategic points of the ground to see how far we were the target, with a little patience we got to the last position given by the locator, we were looking for a long time but we found nothing, decided to withdraw and return for home, it was then half way, the locator again gave us a number of positions. We were very far and it was decided to return the next morning with a GPS mapping. The next morning was very easy to find the locator in a field near a road.

Figure 33 Launch pad landed

5.2 Flight results

The reason of this launch was, above all, to validate the method of launch and the launch pad, everything else was over, only to take advantage of the launch, as well as the results were as follows:

Data:

Launch point: Zuera (Zaragoza).
Launch coordinates: 41.858542N, 0.751805W.
Flight time: 3 hours, 3 minutes.
Record time: 2 hours, 50 minutes.

Landing point: Ola (Huelva).
Landing coordinates: 42.105225N, 0.290180W.
Balloon type: Latex 800 gr.
Free lift: 700 grams.

Components to validate:

Localizer Loc8tor: Validated.
Balloon filling system: Validated.
Payload encapsulation: Validated.
ANIKA camera: Validated.
LiPoly 400 mA battery: Validated.
Arduino Mini PRO: Not work.
Scientific data: Lost.

5.2.1 Failure analysis

The reason that the arduino did not work and, therefore, lose all the relevant scientific data, it was basically the cold, the wires and solder used to assemble the various components making up the payload did not withstand the freezing temperatures of near space breaks with any balloon wiggle, as well as opening the payload we saw bare wires and dropped of battery which have to give power to the arduino board and the wires that went to the igniter.

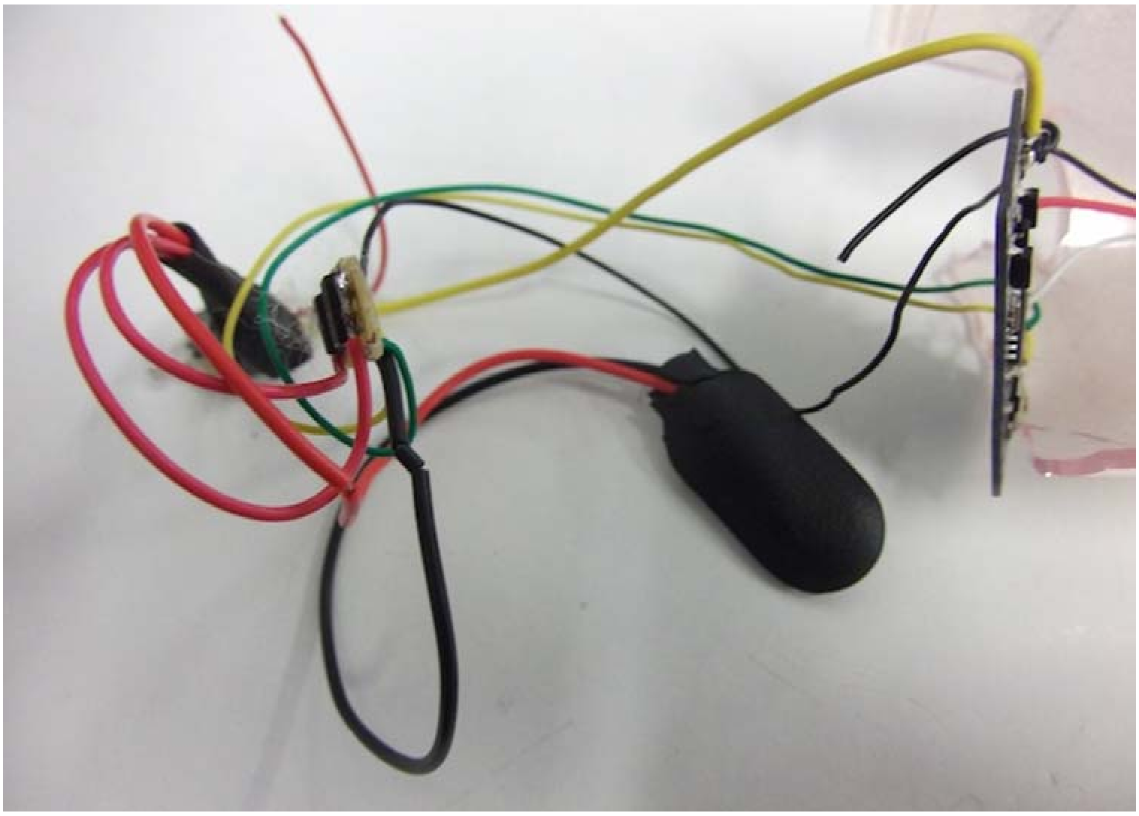

Figure 34 Arduino with the wires cut and broken

5.3 Things to be improved for future launches

In future launches, we have to improve a data collection system; it has to be a system more robust and resistant to extreme temperatures.

We have to use the Loc8tor system for tube-launcher and can so to have pictures and track of the balloon after the launch of the Stage2.

We have to close the mission a week before the launch, in this mission we worked all night before the launch, it means that there are things that can not be completed on time and things done wrong, not to mention the danger of a long trip slept little and poorly, besides the fatigue-induced errors that may have at the time of assembly.

If the mission is recoverable must wear a GPS map to help locate it quickly and think on some kind of parachute system, because we don’t have a payload encapsulation crash test and we can broken all the payload components loosing, therefore again, all the data.

CHAPTER 6. CONCLUSIONS

It has been seen as with imagination, hard work and a fairly low budget we can achieve amazing things, and although in the final launch we have not achieved our main goal, which was to reach the space to validate the components that, in future will go with the WikiSat to the space, we have been just a greater capacity balloon and improved thermal insulation to achieve our goal. Yes, much remains to be done, but with this work we have laid the foundations on on which it can base the future space missions by high altitude ballons, solid and validated bases. I've also learned to work as a team without him I can confirm that this project could not have been done, mainly due to the wide variety of fields that have touched, and in the group wikisat each member is an expert in their field and can help, in one point, to another component of the group that requires experience.

This project was itself the union of several projects that I have been fortunate to participate directly helping to manufacture the components and test, as well as indirectly reporting the tests they had done previously, thanks to this I have learned to test components, report the tests and analyze for failures.

And thanks to the final launch we did, I learned how to prepare and manage this kind of mission would not only theoretically but also practically, it was certainly a great experience and of great value for me.

6.1 Results analysis

Throughout this work we have reached the following conclusions:

- You can reach the space with a high altitude LATEX balloon and amateur technology.
- We can use a PVC tube as a platform to launch our sounding rocket.
- We can attach a high altitude balloon with a PVC tube 75 mm diameter introducing it by the nozzle of the balloon
- PVC tube and balloon can share atmosphere thanks to the cover with the fitting (sealed with adhesive and tape), is not leaking helium.
- We can find the launch pad with a Loc8tor and GPS surveying.
- We must use a better insulation for the payload or using materials that can withstand the super low temperatures.

6.2 Future work

The bases for this type of project are already settled, but there are still some things that can be improved for future missions:

- Making a launch with the second final stage, with the vector control, use none amateur solid fuel, final nozzle, etc.

- Instead of relying on the recovery of the sounding rocket to retrieve data from the mission, transmit basic telemetry to the launch station the maximum possible time or altitude. At least enough to detect that we have reach the space (100 km altitude).

- Achieve to use this kind of mission, rather than to validate components, in order to launch a rocket to get to put a satellite in orbit.

CHAPTER 7. BIBLIOGRAPHY

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Annex A

N-Prize Rules (obtained from http://www.n-prize.com/)
These rules are effective from: 18th November, 2008

1. **The Spirit of the N-Prize Challenge**
The N-Prize Challenge is intended to encourage creativity, originality and inventiveness in the face of severe odds and impossible financial restrictions. The remainder of these rules has been drafted to reflect and ensure this as far as possible. Nevertheless, it is possible that loopholes in these rules may make it possible to complete the challenge in a spirit not intended by the N-Prize organisers, but nevertheless within the letter of the rules. The organisers therefore reserve the right to exclude entrants (or to require entrants to modify their entry) if the organisers feel that the spirit of the N-Prize challenge is not being adhered to, regardless of literal compliance with the rules. Such decisions will be made fairly and after discussion with the entrant, but the decision of the organisers in these matters is final. All entrants are therefore urged to discuss their plans with the organisers from the outset to ensure compliance with both the rules and the spirit of the N-Prize Challenge.

2. Amendment of Rules

These rules may be amended at any time without prior notice. Such amendments will normally (but not necessarily) be made in order to clarify points, to close loopholes in order to ensure that all entrants remain within the spirit of the N-Prize, or for unavoidable legal reasons. Therefore, all entrants are strongly advised to contact the organisers before and during the preparation of their entry. Continuation of entrants' registration for the N-Prize Challenge is dependent upon acceptance of any such amendments to these rules. The only rule that is not subject to change is the rule regarding withdrawal from the N-Prize challenge.

3. Prizes offered

Prizes are offered in two categories. One prize (the "single-spend-to-orbit", or "SSO" category) will be awarded to the first entrant to complete the challenge using a non-reusable launch system. The other prize (the "reusable vehicle" or "RV" category) will be awarded to the first entrant to complete the challenge using a partially or wholly reusable launch system. Both prizes carry equal status. All of these rules apply equally to both prizes, except where stated otherwise. The two prizes differ primarily in the way in which the budget for the launch is calculated (see below).

Entrants need not specify at the time of registration which of the two Prizes they are competing for, but must do so prior to launch.

No single entry may win both prizes. In brief (see below for definitions and budget details) any entry for which the total cost of the launch vehicle exceeds £999.99 will be eligible only for the RV Prize. Any entry for which the cost of the launch vehicle is £999.99 or less will be eligible only for the SSO Prize, even if part or all of the launch vehicle is recovered. However, one team may, if they wish, make separate entries in both categories.

4. Eligibility

Individuals or teams are permitted to enter; teams must do so under the name of a single individual who will be the point of contact for the challenge; this person must be at least 21 years old at the time of registration. The N-Prize is aimed at amateurs, enthusiasts, would-be boffins and foolhardy optimists. Individuals or organisations connected with aerospace and other relevant industries are eligible, but must satisfy the organisers that they are acting without substantial support from their current (or former) employer, and are not making unreasonable use of facilities, donated equipment or resources etc. provided by established industry contacts. If in doubt, ask the organisers.

5. Safety

Safety is entirely the responsibility of the entrants. The N-Prize organisers offer no advice whatsoever on safety, and it is assumed that entrants are aware of all risks to themselves, to third parties, and to property, whether on the ground, on water, in the air or in space. Entrants are liable for any and all injuries to, or deaths of, humans or animals, and for any and all damage to property arising through preparation for, or participation in, the N-Prize Challenge. This includes any injury or damage arising after completion of the challenge, for example through re-entry of devices. The organisers accept no responsibility or liability, and in any case are not responsible people.

6. Legalities

Compliance with all necessary regulations (for example those relating to the handling or construction of hazardous materials or devices; permissions to launch devices, and so on) is entirely the responsibility of the entrants, and the N-Prize organisers offer no advice on this matter. The N-Prize organisers do not require proof of compliance with regulations, but entrants should make themselves aware of the penalties for non-compliance. Any penalties incurred as a result of failure to comply with relevant local, national or international regulations are entirely a matter for the entrants.

7. Confidentiality

Entrants are strongly encouraged to discuss their plans with the organisers, to ensure that their proposals fall within the rules and spirit of the N-Prize Challenge. The organisers encourage entrants to exchange ideas and share experiences for their mutual benefit or amusement. However, any information divulged to the organisers will be kept confidential as far as possible if this is explicitly requested; any communications that are to be kept confidential should carry the words ‘IN CONFIDENCE’ at the beginning of the confidential material. This confidentiality cannot be guaranteed in all circumstances (for example, if the organisers are required to divulge information for legal purposes). The organisers reserve the right to use any material communicated to them, in publications, websites etc, unless the material has been marked as ‘IN CONFIDENCE’; where such non-confidential information is used, its source will be credited.

8. Intellectual Property

Entrants are entirely responsible for any intellectual property issues arising from their entries. If you believe you have invented a valuable new way to get things off the ground, and would like to protect the idea, please go ahead. The organisers cannot become involved in the entrants' IP issues. We will not sign confidential disclosure agreements (CDAs), nor can we get involved in patent disputes and similar issues.

9. Definitions

For the purposes of this challenge, the following definitions apply:
a - The 'Launch Site' is defined as the area of land from which the launch takes place; launches may also be made from water, in which case the "Launch Site" is the ship, raft or other vessel from which the launch takes place.

b - The 'Launch Equipment' is defined as all items of hardware required for the launch, but which remain on the ground. These may include, for example, ignition systems, monitoring equipment, safety screens etc. Any items which are not required after a time 24 hours prior to the launch (for example, pumps to transfer fuel, battery chargers) are not considered to be part of the launch equipment.

c - The 'Launch Vehicle' is defined as all items of hardware that leave the ground, including any fuel or other consumables. In a conventional satellite launch, for example, the launch vehicle by this definition would include the rocket (with all onboard telemetry and control devices), its fuel, and the satellite. In the example of a rocket launched from a balloon, the balloon and its lifting gas are considered part of the launch vehicle. In the case of a device launched from a ground-based gun, the gun and propellant are considered part of the launch *equipment*, whilst the projectile (with any shielding, sabots etc) is considered the launch vehicle.

d - The 'Satellite' is defined as the part of the launch vehicle that enters orbit around the Earth. Note that, if more than one item enters orbit (for example, if the satellite separates from a rocket but both the satellite and the spent rocket remain in orbit), the entrant must define, prior to launch, which item is to be considered the 'Satellite'.

10. Acceptable Methods of Attaining Orbit

Any method of attaining orbit is acceptable, provided it does not breach the rules or spirit of the N-Prize Challenge. Examples might include (but are by no means limited to) conventional rockets; balloon-launched rockets (rockoons); gun-launched projectiles; or combinations of these or other methods. All entrants are strongly advised to contact the organisers at the outset to ensure that their proposal falls within the rules and spirit of the N-Prize Challenge.

11. The Satellite

The satellite must have a mass of between 9.99 and 19.99 grams, including the weight of any propellant or fuel. The organisers reserve the right to weigh the satellite before launch (or to have it weighed by a third party) to ensure compliance. The satellite must be a single object; for example, a cloud of un-connected co-orbiting particles does not count. The satellite may include (for example) shielding or fuel that takes its weight over the 19.99 gram limit, but orbits will not count toward the 9 orbit target until such over-weight items have been jettisoned or consumed. As noted, other items (spent rockets; shielding etc) may enter orbit with the satellite, but must not remain attached to it. Nor may the satellite be dependent upon the co-orbiting items in any way (for example, for relaying communications) during the nine qualifying orbits.

12. The Orbits

The satellite must complete a minimum of 9 orbits of the Earth, after its separation from or consumption of any items or consumables which put its weight over 19.99 grams. The orbits need not be regular, nor do they need to be at a constant altitude. No part of any orbit may be lower than 99.99 km above the surface of the earth.

13. Budget

The budget for each launch is calculated differently for the SSO and RV categories, as follows:

i) Budget for the SSO category

For the SSO category, the budget for each launch is £999.99, and all costs are entirely the responsibility of the entrant. The budget must cover the following:

a. The total cost of the launch vehicle, including the satellite itself, and any fuel, gases or other materials which it carries; in other words, anything which leaves the ground.

b. Any items of the launch equipment that could not be re-used for a second identical launch (for example, gun-type propellants, or railgun rails which are rendered unusable in the course of the launch).

c. The cost that would be incurred for refurbishing, refilling, re-testing or otherwise preparing any launch equipment or any aspect of the launch site, if a second identical mission were to be carried out.

d. Any manufacturing costs for any parts of the launch vehicle; or for any parts of the launch equipment that would require replacement in order for a second identical mission to be carried out (for example, such costs would include the custom machining of a piece of metal forming part of the launch vehicle, if this is contracted out).

As a rule of thumb, the budget of £999.99 should enable you to conduct a repeat of a successful mission, assuming that no part of the launch vehicle is recovered. However, all entrants are advised to contact the organisers to confirm that their calculation of expenditure is acceptable.

Items which need not be covered by the budget include prototyping costs; launch equipment or the launch site (except for costs which would be incurred for a repeat mission, as stated above); licence fees, permissions etc; charges made for attendance by safety personnel (provided that such personnel play no direct role in the mission); legal costs; medical costs; insurance costs; fines, penalties or loss of earnings arising from any cause whether prior to, during or after the mission; travel costs of people associated with the mission.

ii) Budget for the RV category

For the RV category, the budget for each launch is £999.99, and all costs are entirely the responsibility of the entrant. The budget must cover the following:

a. The cost of the launch vehicle, including the satellite itself, and any fuel, gases or other materials which it carries; in other words, anything which leaves the ground. However, any parts of the launch vehicle may be recovered by the entrants. In this case, the costs of the recovered components do not form part of the £999.99 budget. In order to qualify, the components must be recovered within one week from the time at which the 9th orbit is completed and must be shown to be in a state fit for use in a second, identical mission. If the recovered components require refurbishment, refuelling etc. to render them ready for reuse, then the costs of such refurbishment, refuelling etc. will be counted as part of the £999.99 budget. The cost of locating and recovering the components does not count as part of the budget (though of course any transmitters etc carried on the recovered components to aid recovery do count). In determining the reusability of components of the launch vehicle, the organisers' decision will be final. It is the responsibility of the entrants to satisfy the organisers that they have recovered the original components and that the components are in a fit state for use or can be rendered so within budget. The organisers reserve the right to seek the opinions of impartial experts in judging reusability. The organizers may (depending on circumstances) request visual inspection, structural tests, demonstration of function or other tests that are reasonable and necessary in order to show reusability. The costs of such tests are to be borne by the entrant but do not contribute to the £999.99 budget. The tests may include a repeat of part or the entire mission only if there is no other way to reasonably confirm reusability.

b. Any items of the launch equipment that could not be re-used for a second identical launch (for example, gun-type propellants, or railgun rails which are rendered unusable in the course of the launch).

c. The cost that would be incurred for refurbishing, refilling, re-testing or otherwise preparing any launch equipment or any aspect of the launch site, if a second identical mission were to be carried out.

d. Any manufacturing costs for any parts of the launch vehicle; or for any parts of the launch equipment that would require replacement in order for a second identical mission to be carried out (for example, such costs would include the custom machining of a piece of metal forming part of the launch vehicle, if this is contracted out).

As a rule of thumb, the budget of £999.99 should enable you to conduct a repeat of a successful mission, once the savings made by recovering and reusing part or all of the launch vehicle are considered. However, all entrants are advised to contact the organisers to confirm that their calculation of expenditure is acceptable. Items which need not be covered by the budget include prototyping costs; launch equipment or the launch site (except for costs which would be incurred for a repeat mission, as stated above); licence fees, permissions etc; charges made for attendance by safety personnel (provided that such personnel play no direct role in the mission); legal costs; medical costs; insurance costs; fines, penalties or loss of earnings arising from any cause whether prior to, during or after the mission; travel costs of people associated with the mission.

14. Currency Conversion

For teams whose national currency is not Pounds Sterling, the exchange rate which is used in determining the allowable budget (equivalent to £999.99) will be the highest (best) exchange rate which their national currency has attained, during the first 9 months of the competition (ie, between 9th April 2008 and 9th January 2009, inclusive), using the closing mid-price against the Pound as published in the London Financial Times. If teams purchase items in currencies other than their own, then the contribution to their budget will be based on the actual exchange rate at the time of purchase including any commissions etc. For example, if a US team buys a French component at a cost of 50 Euros using a credit card, and if the final charge made by the credit card company (including transaction fees etc) is $62, then that component will be counted as having cost $62. Please note that the prizes will be paid only in Pounds Sterling.

15. Use of 'Salvaged' and Donated Items

Entrants are encouraged to make imaginative use of items that are salvaged, recycled, donated etc, and provided this is within the spirit of the N-Prize Challenge. Broadly, it should be possible for any skilled person to replicate your entry for the same budget and with the same amount of luck and negotiating skills. So, for example, using a discarded mobile phone as part of the telemetry equipment, or the tube from a vacuum cleaner as part of a rocket nozzle, are acceptable. On the other hand, using a complete rocket assembly from a satellite launch system, bought as scrap from a close friend at NASA for $10, would not be considered acceptable. Donations of hardware will be judged on a case-by-case basis. If your neighbour gives you five metres of surplus electrical cable, that's fine. If a local machine shop custom builds a complete rocket casing and 'gives' it to you in exchange for a little publicity, that's less likely to be acceptable. Entrants are strongly advised to contact the organisers to confirm that they are remaining within the rules and spirit of the N-Prize Challenge.

16. Piggybacking and Shared Resources

Entrants may not 'piggyback' on other aerospace projects (for example, by launching a satellite as a passenger on a larger launch vehicle). If they do so, the entire cost of the launch will be considered part of the budget of their N-Prize entry. Similarly, no two entries (whether simultaneous or consecutive; whether by the same entrant or different entrants) are allowed to 'share' the cost of common hardware (for example, if a single launch vehicle carries two satellites, then the total cost of the launch vehicle will be considered part of the budget for each of the two satellites; in such cases, please contact the organisers for further clarification).

17. Orbital Monitoring

All entrants must be able to provide evidence that their satellite has completed a minimum of 9 orbits of the Earth. The costs of providing this evidence must be borne by the entrant, but do not form part of the £999.99 budget, except for the costs of any equipment (transmitters, reflectors etc) mounted on the launch vehicle (including satellite) to enable detection. For example, the cost of a radio transmitter on the satellite will be considered part of the budget, but the cost of ground-based equipment to detect and monitor transmissions from the satellite will not be considered part of the budget. All entrants must explain before launch how they will provide proof of orbits, and must agree with the organisers that this proof will be acceptable. There is no need to observe or track the satellite throughout its orbit, as long as sufficient data is collected to confirm that 9 orbits have taken place. Entrants are welcome to recruit third parties to assist with orbital verification. The organisers must be satisfied that the collection of proof-of-orbit data is reliable, unambiguous and (if judged necessary) validated by disinterested parties. Note also that proof may be required that a detected signal originates from the satellite itself. The acceptability or otherwise of proof of orbit will be decided by the organisers.

18. Monitoring and Compliance with the Rules

The organisers must be satisfied that all rules have been adhered to. Receipts must be produced, if requested, for all items or services purchased which fall within the £999.99 budget; in the absence of receipts, the entrant must be able to provide proof of the actual costs of items used. Entrants should keep the organisers informed of their plans and activities. The organisers or their nominated representatives reserve the right to inspect any part of the launch site, launch equipment or launch vehicle (including the satellite) during the construction process, if they consider this necessary (for example, to satisfy themselves that no costly components have been hidden inside the launch vehicle). The organisers also reserve the right to be present during the launch, and must be given reasonable notice (at least one month) of any intended launch. The organisers reserve the right to ask for construction or a launch to be delayed if, for example, they wish to make an inspection but are unable to do so at the necessary time; such delays will not be made unreasonable. Entrants are welcome to offer food and drink to visiting organisers, but such offerings (unless of a particularly high standard) are unlikely to secure favouritism from the organisers. Entrants should be aware of the possible amendment of rules and of the need to comply with such amendments.

19. Post-orbit Recovery of the Satellite

There is no requirement for the satellite, or any other part of the launch vehicle, to be recovered. However, if the N-Prize winner is able, within 99 days of completing their 9th orbit, to recover any part of their satellite weighing more than 0.99 grams, they will be eligible for the N-Plus Prize instead of the N-Prize. There is no limit on the cost of any recovery programme, except insofar as it impacts on the cost of the launch vehicle or launch equipment. The value of the N-Plus Prize is £10,000.00 (ten thousand pounds sterling).

20. Repeat Attempts

Each entrant may make as many attempts at the N-Prize as they wish. The budget of £999.99 is allowed for each attempt. If a repeat attempt is significantly different from the earlier attempt, the organisers should be consulted to make sure that the revised plan still conforms to the rules and spirit of the N-Prize challenge. If any hardware, fuel etc is re-used in a repeat attempt, its value will be considered to be the cost of its original purchase or construction. Any failed attempts can be considered prototype development, and hence do not count towards the budget of a later attempt, unless (as noted above) items are recycled.

21. Judging and Awarding of the Prizes

The decision of the organisers of the N-Prize will be final in all matters of judging and eligibility. The prizes in each category will be awarded to the entrant whose satellite first completes its 9th orbit of the Earth. A period of 19 days (from completion of the 9th orbit) will be allowed for the entrant to collate and present evidence of the success of the mission; this period may be extended at the discretion of the organisers. The N-Prize will be awarded as soon as the organisers are satisfied that the criteria have been met, and as soon as suitable arrangements can be made (without unreasonable delay).

22. Closing Date and Runner-Up Prizes

The prizes will be available for entrants whose satellites complete their 9th orbit before 19:19:09 (GMT) on the 19th September 2011. In the event that either prize remains unclaimed at this time, the organisers reserve the right (at their discretion) to extend the period of the competition. Alternatively, if the either prize remains unclaimed by the closing date, the organisers also reserve the right to award, at their discretion, a prize of equal or lesser value to the entrant or entrants who have come closest to completing the challenge, or who have failed in the most original, interesting or spectacular way.

23. Premature Termination of the N-Prize Challenge and Exclusion of Entrants

The organisers reserve the right to close or suspend the challenge in exceptional circumstances, though every effort will be made to avoid this. Such circumstances may include, for example, unacceptable levels of injury, loss or death (particularly amongst innocent third parties), whether actual or anticipated, arising from attempts to win the N-Prize; or unforeseen legal reasons. In the event of premature termination of the challenge, the organisers may, entirely at their discretion, award one or more prizes to entrants who have made most progress towards completing the challenge, or who are otherwise deemed to deserve a reward. The organisers also reserve the right to exclude applicants on a case-by-case basis, at any point during the challenge. Possible reasons for exclusion might include, for example, a clear disregard for the safety of the entrant or of innocent bystanders, or a proposal which is so clearly in contradiction of the laws of physics as to be considered frivolous or unworkable (though such attempts may, at the organisers' discretion, be allowed). The organisers accept no liability for any losses arising from premature termination of the N-Prize challenge or from the exclusion of entrants at any point.

24. Funding and Sponsorship

No funding whatsoever, other than the prize money, is available from the organisers of the N-Prize. Entrants are strongly encouraged to fund their entry from their own pockets. If entrants seek sponsorship, the entrant should refer the potential sponsor to the current version of these rules, and the sponsor should be aware of the uncertain nature of this venture and consider any potential liability that they may incur as a result of their sponsorship. Any sponsorship money that is spent on the launch vehicle and non-reusable launch equipment will, of course, be considered part of the £999.99 budget. Any sponsorship in kind may also be considered part of this budget depending on the circumstances. The organisers cannot provide publicity for the sponsors of individual entrants. Entrants may provide publicity for sponsors, but only within reason and only with the prior agreement of the organisers. The organisers reserve the right to exclude entrants whose primary objective seems to be to promote or advertise a particular product, company etc, rather than to successfully complete the N-Prize challenge.

25. How to Enter

There is no entrance fee. Interested parties should contact the organisers in the first instance, explaining their interest and intent. If the organisers are confident that the applicant is in earnest, the organisers may (at their discretion) register the applicant as an N-Prize contender. All registered contenders will be given a unique entrant number, and only registered contenders will be considered for the N-Prize. The organisers reserve the right to suspend or withdraw the registration of any entrant at any point. Reasons for suspension or withdrawal might include (but are not limited to) a clear disregard for the safety of the entrant or of others, or actions which are in contradiction of either the rules or the spirit of the challenge. However, registration (or failure of the organisers to withdraw registration) does not constitute an opinion by the organisers that the entrant is competent to undertake the challenge, nor that the entrant's proposals do not violate any laws (local, national, international or physical), nor that the entrant's proposals are safe.

26. Limitation on Number of Entrants

Depending on the level of interest, it may be necessary to limit the number of entrants by refusing to accept new registrations. In such cases, every attempt will be made to accommodate earnest contenders. The organisers reserve the right to withdraw the registration of any applicant whom they judge (after appropriate discussions with the entrant) not to be an earnest or active contender, in order to allow registration of new contenders.

27. Withdrawal of Entrants

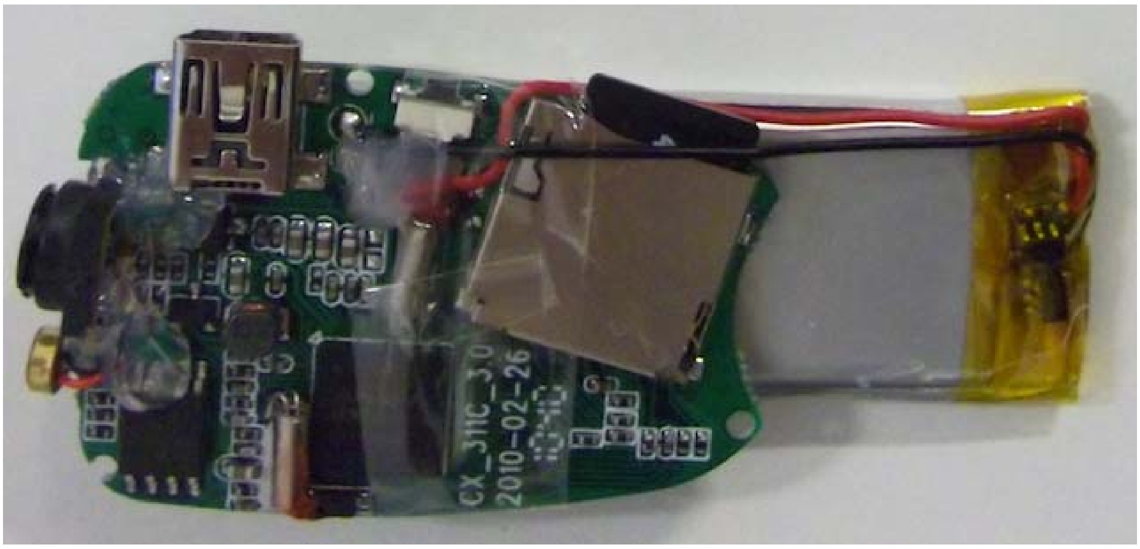
Any entrant is free to withdraw from the N-Prize challenge at any time, with no obligations to the organisers whatsoever and with no period of notice, provided that they notify the organisers as soon as they wish to withdraw.

Annex B

This Annex show the specifications of the payload and launch ramp cameras, the pictures are done without encapsulation and with a larger battery (LiPoly 400 mA).

Specifications:

Keychain camera[31]:
Size: 52x30x12mm
Weight: 18g incl. battery & keychain
Video lense: 640x480 pixel (correct aspect ratio)
Battery: Lithium Polymer
Bideo frame rate: 30 fps (True Rating)
Pixel: 1280x960
Continuous video recording time: 60min
Voice-activated standby time: 120 hours standby time
Storage support: MicroSD card (TF), support max 16GB TF CARD
USB interface: USB1.1/2.0



Pen camera[32]:
Video format: AVI
Video encoding: M-JPEG
Video resolution: 1280x960
Video frame rate: 30 fps
Media playing software: Attached software of the operating system or Mainstrea m audio and video media playing software
The ratio of image: 4:3
Supporting system: Windows me/2000/xp/2003/vista, Mac OS, Linux
Charging voltage: DC-5V

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[31] Can be purchased at: http://www.hobbyking.com/hobbyking/store/uh_viewitem.asp?idproduct=11867
[32] Can be purchased at: http://www.aliexpress.com/product-fm/334458898-Big-Discount-High-resolution-Pen-DVR-HD-Camera-pen-Support-11MP-picture-Free-Shipping-wholesalers.html

Interface type: Stand USB
Storage support: MicroSD card (TF), support max 16GB TF CARD

Annex C

Step one, drink can. Put water in to reduce the concentration of sugar that remains when it dries. The can have be steel. We know is steel because it says that is not aluminum.

It takes a total of 2 cans to make the stage2. Cans should be inspected because if you have dings, rust or holes, are useless.

To a can is cut concave bottom part without reaching the bottom fold sheet with scissors. This part will be used in rear bulkhead. It is usually full of coke sugar and must be cleaned with water to dissolve all the sugar being careful not to cut. This is the hardest part of the can. With Acetone is erased external references. That side will then be on the inside.

And the other can we remove the ring and put it on the lathe to cut the top of the ring by its edge closest to the seam of the lid. This measurement is critical because it ensures proper closure to the rear bulkhead and also ensures that you can enter later. It is essential to use the Dead center and oil because any blade effort of the tool makes it off-center and break the can. Usually one party remains strong but not cutted, must finish by hand with a knife. Clean with acetone to remove the oil. It is important to file the burr of the court to prevent the formation of radial cracks in the remaining lip. Then you flip the can and put in around the other side. It marks the center to make a cut concentric about 30 mm in diameter, that when cut with the punch can not be wrinkled, and then the crease long enough without making too many cracks.

To get the punch machine or manual circlecutter (http://basqueradicalmods.blogspot.com/2011/03/herramienta-corta-circulos-manual.html) sheet to enter the blade is flipped because we will not cut it move a fold. You must use a pen to form extension to secure the blade while on the other side is to put the piece to accommodation and fine-pitch screw, with the fingers is not reached. After threading the screw and just before it is pressed, focused to make the fold evenly. This chapel millimeter eccentricity, beyond the crease cracking and makes flash. We used a wrench of 17 mm and adjustable jaw wrench (http://www.stanleyworks.com.es/sub_category/Mordazas+Ajustables.ctlg) until the sheet is folded. To remove the punch needed a tube to avoid damaging the can. The blade is usually a little hard to stay tight and if we can force defromar can.

We will use the nozzle to the specifications of Ernest [4]. With a brush resin is placed in the area of contact with the can. He twists some fibers to avoid cracks if dropped or get hit in the nozzle. Enter, with the help of a wood tip and wait for the resin cure by some tension between the nozzle and the can to ensure that no bubbles enter. Asegirarse is important that the nozzle has been straight for not having a drive deflected from the longitudinal axis. It is possible that there is even a millimeter of deviation between the axis of the nozzle and the axis of the can as long as these lines are parallel. It is not permissible that there is an angle between these axes.

Put the tin on the wheel by grasping the nozzle. Can focus the comparator as shown in Figure (It's the little clock) to ensure that during the spin cycle the resin will be distributed evenly. The can be rotated about 300 rpm to ensure a G on top and two G in the bottom of the rotation. It is very important to make sure everything is well grasped by the nozzle and the wheel does vibration that could break the resin that holds the nozzle to the can. Using a semi-funnel for introducing the resin has been started. They get about 50 grams of resin. Due to the constant stress elongates the gel phase usually lasts several hours when a few minutes. If turning arches its gel phase, the resin lost its cylindrical shape and could detach from the can.

It takes place about 10 grams of resin settles to the bottom where the nozzle to fill the crease and the bottom. This part will be exposed to direct flame. This layer ensures that no heat gets to the root of the nozzle until it is finished burning. This resin is burning for about 5 minutes until the handle is released. Glass fibers are often burned. In the tests to be face up gets to the inside. In flight, but everything does not get burn on re-entry.

The next step is to put the beads. If it were APCP this step does not apply. Grains extracted from other amateurs have been previously treated by filing and removing impurities from the three surfaces of the cylinder. One side, which faces the nozzle must be smooth and without resin to ensure a continuous flame start. Any defect in the surface results in an asymmetry of the flame burning and Dalea momentarily. He was covered with fiberglass impregnated with a resin and fiberglass yarn is rolled up so it does not take off and then air bubbles. This thin coating is sufficient to keep the flame for 3 seconds it takes the burn. Having fiberglass does not burn (see photo of the inside of the fifth burned where the accommodation is in black beans but intact). Usually the grains are separated equidistantly with a few pieces of wood and glued with resin to the sides of the can so they do not move during burning or if the can is exposed to shock. In the seventh blown (http://www.youtube.com/watch?v=4a6-iBMq5b8) showed that even a strong shock alters the internal structure, making it a very robust design. A resin cured, remove the kindling.

Later you have to close the combustion chamber with the bulkhead we cut earlier. To enter the bulkhead must bend a bit and there can be a little crushed. According to the model, the bulkhead can take the ignitor and the pressure bleed port. should thoroughly wet the entire area of contact between the lip and bulkhead, then a thin tube is around the igniter pressure to ensure contact around the lip. You have to keep pushing all the time so it does not form any bubbles here and could burst the rear bulkhead as we spent on the disastrous burn 6 (http://www.youtube.com/watch?v=tE0GVbTbtDU) To aid maintain consistency of the seal and the bulkhead should be muva shock, the bulkhead must be coated with a layer of fiberglass and resin. There is no need to put much weight because it makes no strength. The force is made by the bulkhead.

If using APCP, it pushes the bulkhead tube pan makes the channel. It takes a special mouth to create a vacuum and put the mixture of APCP before the start of the gel phase. During curing can reach 70 ºC there is no danger of ignition. After a few hours, eliminating the gap and cover the nozzle so that no dirt or moisture. For Stage 2, the nozzle is attached to the bulkhead of the first stage the system makes jetison so both stages after assembly there is no danger of contamination.

Annex D

Apogee detection and parachute deployment code, made by Joshua Tristancho and Juan Martínez and revised by Victor Kravchenko.

```
// ATmega168@16MHz 5V
// Garmin GPS-18x VLC 010-00321-36
http://www8.garmin.com/manuals/GPS18x_TechnicalSpecifications.pdf
//    ITG-3200    http://invensense.com/mems/gyro/documents/PS-ITG-3200-00-
01.4.pdf
//LIS331HH http://www.st.com/stonline/products/literature/ds/16366.pdf

#include <Wire.h>
#include <SoftwareSerial.h>
#include <EEPROM.h>
#include <math.h>
#define  IGNITION_ALTITUDE  30000  //  Above  this  altitude  in  meters  the
igniter is activated
#define  PARACHUTE_ALTITUDE  2000  //  Below  this  altitude  in  meters  the
parachute is deployed
#define SAFETY_ALTITUDE 3000 // Safety altitude above wich the parachute
can be deployed
#define APOGEE_ADDR 0 // Apogee EEPROM Address
#define IGNITION_PIN 12 // Ouput pin number to activate the igniter 5V
#define PARACHUTE_PIN 10 // Ouput pin number to activate the parachute 5V
#define GPSRX_PIN 11 // Input pin for GPS Rx serial port
#define GPSTX_PIN 13 // Output pin for GPS Tx serial port
//#include "itg3200.h" // GYRO ITG-3200
#define GyroID B1101001
//Register 22 - FS_SEL, DLPF_CFG
#define R22 0x16
#define R22INIT B00011011
//Register 62 - Power Management
#define R62 0x3e
#define R62INIT B00000001
//Registers 27 to 34 - Sensor Registers
#define TempH 0x1b
#define TempL 0x1c
#define GyroXH 0x1d
#define GyroXL 0x1e
#define GyroYH 0x1f
#define GyroYL 0x20
#define GyroZH 0x21
#define GyroZL 0x22
//#include "lis331hh.h" Accelerometer LIS331HH
#define AccID 0x18
//Register CTRL_REG0 - Power management and conf
#define RCTR0 0x20
#define RCTR0INIT B00100111
//Sensor Registers
#define AccXH 0x29
#define AccXL 0x28
#define AccYH 0x2B
#define AccYL 0x2A
#define AccZH 0x2D
#define AccZL 0x2C
#define AccStat 0x27
```

```
void i2cSetRegister(int device, int address, int value)
{
  Wire.beginTransmission(device);
  Wire.send(address);
  Wire.send(value);
  Wire.endTransmission();
}
byte i2cGetRegister(int device, int address)
{
  Wire.beginTransmission(device);
  Wire.send(address);
  Wire.endTransmission();
  Wire.requestFrom(device, 1);
  if(Wire.available())
  return Wire.receive();
  return B00000000;
}
int i2cGetValue(int device, int addressH, int addressL)
{
   return  i2cGetRegister(device,  addressH)  *  256  +  i2cGetRegister(device,
addressL);
}
// Globals
SoftwareSerial GPS = SoftwareSerial(GPSRX_PIN,GPSTX_PIN);
int addr;
int val; // Last byte read from GPS
float alt; // Last altitude read from GPS
float apogee; // Highest altitude read from GPS. This variable is mirrored
in EEPROM.
byte k[]={0,0,0,0,0,0,0,0,0,0,0,0,0}; // Read buffer for GPS input
float EEPROMGetFloat(int addr)
{
  float num;
  ((byte*)&num)[0]=EEPROM.read(addr++);
  ((byte*)&num)[1]=EEPROM.read(addr++);
  ((byte*)&num)[2]=EEPROM.read(addr++);
  ((byte*)&num)[3]=EEPROM.read(addr++);
  return num;
}
void EEPROMSetFloat(int addr, float num)
{
  EEPROM.write(addr++,((byte*)&num)[0]);
  EEPROM.write(addr++,((byte*)&num)[1]);
  EEPROM.write(addr++,((byte*)&num)[2]);
  EEPROM.write(addr++,((byte*)&num)[3]);
}
byte Next()
{
  // BYTE, BIN, OCT, HEX, 1 = number of decimals
  val=byte(GPS.read());
  Serial.print(val,BYTE); // For debbuging purpose only
  return val;
}
int ReadParam(byte chr=',')
{
  int i=0;
  while(true)
    if(i>=sizeof(k))
      return -1; // Buffer overrun
    else if((k[i]=Next())==chr)
      return i; // Read 'i' bytes
    else
      i++;
}
```

```
void setup ()
{
  pinMode(IGNITION_PIN,OUTPUT);
  digitalWrite(IGNITION_PIN,LOW);
  pinMode(PARACHUTE_PIN,OUTPUT);
  digitalWrite(PARACHUTE_PIN,LOW);
  GPS.begin(4800);
  Serial.begin(4800);
    // EEPROM dumping
  /*
  for(addr=0;addr<512;addr++)
  {
    if
(!(addr%16)){Serial.println();Serial.print(addr/1000.0f,3);Serial.print(":
");}
    Serial.print(EEPROM.read(addr)/1000.0f,3);Serial.print(" ");
    //EEPROM.write(addr,0); // WARNING: This line will erase all the EEPROM
memory
  }
  Serial.println();
  */

  addr=0;
  val=0;
  alt=0;
  apogee=EEPROMGetFloat(APOGEE_ADDR);
  Wire.begin();
  // Hyperterminal at 57600 and Arduino at 115200 bauds
  //Serial.begin(115200);
  // Accelerometer LIS331HH setup
  i2cSetRegister(AccID, RCTR0, RCTR0INIT);
  // Gyro ITG-3200 setup
  i2cSetRegister(GyroID, R62, R62INIT);
  i2cSetRegister(GyroID, R22, R22INIT);
  // Hardware-on-the-loop config
  //i=0;
}
void loop()
{
  int i;
 if(Next()=='$')if(Next()=='G')if(Next()=='P')if(Next()=='G')if(Next()=='G'
)if(Next()=='A')if(Next()==',')                                            {
    if(ReadParam()>=0)      // Time in UTC of position
    if(ReadParam()>=0)      // Latitude of position
    if(ReadParam()>=0)      // Latitude N or S
    if(ReadParam()>=0)      // Longitude of position
    if(ReadParam()>=0)      // Longitude E or W
    if(ReadParam()>=0)      // GPS quality
(0=fix not available, 1=Non-differential GPS fix available, 2=Differential
GPS (WAAS) fix available, 6=Estimated)
    if(ReadParam()>=0)      // Number of satellites   (00 to 12)
    if(ReadParam()>=0)      // Horizontal dilution of precisión     (0.5 to
99.9)
    if(ReadParam()>0)       // Antenna altitude above mean sea level  (-
9999.9 to 99999.9)
    {
      alt=atof((char*)&k[0]);
      if(ReadParam()>=0)    // Units of antenna altitude, meters      M
      if(ReadParam()>=0)    // Height of geoid above ellipsoid        (-
999.9 to 9999.9)
      if(ReadParam()>=0)    // Units of geoid height, meters          M
      if(ReadParam()>=0)    // Age of differential GPS data, seconds  Null
      if(ReadParam('*')>=0) // Differential reference station ID      Null
      if(ReadParam(10)>0)   // Checksum                               *HH
```

```
      {
        if(alt>apogee)
        {
          apogee=alt;
          EEPROMSetFloat(APOGEE_ADDR,alt);
        }
        if(alt>IGNITION_ALTITUDE)digitalWrite(IGNITION_PIN,HIGH);
       if(alt<PARACHUTE_ALTITUDE)if(apogee>SAFETY_ALTITUDE)digitalWrite(PARACHUTE_PI
N,HIGH);
      }
    }
  }
}
```

Annex E

REGULATION JAR Part 101 (THIS DATA CURRENT AS OF THE FEDERAL REGISTER DATED NOVEMBER 26, 2001)

Extracted from http://www.eoss.org/pubs/far_annotated.htm, once obtained from [6]

14 CFR PART 101 -- MOORED BALLOONS, KITES, UNMANNED ROCKETS AND UNMANNED FREE BALLOONS

Subpart A -- General

§101.1 Applicability.

(a) This part prescribes rules governing the operation in the United States, of the following:

(4) Except as provided for in §101.7, any unmanned free balloon[1] that --

(i) Carries a payload package that weighs more than four pounds and has a weight/size ratio of more than three ounces per square inch on any surface of the package, determined by dividing the total weight in ounces of the payload package by the area in square inches of its smallest surface;

(ii) Carries a payload package that weighs more than six pounds;

(iii) Carries a payload, of two or more packages, that weighs more than 12 pounds; or

(iv) Uses a rope or other device for suspension of the payload that requires an impact force of more than 50 pounds to separate the suspended payload from the balloon.[2]

§101.3 Waivers.

No person may conduct operations that require a deviation from this part except under a certificate of waiver issued by the Administrator.

§101.5 Operations in prohibited or restricted areas.

No person may operate a moored balloon, kite, unmanned rocket, or unmanned free balloon in a prohibited or restricted area unless he has permission from the using or controlling agency, as appropriate.

§101.7 Hazardous operations.

(a) No person may operate any moored balloon, kite, unmanned rocket, or unmanned free balloon in a manner that creates a hazard to other persons, or their property. [3]

(b) No person operating any moored balloon, kite, unmanned rocket, or unmanned free balloon may allow an object to be dropped therefrom, if such action creates a hazard to other persons or their property.

Subpart D -- Unmanned Free Balloons [4]

§101.31 Applicability.

This subpart applies to the operation of unmanned free balloons. However, a person operating an unmanned free balloon within a restricted area must comply only with §101.33 (d) and (e) and with any additional limitations that are imposed by the using or controlling agency, as appropriate.

§101.33 Operating limitations.

No person may operate an unmanned free balloon --

(a) Unless otherwise authorized by ATC, below 2,000 feet above the surface within the lateral boundaries of the surface areas of Class B, Class C, Class D, or Class E airspace designated for an airport;

(b) At any altitude where there are clouds or obscuring phenomena of more than five-tenths coverage;

(c) At any altitude below 60,000 feet standard pressure altitude where the horizontal visibility is less than five miles;

(d) During the first 1,000 feet of ascent, over a congested area of a city, town, or settlement or an open-air assembly of persons not associated with the operation; or

(e) In such a manner that impact of the balloon, or part thereof including its payload, with the surface creates a hazard to persons or property not associated with the operation.

§101.35 Equipment and marking requirements.

(a) No person may operate an unmanned free balloon unless --

(1) It is equipped with at least two payload cut-down systems or devices that operate independently of each other; [5]

(2) At least two methods, systems, devices, or combinations thereof, that function independently of each other, are employed for terminating the flight of the balloon envelope;[6] and

(3) The balloon envelope is equipped with a radar reflective device(s) or material that will present an echo to surface radar operating in the 200 MHz to 2700 MHz frequency range. [7]

The operator shall activate the appropriate devices required by paragraphs (a) (1) and (2) of this section when weather conditions are less than those prescribed for operation under this subpart, or if a malfunction or any other reason makes the further operation hazardous to other air traffic or to persons and property on the surface. [8]

(b) No person may operate an unmanned free balloon below 60,000 feet standard pressure altitude between sunset and sunrise (as corrected to the altitude of operation) unless the balloon and its attachments and payload, whether or not they become separated during the operation, are equipped with lights that are visible for at least 5 miles and have a flash frequency of at least 40, and not more than 100, cycles per minute. [9]

(c) No person may operate an unmanned free balloon that is equipped with a trailing antenna that requires an impact force of more than 50 pounds to break it at any point, unless the antenna has colored pennants or streamers that are attached at not more than 50 foot intervals and that are visible for at least one mile. [10]

(d) No person may operate between sunrise and sunset an unmanned free balloon that is equipped with a suspension device (other than a highly conspicuously colored open parachute) more than 50 feet along, unless the suspension device is colored in alternate bands of high conspicuity colors or has colored pennants or streamers attached which are visible for at least one mile.

§101.37 Notice requirements.

(a) Prelaunch notice: Except as provided in paragraph (b) of this section, no person may operate an unmanned free balloon unless, within 6 to 24 hours before beginning the operation, he gives the following information to the FAA ATC facility that is nearest to the place of intended operation: [11]

(1) The balloon identification.

(2) The estimated date and time of launching, amended as necessary to remain within plus or minus 30 minutes.

(3) The location of the launching site.

(4) The cruising altitude.

(5) The forecast trajectory and estimated time to cruising altitude or 60,000 feet standard pressure altitude, whichever is lower.

(6) The length and diameter of the balloon, length of the suspension device, weight of the payload, and length of the trailing antenna.

(7) The duration of flight.

(8) The forecast time and location of impact with the surface of the earth.

(b) For solar or cosmic disturbance investigations involving a critical time element, the information in paragraph (a) of this section shall be given within 30 minutes to 24 hours before beginning the operation.

(c) Cancellation notice: If the operation is canceled, the person who intended to conduct the operation shall immediately notify the nearest FAA ATC facility.

(d) Launch notice: Each person operating an unmanned free balloon shall notify the nearest FAA or military ATC facility of the launch time immediately after the balloon is launched. [12]

§101.39 Balloon position reports. [13]

(a) Each person operating an unmanned free balloon shall:

(1) Unless ATC requires otherwise, monitor the course of the balloon and record its position at least every two hours; and

(2) Forward any balloon position reports requested by ATC.

(b) One hour before beginning descent, each person operating an unmanned free balloon shall forward to the nearest FAA ATC facility the following information regarding the balloon:

(1) The current geographical position.

(2) The altitude.

(3) The forecast time of penetration of 60,000 feet standard pressure altitude (if applicable).

(4) The forecast trajectory for the balance of the flight.

(5) The forecast time and location of impact with the surface of the earth.

(c) If a balloon position report is not recorded for any two-hour period of flight, the person operating an unmanned free balloon shall immediately notify the nearest FAA ATC facility. The notice shall include the last recorded position and any revision of the forecast trajectory. The nearest FAA ATC facility shall be notified immediately when tracking of the balloon is re-established.

(d) Each person operating an unmanned free balloon shall notify the nearest FAA ATC facility when the operation is ended.

EOSS Annotations:

[1] Payload strings that don't exceed any of these four limits are exempted from all other FAR 101 provisions, except 101.7. EOSS reads "payload" to mean those parts of the flight string that do the work of the mission, independent of how they get to altitude and back down. Thus we do not include the weight of the balloon, parachute or cutdowns in this tally; the latter are members of the "flight system". Tracking beacons, although arguably flight system components, are included in payload weight, however, since they are critical to the payload recovery mission goal.

[2] This applies only to the load line between the balloon and parachute. "Impact strength" is undefined, but should not be equated to the line's rated tensile strength; a 50 lb tensile line will break during launch. The intent of this limit is to ensure that the balloon detaches in the event of collision with an aircraft. EOSS uses 250 lb woven nylon kite line which did break at a knot during "post-burst chaos" on one flight.

[3] This is the dreaded "Catch 22" clause that the FAA may impose on those who have gained its unfavorable attention. One cannot successfully argue that a payload string in flight is totally free from all risks to others. However, taking all reasonable steps to mitigate those risks, such as keeping the flight crews and controllers up to date on your location and altitude and avoiding heavily populated areas, will garner the FAA's respect and cooperation.

[4] This subPart applies only to those payloads which are not exempt according to Section 101.1 (a) (4). However, it's still advisable to adhere to as many of these requirements as reasonably possible (Ibid).

[5] A latex balloon which will burst at altitude is considered to be its own independent cutdown device. The second device should be a radio-commandable cutter. Plastic balloons must have a commandable primary cutdown and an independent timer-based backup.

[6] A plastic balloon must have some means to dump the fill gas to ensure that it returns to the surface. A latex "burster" serves as its own destruct device.

[7] The FAA rarely tracks "primary returns" from balloons, relying more on Mode C transponders, and they may require one on "heavy" non-exempt flights. However, having a GPS-based beacon and a reputation for accurate and timely reports on prior exempt flights may alleviate you from having to carry along this expensive and heavy (7 lb) RFI generator.

[8] A balloon which fails to return to the surface via either commanded or timed termination means or burst is labeled a "derelict" and presents a serious hazard to air navigation. It will descend into commercial airspace at night, and if its batteries die, its location and altitude are unknown except by visual encounter by flight crews. Flying a derelict is the surest means to gain the unfavorable attention mentioned in footnote 3 above.

[9] Battery-operated xenon flashtube strobe lights, available at sporting goods stores, have been used for this service, but special care should be taken to conformal coat the high-voltage circuitry which may develop corona or destructive arcover at altitude. The latest generation of high intensity LEDs, such as those seen more and more in traffic lights, may met this requirement while avoiding high-voltage problems.

[10] These visibility requirements highlight the FAA's reliance upon visual collision avoidance by flight crews. Thus it is a good idea to give your payloads a light coat of dayglo orange. This also helps the recovery crew make a tally-ho call at a distance. The physical dimensions conforming to the one mile visibility requirement are unclear and may be highly dependent upon the viewer's visual acuity.

[11] This section describes the minimum content of the "HiBal Prelaunch Notice" filed with ARTCC, the TRACON of the nearest airport and FSS. EOSS faxes this notice about 1 week in advance to give the ARTCC Airways and Procedures folks a chance to respond. The EOSS HiBal requests a written response with "special provisions" instructions to be returned a couple of days before the launch. Those provisions typically include a prelaunch call with forecast trajectory thru several flight levels. This FAA response has served to alleviate concerns by visitors from time to time.

[12] EOSS also makes a T-0:30 phone call to ARTCC and TRACON per the "special provisions". The operations folks invariably have a copy of our HiBal Notice, so there are no surprises. EOSS uses Rick von Glahn's Balloon Track with the latest NWS RAOB winds for our forecast position and altitude estimates. The FAA controllers prefer position reports in radial and NM range from the nearest high altitude VOR. This prelaunch call also includes the launch site cell phone number. If launch is delayed by over 10 minutes, we call in a new estimated launch time.

[13] The TRACON operations folks are typically interested in position reports below FL240, and ARTCC usually requests reports out of FL260, 450 and 600 in ascent and descent. Position accuracy to within a 5-mile radius is sufficient. The GPS-based APRS beacon makes this simple, but good RDF fixes and barometric altitude telemetry will serve just fine.

Annex F

In this annex we can see the detailed study of each municipality of the landing zone, first of all we have de color code.

Color code	population/km^2
	1000
	100 to 999
	40 to 99
	20 to 39
	1 to 19

Municipality	Population	Surface[33]	Population density[34]
Zaragoza (city)	675121	177	3814
Utebo	18000	18	1000
Cuarte de huerba	8658	9	962
Huesca	52347	161	325
La puebla de alfinden	5250	17	309
Cadrete	3054	12	255
Nuez de Ebro	801	8	100
Tierz	691	7	99
El Burgo de Ebro	2321	25	93
Ribera alta del Ebro (comarca)	23231	304	76
Villanueva de Gállego	4376	76	58
Banastás	270	5	54
Maria de Huerba	4729	108	44
San mateo de Gallego	3079	72	43
Chinillas	359	10	36
La Muela	5166	144	36
Igries	627	19	33
Fuentes de Ebro	4617	142	33
Pedrola	3721	119	31
Quicena	302	10	30
Ejea de los caballos	17344	610	28
Botorrita	536	20	27
Alerre	223	9	25
Zuera	7510	332	23
Erla	421	19	22
Torres de Barbués	303	14	22
Osera de Ebro	473	25	19
Tauste	7567	405	19
Ayerbe	1119	64	17

[33] in km^2
[34] in Population/km^2

Alberuela de tubo	355	21	17
Sariñena:	4428	276	16
Alfajarín	2168	138	16
Grañén	1930	124	16
Almuniente	559	38	15
Sietamo	665	49	14
Villafranca de Ebro	837	64	13
Almudevar	2544	202	13
Lalueza	1101	88	13
Bardallur	327	27	12
Argavieso	119	10	12
Plasencia de Jalón	404	35	12
Tardienta	1007	91	11
Monflorite-Lascasas	312	29	11
Alcala del obispo	491	48	10
Robres	630	64	10
Capdesaso	163	18	9
Novales	181	20	9
Vicien	122	14	9
Biota	1115	129	9
Pina de Ebro	2655	309	9
Lanaja	1417	184	8
Biscarrués	228	30	8
Sangarrén	242	32	8
Leciñena	1350	179	8
Sierra de luna	308	42	7
Sesa	225	31	7
Alberto Alto	132	19	7
Poleñino	226	33	7
Las Pedrosas	121	18	7
Tramaced	100	15	7
Piedratajada	150	23	7
Puendeluna	65	10	7
La Sotonera	1061	166	6
Perdiguera	664	110	6
Marracos	100	17	6
Asin	104	19	5
Medina de Aragón	481	91	5
Loarre	371	74	5
Alberto Bajo	96	22	4
Farleta	439	104	4
Santa Eulália de gállego	125	30	4
Piraces	104	25	4
Castejón de Monegros	661	165	4
Alcalá de guerrea	278	71	4

Valpalmas	155	40	4
Nueno	557	147	4
Alcubierre	433	115	4
Lupiñen-ortilla	397	110	4
Senes de Alcubierre	68	21	3
Loporzano	540	169	3
Huerto	272	87	3
El Frago	106	34	3
Ardisa	80	27	3
Luesia	361	127	3
Torralba de Aragón	111	40	3
Luna	846	309	3
Loscorrales	108	40	3
Moneguillo	479	183	3
Castejón de valdejasa	283	110	3
Valmadrid	109	51	2
Ores	101	55	2
Biel	186	131	1
Las Peñas de riglos	268	218	1
Total	888837	8259	108