Title: ODEI –C24

Primary POC: Enrique Vicente Arcones

Organization: ETSIT – UPM

POC email: e.vicente@alumnos.upm.es

NEED

For some years now, there were some institutions which noticed that technological development our world created in the last half of century, made the society especially vulnerable to an eventual "space shut down". The maximum of the 24th space cycle, may 2013, it will be the first test for unfinished scientific models, that are not capable of predict the consequences of such high radiation in 1150 years (according to Max Plank Institute) [1], in our flight systems. Governments highly dependents on their space technology (United States, Finland, etc.) fear serious damage to the satellites of the major agencies, which could also mix with damage at the basic supply networks such as electrical. Our mission is to cover the need to complement these models and protocols for these situations (increasingly close and real), at a low cost and with short implementation time.

MISSION OBJETIVES

Our mission consists in 4 key objectives:

- Quantify the number of sunspots during the solar maximum, and also characterize their activity and magnetism.
- Demonstrate the reliability of a mission in LEO orbit, for an effective solar observation.
- Technology demonstrator: we will take on board an experiment: the PTF (Polymer Filter test in flight), associated with visible cameras.
- Investigation of the potential for exploitation of ground space market through the sale of images taken in flight.

CONCEPT OF OPERATIONS

Briefly the key of our operations are: in the ground segment, is very important to emphasize the great importance that the station system GENSO has in our project. The feasibility of this proposal dependes largely on the monitoring system by 2013, that we expect to be global. In our mission control center (note that the ETSIT-UPM has multiple locations for research and communications) will have a GENSO station. The space segment will consist of 15 nano-satellites constellation, each of which, following the standards defined for CubeSat satellites, will hace a 2 unit structure (in mm approximately 100x100x200) [2]. The constellation will consist of three different types of satellites.

- SunSpot: with a total of 5 units, will be devoted to the observation of sunspots in visible and ultraviolet spectrum.
- SunBeam: with 3 units, the price per unit is higher (around double than of the other models) and its information is redundant. Their mission is to characterize the activity of sunspots.
- SunShine: Its 5 units are designed to study the effects that the solar EMC will have on the Earth.

It is very important to note that the interface of these units is unique, there are three models whose only difference lies in the "payload" carried on board, which allows us a mucho more simple time and price development. Keeping the COMM and the AOCS, we are leaving the door open for parallel development. Finally in regards to the launch, though we follow closely the latest developments (like the new launcher VEGA) and we are open to potential collaborations with NASA or ESA, we cannot ignore the facilities of the Indian launcher PSLV, for its price-quality relation. Of course we always consider travel as secondary payload.

Key Performance Parameters

For the good of the mission is very important to keep certain parameters stable while the mission lasts:

For the observation of sunspots is important to ensure that the satellite is not "blinded", it is therefore necessary to establish a polymer filters system with a step ratio of about 1000:1, for the camera in the visible spectrum. This is achieved with the PTF experiment, which also aims to certify the COST technology in flight. This is perhaps, the primary technical risk that our mission has. However, note that if this happens, we have other instruments that could complement this lack, ensuring our ability to overcome a general failure.

The inclination of the satellite in orbit is crucial. Recall that sunspots are located between 5 ° and 40 ° of solar latitude, and that at the distance we want to see, slight variations in the inclination stop outside our field of vision the object observed. Therefore, the definition of the three proposed plans (with respect to the equatorial inclination of 23.5 °, 68.5 ° and 158.5 °) has been crucial. To maintain this stable, we will include a package of inertia wheels in three axes that are already commercially available for assembly into CubeSat structures. Separation between the consetallation units is also important but not critical. This should be maximum. Note the slow evolution of the solar surface spots, therefore, spacing the units is very important in order to be able to observe changes from one image to the next one. However, if during the mission, this parameter varies, the three level provision should enable us to minimize the impact on our observations.

These last two notes, show a second technical risk. That the observations are not these we expect to be. Although, then, the final scientific value of our data would be diminished, the mission could remain a reference for their observations of Earth´s magnetic field and the UV radiation reaching the Earth. The time of access with land also could become a problem. Failure to achieve sufficiently frequent access could make happen that the memory is overwhelmed, and we could lose information that may be extremely important. Therefore we emphasize again the importance of global coverage network (GENSO) to ensure the viability of the project.

Space Segment Description

Our constellation it's made up of three different kinds of Nano-Satellites. They are similarity on basic subsystems and only distinguish on payload that they carry. Because of the load, it is very important to have three different models of nanosatellites. The measures are then more diverse, and redundancies follow logic, so that we can always rebuild the information from one instrument to another in case of failure.

SunSpot: Includes a camera in the visible spectrum to quantify sunspots, along with an UV camera to characterize their activity. Both are COST.
SunBeam: Includes redundancy UV cameras, designed to compare expected values of radiation, with data obtained from a radiometer, also included. We are referring to the higher load cost, therefore the least developed units.
SunShine: Includes a COST magnometer and a radiometer redundancy, so as to obtain data on the effect on Earth from solar radiation, independently if solar observation is with or without success.

Let's see the other subsystems:

- Structure and configuration.
- Energy Power System. (Include Solar cellar and Power battery)
- On-Board Data Handling. (Include two OBDH to minimize mission risk)
- Comunication System. (Include antenna and transceiver UHF/VHF)
- Attitude Control System. (Include sun sensor and reaction wheels)

The mass budget is based on subsystem mass estimates. The maximum mass of the "ODEI-C24" cannot exceed four kilogram which its max weight supported by our structure.

Mass Budget [gr]			
Subsystems	SunSpot	SunBeam	SunShine
Payload	406	950	750
Structure and Configuration	390	390	390
Energy Power System	253,1	253,1	253,1
On-Board Data Handling	200	200	200
Communications System	185	185	185
Attitude control system	740	740	740
Safety Margin	10%	10%	10%
Total	2391,51	2989,91	2769,91

With respect at volume of our Nano-Satellite, they are limited to approximately to 2000 cm^3. This volume it's enough for any of our kinds of Nano-Satellites like it's displayed in the table.

Volume(cm3)			
	SunSpot	SunBeam	Sunshine
Payload	600,2086	538,5487	588,5846
Energy Power System	241,61	241,61	241,61
On-Board Data Handling	172,8	172,8	172,8
Communications System	110,428	110,428	110,428
Attitude control system	434,56	434,56	434,56
Safety Margin	10%	10%	10%
Total Busy Space	1715,56	1647,74	1702,78
Structure(Inner Free Space)	1905,52	1905,52	1905,52
Total Free Space	189,96	257,78	202,74

The Power budget will be shown in function of the Operation's Mode of Satellites. The Operation's Mode, which will need more energy, it's the Data Acquisition Mode. In this mode the satellite will be taken information about sun spots. This information will vary between the kinds of Nano-Satellite.

Owning to the simulations, which we had made on computer, we know that our solar cells can generate a 9.73 (W) of average power when they have visibility. We had include a power battery of 30 (W) for be use by Nano-Satellite when they haven't visibility of sun.

Power Budget						
	SunSpot		SunBeam		Sunshine	
Subsystems	Peak Power	Average Power	Peak Power	Average Power	Peak Power	Average Power
Payload	4000	0	1291	922	2326	326
EPS(Solar Cells)	9730	9730	9730	9730	9730	9730
OBDH	2000	2000	2000	2000	2000	2000
CS	250	250	250	250	250	250
ACS	2400	2400	2400	2400	2400	2400
Safety Margin	0,1	0,1	0,1	0,1	0,1	0,1
Total Free Power	490	4890	3469,9	3875,8	2331,4	4531,4

Constelattion Description [2]

Is decided the fact that it will be a constellation distributed evenly in three plans. We first define some parameters to helps understand the “way of working” of the constellation. We will consider now the modes and parameters that define this operation. We will launch all of our units in “off”, all systems completely off. Once airborne, each of the units comes in “launch” while positioning and orientation to the sun for the first time. Meantime, the satellite will only send a pulsing signal to locate it.

Once the satellite takes view of the Sun for the first time, enter in “photograph”, and takes useful images of the Sun while the shooting is in latitudes between 40 ° and 5 °. When the unit loses partial view of the sun, or the alignment is not adequate, the satellite goes into “market” and will only activate those units loaded with cameras in visible and/or ultraviolet light, and will photograph the area pointed to without having any pointing requirement. During this period, the frequency of photography will decrease, and the other systems will come into “stand by”. When the satellite enters in total eclipse and receives no power, activates the “stand by”, all payment charges stop and other devices come in low-consume, until it receives power again.

Similarly, when one of the ground stations sees a unit of the constellation, the unit enters in “transmission” to download the data that will be processed once downloaded from the space segment. In case of failure or unforeseen circumstance, the unit will enter in “warning”, until the problem is fixed from de ground. It is important to mention that the time the satellite will be in “launch” is determined by the conditions that are imposed by the launcher, after which the expected parameters are as follows (see table).

To consider the following table, please note that we have assumed a simulation period that includes the whole 2013 and we placed the central station in the ETSIT-UPM (STK level that we have considered the city of Madrid).

Inclination plan	Average viewing time of the sun (seconds)	Maximum time viewing of the sun (seconds)	Minimum time viewing of the sun (seconds)	Time orbital eclipse period (seconds)	Orbital period	Contact time with the control station (seconds)
23.5º	3945	3947	2606	3015 (43%)	1h 56min	629.7

68.5º	4141.5	4394	2007	2819 (40.5%)	1h 56min	705.7
138.5º	4133	4387	1515	2827 (40.6%)	1h 56min	518.8

We should add some more information:

We propose an altitude of 900km LEO orbit, using this constellation as a demonstration of its sufficiency for solar research missions. This will allow us not to exhaust higher orbits (such as GEO), reduce the production of debris (our constellation will disintegrate on re-entry) and save some money in the research area. Finally we want the make noticed that from the ground, the number of satellites visible at all times depends on the development of GENSO for the year 2013, but according to our estimations, at each moment can be accessible from 25% to 40% of the constellation.

Implementation Plan

Overall we have to follow these steps: Development of the satellite (first unit):

- Satellite design step (6 months): design and specification of subsystems and sensors, selection of commercial components, etc.
- Development and testing of engineering models (8 months): integration of subsystems into a prototype and testing. Includes test for each of the sensors.
- Development of the flight model (6 months): development of the flight unit. To be consistent with the launch model, we will start with a prototype of each model
- In parallel with the design of the satellite, it is designed and installed a GENSO ground station

Finally about the launch, we want to note the complication that would suppose to launch in flight the entire constellation. Therefore, we propose a first launch of three satellites (one of each model) that will be located in the same plan. After this first step, the design and launching of the remaining units could be constructed with data from the first design. Here are the last two risks we consider important in our proposal: The project is developed in a university world/frame, and a development period of two years is, at least, a relay in the team. This relay can collapse the project, if the documentation is inappropriate, which could mechanize our work. To eliminate this risk, we already have the ECSS templates and standards from ESA, on which we have already collected all information relating to this proposal (at internal level), having a basis on that we can continue.

Finally, all projects depend on greater measure on their launchers. Or mission must be operational to record and study the solar maximum (May 2013), that makes a highlight on the very delicate position in which we place in lack of a launcher in the appropriate date. However, if this would happen, studying solar phenomenon after the peak of the cycle is also sufficient at scientific interest level, to further promote our mission without risk of losing the great amount of money. In addition, it must be added that the proposed launch model encourages adherence to these deadlines.

To close this document, we list the main supporters of our project:

- Participation of Bach, MsC and PhD students (mention that UPM has degrees in all Enginering areas)
- Supervision of student team(s) from University Professors (with strong experience in ESA and EC Projects and contracts with industry)
- Support from local space industry (consulting, technical, laboratories, tests, hosting of students)

Referencias

[1] Sami Solanki, director of Max Plank Institute, Katlenburg-Lindau, Alemania
[2] Calpoly University The CubeSat: The Picosatellite Standard for Research and Education
[3] All pictures and data shown below have been obtained by simulation in the STK program (v.9)