Departament de Projectes d'Enginyeria
UNIVERSITAT POLITÈCNICA DE CATALUNYA

ESEIAAT

ENGINEERING PROJECT

Astrea Constellation

Project Charter

Group 04: EA-T2016

October 4, 2016

Contents

1 Aim of the project

Design of a **satellite constellation** dedicated to communications relay between LEO satellites and between LEO satellites and the ground.

2 Scope of the project

This section establishes the scope of the project.

Satellite development

- An establishment of the mission requirements that influence any parameter of the satellite will be developed. These requirements include size, weight, spacecraft subsystems and payload.
- Based on these conditions, the CubeSat size will be chosen.
- The design of the spacecraft subsystems will be in charge of a specialized enterprise that will work strictly following the requirements talked before.

Orbital design.

- The orbit design will be accomplished according to the results of several studies such as visibility between satellites and between satellites and ground stations, collision avoidance, orbital decay avoidance and stated requirements as global coverage, low earth orbit, low latency.
- The number of satellites and the number of orbital planes will be deducted from those studies.
- A study will be carried out to clarify if the Earth is the only celestial body that will influence the satellites or others, for instance, the Moon or the Sun will also have to be considered.
- The specific existing legislation will be taken into an account and followed during all the orbit development.

Constellation Deployment.

- A comparison among the existing launch platforms will be carried out to find out the one that fulfills the mission requirements and a reasonable economical conditions.
- A launching window/s will be reserved if the launch platform chosen requires it.

- The recommendations of Joint Space Operation Center will be followed and their application form will be filled up to ensure all the launch procedure accomplishes the legislation.

Operation.

- An analysis will be done to clarify how many ground stations must operate and the possibility of placing a central one in UPC ESEIAAT.
- The requirements and costs of the ground station will be determined.
- Communication logistics will be defined.
- An end of life strategy will be designed according to CubeSat lifespan, orbit decay, replacement stratagem of the company and legislation procedures.

Exhibition.

- It will consist on a simulation of the constellation.

3 Basic requirements of the project

Feature	Description
1	Provide communication relay between two LEO nanosatellites with a latency **lower than 1 minute**.
2	Provide communication relay between a LEO nanosatellite and the ground with a latency **lower than 5 minutes.**.
3	Back-up system prepared to handle **up to two major failures** in the system. A major failure can be defined as the loss of a client's satellite coverage because of a failure in the network.
4	Switch time after major failure happens, shall be **below 6 hours**.
5	Each Satellite Node volume should be equal or **lower than a 3U Cubesat.**
6	Each Node should be able to handle **at least 25 Mbit/s** of data rate.

Table 1: Project Requirements

4 Justification

One of the major drawbacks of satellites is their poor temporal resolution. Although they can gather high quality data, they frequently lose contact with ground stations as they orbit. Therefore, their connection is limited to once every few hours. Astrea's objective is to solve this issue by creating a network between ground stations and LEO satellites providing near real-time communication to the customer. A network like the aforementioned can only be carried out by a CubeSat constellation because they are economical and easily reproducible satellites, making their mass production affordable.

Another problem which is normally faced when designing a satellite is that the systems it contains become obsolete in a relatively short period of time. In order to prevent this premature obsolescence, we propose a constant refilling of the constellation, possible due to the low cost of CubeSat. Our preliminary study leads us to the fact that the orbit decay would make the CubeSats fall after 2 years of operation making us capable of updating the systems as the technology evolves.

Since 2013 CubeSat launches have experienced an incredible raise (as shown in Figure 1) mainly because of their economic advantage. The future projection shows that the launches are going to continue increasing. However, more than the half of these CubeSat constellations are going to be focused on earth monitoring or become multiple-point sensors [E. Buchen and D. DePasquale(2014)]. In these situation, Astrea have the opportunity to take a unique position in the market, sharing the communication segment only with Kepler Communications[kep(2016)].

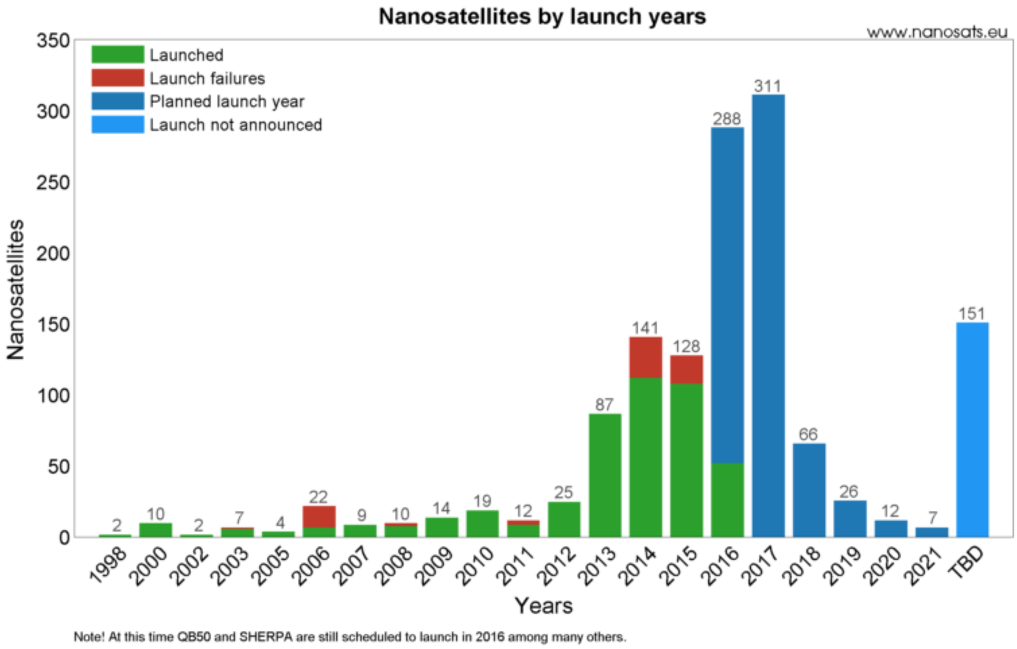


Figure 1: Nanosatellites by launch years. Extracted from [Kulu(2016)]

Currently, there isn't any mission involving a large number of satellites implementing inter-satellite connection. However, missions like **QB-50** and **Keppler** are going to use this technology. the objective of these missions and other small satellites related projects is exposed at the Table 1 . For Astrea, this is an imperative requirement since normally, the CubeSat that connects with ground it's not the same that stablish a link with the customer satellite. In addition, this will enable them to configure and maintain dynamic routes and manage intermediate nodes.

Mission Name	Number of satellites	Launched/Projected launch year	Products or Services
Spire	+100	2012	weather monitoring system
GHSat	1	2013	Greenhouse gas and air quality gas emissions monitoring
SpacePharma	-	2013	Microgravity service with 3U CubeSats
Sky and Space global	200	2015	Communication service (voice, data and M2M)
Astro Digital	20	2015	Earth Obervation (Landmapper-HD)
EDSN	8	2015	Demonstration of small satellite applications using consumer electronic-based nano-satellites
QB-50	50	2016	International network for thermo sphere exploration
PROBA-3	2	2017	Demonstrate the technologies needed for formation flying
Keppler	50	2017	Coordinate and relay the communication between satellites and ground

Table 2: Current and future small satellites missions. Adapted from [Kulu(2016), Radhakrishnan et al.(2016)Radhakrishnan, Edmonson, Afghah, Rodriguez-Osorio, Pinto, and I

5 Internal Structure

5.1 Hierarchy

In order to build a work strategy, the project is divided in task that will be described later on. As the different tasks depend on each other, the project members have decided to follow a hierarchy. Every task is developed by a small team between 2 and 5 people depending on the amount of work the task requires.

Each small team has to have a coordinator which has two principal functions. The first one is to manage the group so he is responsible for the good organisation and progression of the task. The second is that he is the voice of the team. That means that the coordinator is the one who represents his work team when transferring information to the other group coordinators and the project managers and vice versa.

Over all the teams Boyan Naydenov is the project manager who ensures the project progress, manages people for major decisions and is the contact point with the costumer. Finally, Silvia González is the secretary in charge to write and delivery the minutes and agendas of each meeting. She is also in charge of the organization and storage of all the documents in BSCW.

Department	**Coordinator**	**Team members**
Orbits Design	Oscar Fuentes Muñoz	Lluís Foreman Campins
		Sílvia González García
		Víctor Martínez Viol
		Laura Pla Olea
Satellite Design	Pol Fontanes Molina	Fernando Herrán Albelda
		David Morata Carranza
Communications	Eva María Urbano González	Boyan Naydenov
		Josep Puig Ruiz
		Josep María Serra Moncunill
		Sergi Tarroc Gil
Constellation Deployment	Xavi Tió Malo	Joan Cebrián Galán
		Roger Fraixedas Lucea
		Marina Pons Daza

Table 3: Roles and Responsabilities

5.2 Documents organisation

The Astrea team has 17 members so it is essential to define protocol to organise all the documents and information found to take advantage of resources.

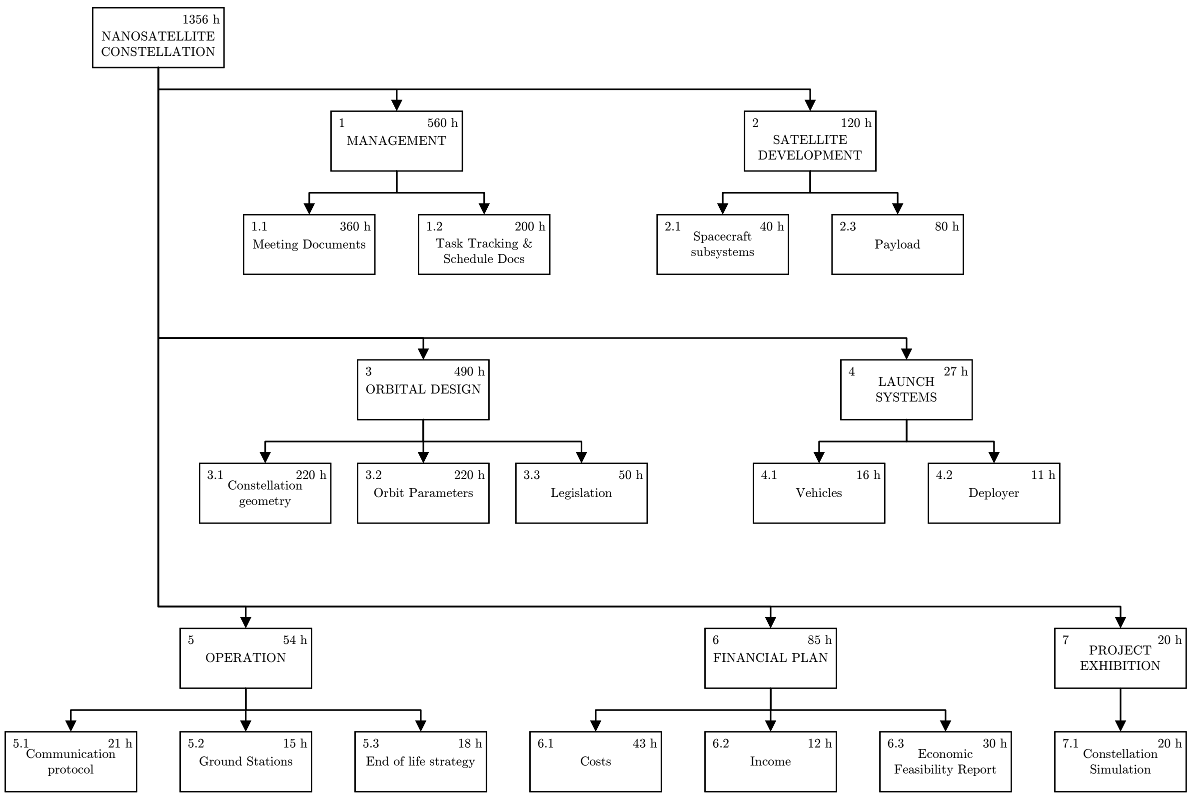
The main internal communication tool used is *Slack* which is a platform specialised in team communication. *Slack* defines itself as a real-time messaging, achieving and search for modern team which is interesting for us because it allows the group to communicate at all times for punctual doubts and small decisions. For major decisions a meeting date will be specified using doodle. Communication between the customer and project manager will be carried out via e-mail. Weekly meetings with the customer are scheduled every Thursday and will be formalised through the agenda.

Moreover, to share documents we use two platforms: *Slack* and *BSCW*. On slack we put first drafts or documents that can be interesting. BSCW is the main information storage because information and documents are stocked and organised in folders.

At last, the text editor used to develop the project is Latex which combined with Git allows us to work remotely on a same document without overriding someone else's work. This work system is really interesting for such a big group in order to work on the same document while keeping a record of the changes.

6 Planning of the project

6.1 Tasks identification from work breakdown structure (WBS)



6.2 Description of the tasks

ID	Work Package	Biref task description list
		1.Managment
1.1	Meetings Documents	·Writing agendas of the meetings: The team's secretary will take note of the topics pending to debate and make a list to be checked by the team. ·Writing minutes of the meetings: The team's secretary will take note of the debate and conclusions of the meeting.
1.2	Task tracking and scheduling	·Project Charter: A description of the project to develop is going to be detailed by all the group members during the first weeks. ·Team tasks monitoring: The coordinator will ensure tasks compliance and register the progress. ·WBS and Gantt update: The documents summarizing the project organization will be updated with final dates and final topics assessed.
		2. Satellite
2.1	Spacecraft Subsystems	·Establishment of requirements once orbits are defined. ·External enterprise hiring for hardware and software design.
2.2.1	Payload antenna	·Calculation of the size of the antenna needed to communicate with the other satellites. ·Search the available antenna in the market that best fits the needs of the project.
2.2.2	Payload Data Handling System (PDHS)	·Selection of the configuration. ·Establishment of the desired hardware and software. ·Search the available PDHS in the market that best fits the needs of the project.
		3. Constellation
3.1	Constellation geometry	·Number of satellites: It is necessary to determine the total number of satellites in order to get global coverage. ·Distribution of the satellites: Compute the correct distribution of these satellites.
3.2.1	General parameters	·Parameter description: Physical definition of the orbits for each satellite of the constellation.
3.2.2	Drifts	·Orbit modifications: Compute the possible orbit deviations of the different satellites.

3.3	Legislation	•Research: Study the legislation referred to nanosatellites. •Implement: Apply the necessary measures to accomplish the legal requirements.
	4. Launch Systems	
4.1	Vehicle	•Study of the requirements for the launch of the cubesats. •Research of the main companyies that offer launch services, including their features and costs. •Decision of the best launch system for our goal, regarding the requirements and the available technology.
4.2	Satellite Deployer	•Study of the requirements for the launch of the cubesats. •Research of the deployment systems that the main companies offer. •Decision of the best launch system for our goal, regarding the requirements and the available technology.
	5. Operations	
5.1	Communication protocol	•Study the existing communication protocols. •Adapt the existing protocols or create new ones.
5.2	Ground station	•Determine the number of ground stations needed. •Design a model of a ground station capable of communication efectively with the constellation.
5.3	End of life strategy	•Study the existing end of life protocols. •Choose the protocol that applies to the satellites.
	6. Financial Plan	
6.1.1.1	Maintenance cost analysis	•Determine maintenance costs related to the constellation and the ground station.
6.1.1.2	Insurance cost analysis	•Study of the insurance market and choosing the best option.
6.1.1.3	Administration cost analysis	•Determine how much it will cost to manage the constellation.
6.1.1.4	Taxes cost analysis	•Analysis of taxes related to the service provided and how it will affect the economic balance.
6.1.2.1	Manufacturing cost report	•Determine the cost of production of the different elements of the constellation.
6.1.2.2	Launching cost report	•Study of the best options in the market to launch the satellites and choosing one of them.
6.2.1	Price analysis	•Determine the price of the service provided for optimum income.
6.2.2	Revenue forecast	•Study of the demand for the service provided.

6.3	Economic feasibility report	•Study of the costs and income of the project to determine if it can carry out.
7. Project Exhibition		
7	Project Exhibition	•Perform a simulation of the constellation in order to show how it will work

Table 4: Tasks Description

6.3 Interdepency relationships among tasks, human resources and level of effort

ID	Work Package	Time (h)	Prelations
1.Managment			
1.1	Meetings Documents	360	
1.2	Task tracking and scheduling	200	BB - 1.1
2.Satellite			
2.1	Spacecraft Subsystems	80	BF-3
2.2.1	Payload antenna	30	BF-3
2.2.2	PDHS	50	BF-3
3. Constellation			
3.1	Constellation geometry	120	-
3.2.1	General parameters	120	BF - 3.1
3.2.2	Drifts	100	BB - 3.2.1
3.3	Legislation	50	BB - 3.1 BB - 2 BB - 1
4. Launch Systems			
4.1	Vehicle	25	BB 3.2
4.2	Satellite Deployer	5	BB 3.1
5. Operations			
5.1	Communication protocol	150	BF - 3.2.1
5.2	Ground station	80	BF- 5.1 BF - 3.3
5.3	End of life strategy	60	BF - 3.2.1
6. Financial Plan			
6.1.1.1	Maintenance Cost Analysis	7	BF -1,2,3,4,5
6.1.1.2	Insurance Cost Analysis	10	BF -1,2,3,4,5
6.1.1.3	Administration Cost Analysis	8	BF -1,2,3,4,5
6.1.1.4	Taxes Cost Analysis	10	BF -1,2,3,4,5

6.1.2.1	Manufacturing Cost Report	10	BF -1,2,3,4,5
6.1.2.2	Launching Cost Report	10	BF -1,2,3,4,5
6.2.1	Price Analysis	15	BF -1,2,3,4,5
6.2.2	Revenue Forecast	10	BF -1,2,3,4,5
6.3	Economic Feasibility Report	30	BF -1,2,3,4,5
7. Project Exhibition			
7	Project Exhibition	30	BF - 3

Table 5: Prelations and Time

7 Budget

7.1 Engineering hours budget

WORKING PACKAGE	Hours (h)	Labor cost (€)
MANAGEMENT		
Meetings documentation		
Meetings	340	6800
Meetings preparation		
Agendas	10	200
Minutes	10	200
Task tracking and scheduling		
Project Charter	170	3400
Team tasks monitoring	20	400
WBS and Gantt update	10	200
SATELLITE DEVELOPMENT		
Spacecraft subsystems	40	800
Payload		
Antenna	40	800
PHDS	50	1000
ORBITAL DESIGN		
Constellation geometry	220	4400
Orbit parameters		
General parameters	120	2400
Drifts	100	2000
Legislation	50	1000
LAUNCH SYSTEMS		
Vehicle	16	320
Satellite deployer	11	220
OPERATION		
Communication protocol	21	420
Ground station	15	300
Enf of life strategy	18	360

WORKING PACKAGE	Hours (h)	Labor cost (€)
FINANCIAL PLAN		
Costs		
Fix		
Maintenance cost analysis	5	100
Insurance cost analysis	6	120
Administration cost analysis	6	120
Taxes cost analysis	6	120
Variable		
Manufacturing cost report	10	200
Launching cost report	10	200
Income		
Price analysis	6	120
Revenue forecast	6	120
Economic feasibility report	30	600
PROJECT EXHIBITION		
Constellation simulation	20	400
TOTAL ESTIMATED	**1400**	**28000**

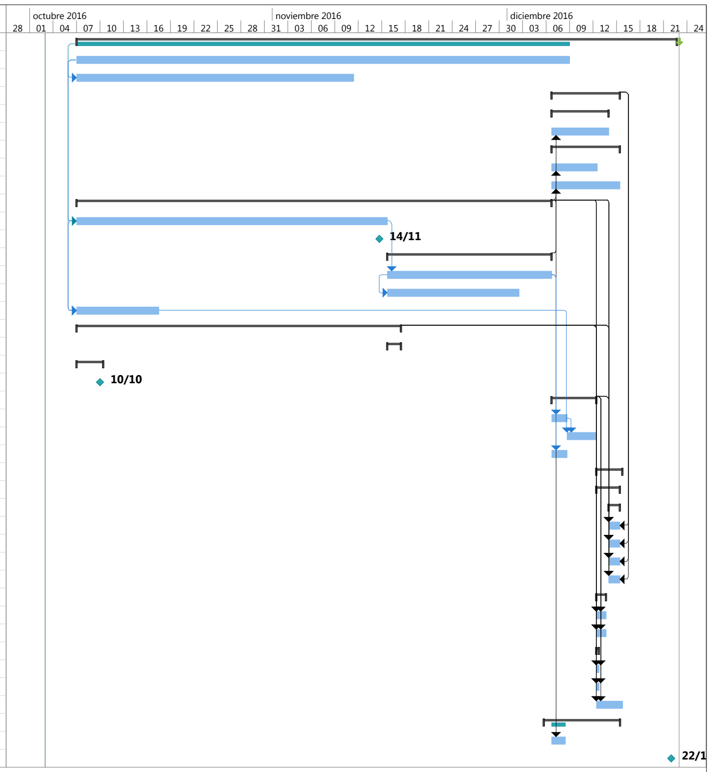
7.2 Preliminary total costs budget

WORKING PACKAGE	Product cost (€)	Hours (h)	Labor cost (€)
MANAGEMENT			
Meetings documentation			
Meetings	-	340	6800
Meetings preparation			
Agendas	-	10	200
Minutes	-	10	200
Task tracking and scheduling			
Project charter	-	170	3400
Team tasks monitoring	-	20	400
WBS and Gantt update	-	10	200
SATELLITE DEVELOPMENT			
Spacecraft subsystems	-?	40	800
Payload			
Antenna	6000	40	800
PHDS	7000	50	1000
ORBITAL DESIGN			
Constellation geometry	-	220	4400
Orbit parameters			
General parameters	-	120	2400
Drifts	-	100	2000
Legislation	Licencia?	50	1000
LAUNCH SYSTEMS			
Vehicle	-	16	320
Satellite deployer	-	11	220
OPERATION			
Communication protocol	-	21	420
Ground station	5000	15	300
Enf of life strategy	-	18	360

WORKING PACKAGE	Product cost (€)	Hours (h)	Labor cost (€)
FINANCIAL PLAN			
Costs			
Fix			
Maintenance cost analysis	-	5	100
Insurance cost analysis	-	6	120
Administration cost analysis	-	6	120
Taxes cost analysis	-	6	120
Variable			
Manufacturing cost report	-	10	200
Launching cost report	-	10	200
Income			
Price analysis	-	6	120
Revenue forecast	-	6	120
Economic feasibility report	-	30	600
PROJECT EXHIBITION			
Constellation simulation	-	20	400
TOTAL ESTIMATED	**18000 + ?**	**1400**	**28000**

8 Gantt of the project

Id	EDT	Nombre de tarea	Duración	Comienzo	Fin
1	**1**	**MANAGEMENT**	**146 días**	**vie 07/10/16**	**jue 22/12/16**
2	1.1	Meeting Documents	120 días	vie 07/10/16	jue 08/12/16
3	1.2	Task Tracking & Schedule Docs	67 días	vie 07/10/16	vie 11/11/16
4	**2**	**SATELLITE DEVELOPMENT**	**17 días**	**mar 06/12/16**	**jue 15/12/16**
5	**2.1**	**Spacecraft subsystems**	**14 días**	**mar 06/12/16**	**mar 13/12/16**
6	2.1.5	Structure and Mechanics	14 días	mar 06/12/16	mar 13/12/16
7	**2.3**	**Payload**	**17 días**	**mar 06/12/16**	**jue 15/12/16**
8	2.3.1	Antennas	10 días	mar 06/12/16	lun 12/12/16
9	2.3.2	PDHS	17 días	mar 06/12/16	jue 15/12/16
10	**3**	**ORBITAL DESIGN**	**114 días**	**vie 07/10/16**	**mar 06/12/16**
11	3.1	Constellation geometry	74 días	vie 07/10/16	mar 15/11/16
12		Constellation geometry frozen configuration	0 días	lun 14/11/16	lun 14/11/16
13	**3.2**	**Orbit Parameters**	**40 días**	**mar 15/11/16**	**mar 06/12/16**
14	3.2.1	General parameters	40 días	mar 15/11/16	mar 06/12/16
15	3.2.2	Drifts	34 días	mar 15/11/16	vie 02/12/16
16	3.3	Legislation	17 días	vie 07/10/16	lun 17/10/16
17	**4**	**LAUNCH SYSTEMS**	**78 días**	**vie 07/10/16**	**jue 17/11/16**
18	**4.1**	**Vehicles**	**4 días**	**mar 15/11/16**	**jue 17/11/16**
21	**4.2**	**Deployer**	**3 días**	**vie 07/10/16**	**lun 10/10/16**
24		Maximum deployable payload fixed	0 días	lun 10/10/16	lun 10/10/16
25	**5**	**OPERATION**	**9 días**	**mar 06/12/16**	**lun 12/12/16**
26	5.1	Communication protocol	5 días	mar 06/12/16	jue 08/12/16
27	5.2	Ground Stations	4 días	jue 08/12/16	lun 12/12/16
28	5.3	End of life strategy	5 días	mar 06/12/16	jue 08/12/16
29	**6**	**FINANCIAL PLAN**	**10 días**	**lun 12/12/16**	**jue 15/12/16**
30	**6.1**	**Costs**	**8 días**	**lun 12/12/16**	**jue 15/12/16**
31	**6.1.1**	**Fix**	**3 días**	**mié 14/12/16**	**jue 15/12/16**
32	6.1.1.1	Maintenance Cost Analysis	3 días	mié 14/12/16	jue 15/12/16
33	6.1.1.2	Insurance Cost Analysis	3 días	mié 14/12/16	jue 15/12/16
34	6.1.1.3	Administration Cost Analysis	3 días	mié 14/12/16	jue 15/12/16
35	6.1.1.4	Taxes Cost Analysis	3 días	mié 14/12/16	jue 15/12/16
36	**6.1.2**	**Variable**	**4 días**	**lun 12/12/16**	**mar 13/12/16**
37	6.1.2.1	Manufacturing Cost Report	4 días	lun 12/12/16	mar 13/12/16
38	6.1.2.2	Launching Cost Report	4 días	lun 12/12/16	mar 13/12/16
39	**6.2**	**Income**	**2 días**	**lun 12/12/16**	**lun 12/12/16**
40	6.2.1	Price Analysis	2 días	lun 12/12/16	lun 12/12/16
41	6.2.2	Revenue Forecast	2 días	lun 12/12/16	lun 12/12/16
42	6.3	Economic Feasibility Report	10 días	lun 12/12/16	jue 15/12/16
43	**7**	**PROJECT EXHIBITION**	**20 días**	**lun 05/12/16**	**jue 15/12/16**
44	7.1	Constellation Simulation	4 días	mar 06/12/16	jue 08/12/16
45		Project Delivery	0 días	jue 22/12/16	jue 22/12/16



Proyecto: NANOSATELLITE CON
Fecha: lun 03/10/16

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