Departament de Projectes d'Enginyeria
UNIVERSITAT POLITÈCNICA DE CATALUNYA

ESEIAAT
ENGINEERING PROJECT

Astrea Constellation

Project Charter

Group 04: EA-T2016

October 5, 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

- Select the proper satellite's weight and size, taking into account the next constraints: the launch system cost, the relation between the weight, size and the orbit decay time and, lastly, the interdependency with the selected subsystems.
- Deep study of the market and of the state of the art so that later choice on which subsystem to include is done accordingly. The most important subsystems will be analysed. These are: the structural subsystem, the power subsystem, the thermal control subsystem, the attitude control subsystem and the data handling subsystem. The information is going to be extracted mainly online. Also, prestigious magazines can be taken into account as well as contacting some satellite companies.
- Eventually, a subsystems choice will be done taking into account the cost, the ease of integration and the need to fulfil the project's requirements.

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. Also, collision and orbital decay avoidance is going to be taken into account. Finally, stated requirements as low latency or the possibility to act in case of a network's failure are going to be contemplated due to their tight dependency on the selected orbit.
- 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. It will consist in the inclusion of empirical or physical models in the orbit calculation software and evaluate the level of significance of these cellestial bodies in the results.

- The specific existing legislation will be taken into 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 fulfils the mission requirements with a reasonable economic conditions.
- A launching date will be reserved if the chosen launch platform requires it.
- The recommendations of *Joint Space Operation Center* will be followed and their application form will be followed up to ensure all the launch procedure accomplishes the legislation.
- An end of life strategy will be designed according to the CubeSats lifespan, orbit decay, replacement stratagem of the company and legislation procedures.

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.
- Communication logistics will be defined. Thus, how the satellites decide whether to send the data or to store it, and if they are to send, where they should do it, is going to be approached. In other words, a high level communications protocol is going to be defined.

Exhibition

- It will consist on a simulation of the constellation. Basically, the results from the orbit's calculations are going to be used here in order to show the client the finish state of the product. A CAD of the Satellite node is going to be used as well.

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 [1]. In these situation, Astrea have the opportunity to take a unique position in the market, sharing the communication segment only with Kepler Communications[2].

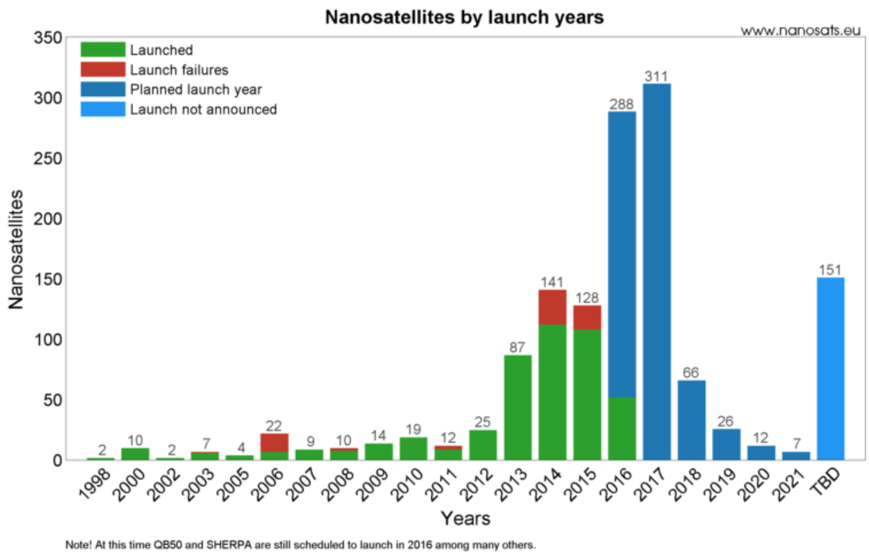


Figure 1: Nanosatellites by launch years. Extracted from [3]

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 intrinsic advantage since normally, the CubeSat that connects with ground won't necessary be the same that the one establishing a link with the customer satellite. This will enable client's satellites 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 and 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 [3, 4]

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 and manages people for major decisions. 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 a protocol to organise all the documents and information found to take advantage of resources.

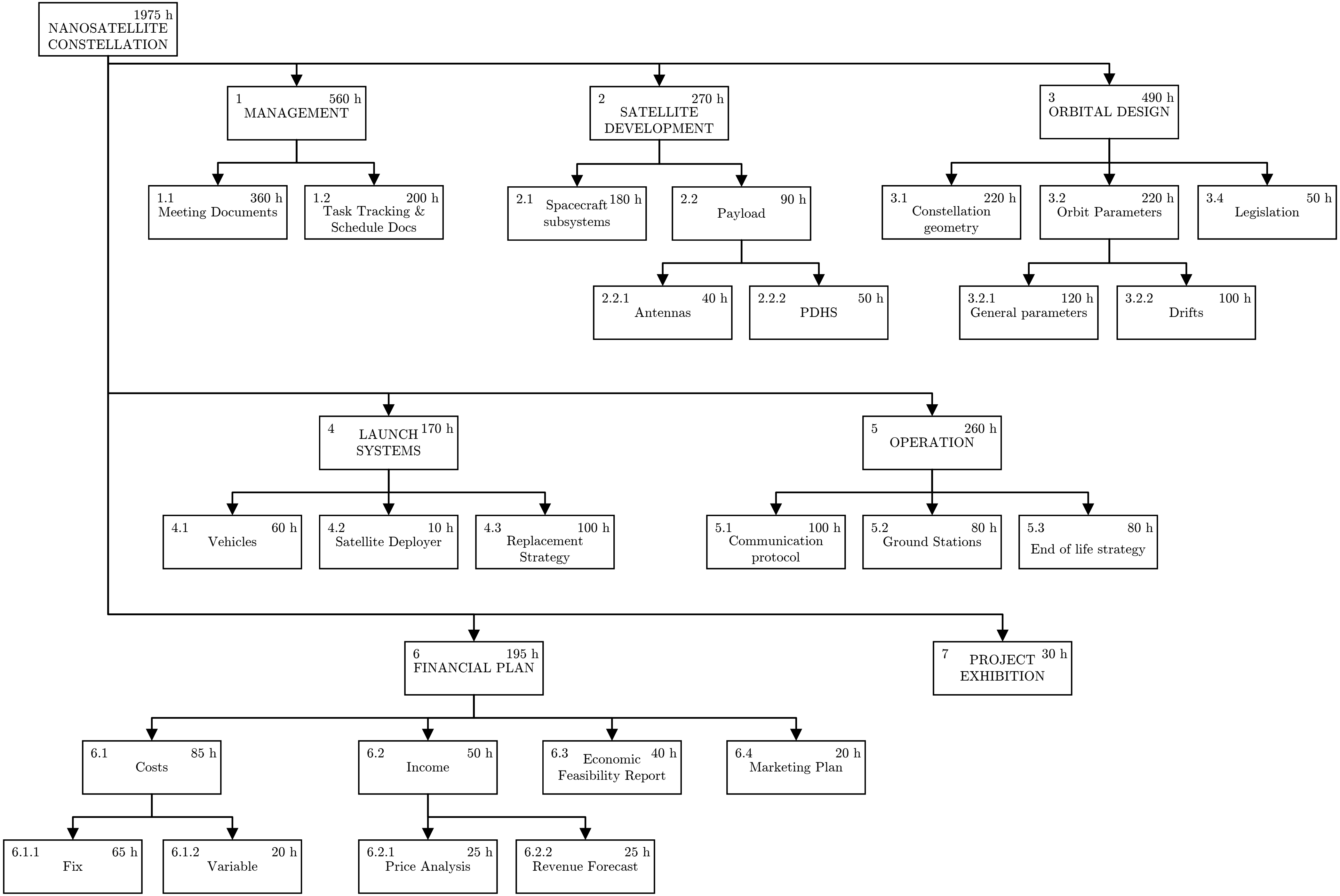
The main internal communication tool used is *Slack* which is a platform specialised in team communication. *Slack* defines itself as a real-time messaging, achieving and search for modern team which is interesting for us because it allows the group to communicate at all times for punctual doubts and 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 G*it* 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)


1975 h NANOSATELLITE CONSTELLATION
1 560 h MANAGEMENT
1.1 360 h Meeting Documents
1.2 200 h Task Tracking & Schedule Docs
2 270 h SATELLITE DEVELOPMENT
2.1 180 h Spacecraft subsystems
2.2 90 h Payload
2.2.1 40 h Antennas
2.2.2 50 h PDHS
3 490 h ORBITAL DESIGN
3.1 220 h Constellation geometry
3.2 220 h Orbit Parameters
3.2.1 120 h General parameters
3.2.2 100 h Drifts
3.4 50 h Legislation
4 170 h LAUNCH SYSTEMS
4.1 60 h Vehicles
4.2 10 h Satellite Deployer
4.3 100 h Replacement Strategy
5 260 h OPERATION
5.1 100 h Communication protocol
5.2 80 h Ground Stations
5.3 80 h End of life strategy
6 195 h FINANCIAL PLAN
6.1 85 h Costs
6.1.1 65 h Fix
6.1.2 20 h Variable
6.2 50 h Income
6.2.1 25 h Price Analysis
6.2.2 25 h Revenue Forecast
6.3 40 h Economic Feasibility Report
6.4 20 h Marketing Plan
7 30 h PROJECT EXHIBITION

6.2 Description of the tasks

ID	Work Package	Brief 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	·Research on the state of the art of the typical CubeSat subsystems. ·Subsystem's Choice Criteria Definition ·Selection of the subsystems.
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.
4.3	Replacement strategy	•Esatblish a way to provide a continuous flow of satellites launches
	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 be carried out.
6.4	Marketing Plan	•Definition of the procedure of the product announcement.
	7. Project Exhibition	
7	Project Exhibition	•Perform a simulation of the constellation in order to show how it will work. Also, a CAD model of the Satellite.

Table 4: Tasks Description

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

ID	Work Package	Time (h)	Prelations
	1.Management		
1.1	Meetings Documents	360	
1.2	Task tracking and scheduling	200	BB - 1.1
	2.Satellite		
2.1	Spacecraft Subsystems	180	BB - 1
2.2.1	Payload antenna	40	BB - 2.1
2.2.2	PDHS	50	BB - 2.1
	3. Orbital Design		
3.1	Constellation geometry	220	BB - 1
3.2.1	General parameters	120	BF - 3.1
3.2.2	Drifts	100	BB - 3.2.1
3.3	Legislation	50	BB - 1, 2, 3.1
	4. Launch Systems		
4.1	Vehicle	60	BF - 4.3
4.2	Satellite Deployer	10	BF - 4.3
4.3	Replacement Strategy	100	BB - 1
	5. Operations		
5.1	Communication protocol	100	BB - 1
5.2	Ground station	80	BF - 5.1
5.3	End of life Strategy	80	BF - 5.2
	6. Financial Plan		
6.1.1.1	Maintenance Cost Analysis	10	BF - 3,4,5; BB - 2
6.1.1.2	Insurance Cost Analysis	15	BF - 3,4,5; BB - 2

6.1.1.3	Administration Cost Analysis	15	BF - 3,4,5; BB - 2
6.1.1.4	Taxes Cost Analysis	25	BF - 3,4,5; BB - 2
6.1.2.1	Manufacturing Cost Report	10	BF - 3,4,5; BB - 2
6.1.2.2	Launching Cost Report	10	BF - 3,4,5; BB - 2
6.2.1	Price Analysis	25	BF - 3,4,5; BB - 2
6.2.2	Revenue Forecast	25	BF - 3,4,5; BB - 2
6.3	Economic Feasibility Report	40	BF - 3,4,5; BB - 2
6.4	Marketing Plan	20	BF - 6.2.1,6.2.2
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	180	3600
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	60	1200
Satellite deployer	10	200
Replacement Strategy	100	2000
OPERATION		
Communication protocol	100	2000
Ground station	80	1600
Enf of life strategy	80	1600

WORKING PACKAGE	Hours (h)	Labor cost (€)
FINANCIAL PLAN		
Costs		
Fix		
Maintenance cost analysis	10	200
Insurance cost analysis	15	300
Administration cost analysis	15	300
Taxes cost analysis	25	500
Variable		
Manufacturing cost report	10	200
Launching cost report	10	200
Income		
Price analysis	25	500
Revenue forecast	25	500
Economic feasibility report	40	800
Marketing Plan	20	400
PROJECT EXHIBITION		
Constellation simulation	30	600
TOTAL ESTIMATED	**1975**	**39500**

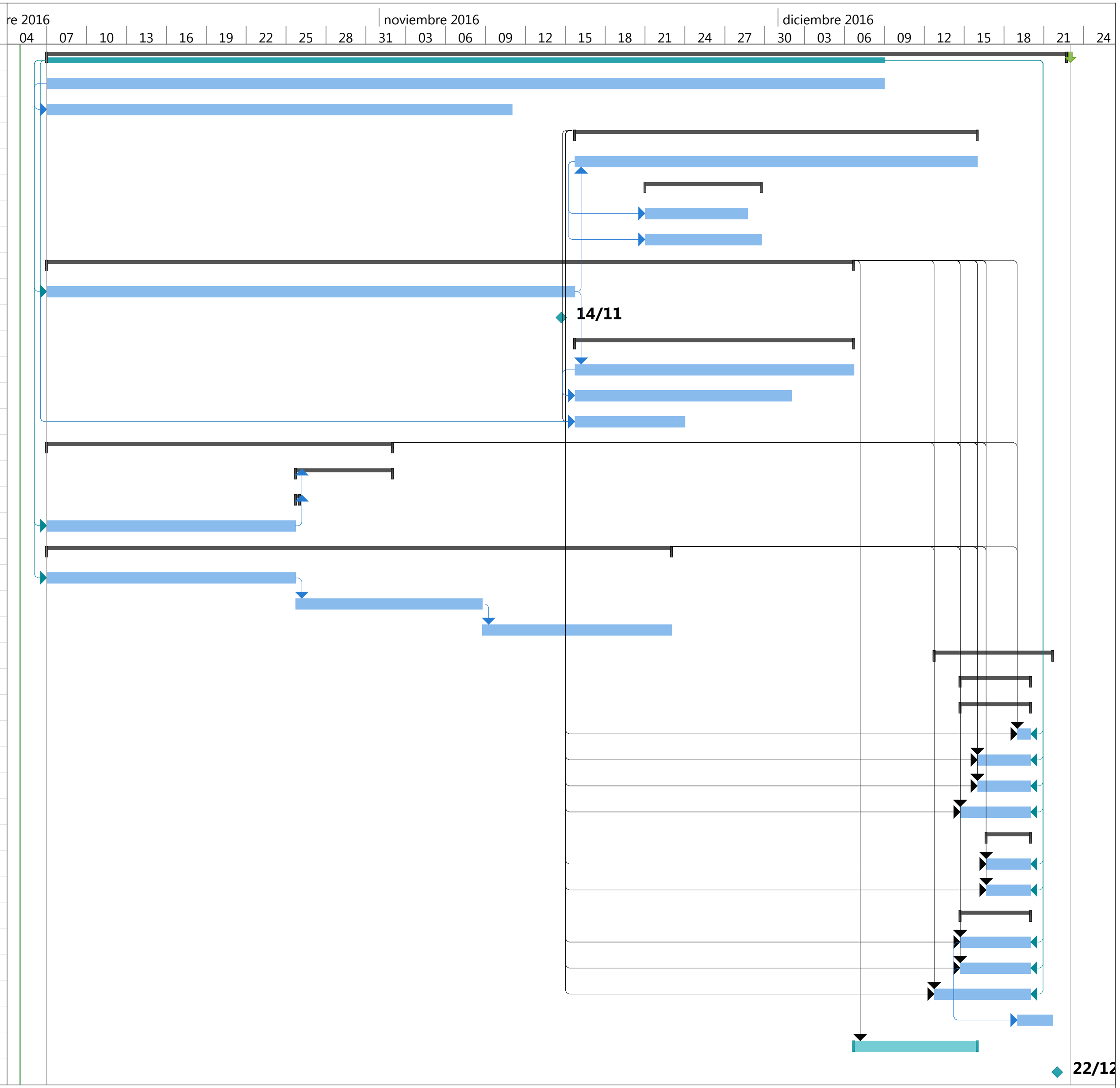
7.2 Preliminary total costs budget

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	75000	180	3600
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	License	50	1000
LAUNCH SYSTEMS			
Vehicle	-	60	1200
Satellite deployer	-	10	200
Replacement Strategy	-	100	2000
OPERATION			
Communication protocol	-	100	2000
Ground station	50000	80	1600
Enf of life strategy	-	80	1600

WORKING PACKAGE	Product cost (€)	Hours (h)	Labor cost (€)
FINANCIAL PLAN			
Costs			
Fix			
Maintenance cost analysis	-	10	200
Insurance cost analysis	-	15	300
Administration cost analysis	-	15	300
Taxes cost analysis	-	25	500
Variable			
Manufacturing cost report	-	10	200
Launching cost report	-	10	200
Income			
Price analysis	-	25	500
Revenue forecast	-	25	500
Economic feasibility report	-	40	800
Marketing Plan	-	20	400
PROJECT EXHIBITION			
Constellation simulation	-	30	600
TOTAL ESTIMATED	**138000**	**1975**	**39500**

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**	**60 días**	**mar 15/11/16**	**vie 16/12/16**
5	2.1	Spacecraft subsystems	60 días	mar 15/11/16	vie 16/12/16
6	**2.2**	**Payload**	**17 días**	**lun 21/11/16**	**mar 29/11/16**
7	2.2.1	Antennas	14 días	lun 21/11/16	lun 28/11/16
8	2.2.2	PDHS	17 días	lun 21/11/16	mar 29/11/16
9	**3**	**ORBITAL DESIGN**	**114 días**	**vie 07/10/16**	**mar 06/12/16**
10	3.1	Constellation geometry	74 días	vie 07/10/16	mar 15/11/16
11		3.1 Frozen configuration	0 días	lun 14/11/16	lun 14/11/16
12	**3.2**	**Orbit Parameters**	**40 días**	**mar 15/11/16**	**mar 06/12/16**
13	3.2.1	General parameters	40 días	mar 15/11/16	mar 06/12/16
14	3.2.2	Drifts	34 días	mar 15/11/16	vie 02/12/16
15	3.4	Legislation	17 días	mar 15/11/16	jue 24/11/16
16	**4**	**LAUNCH SYSTEMS**	**49 días**	**vie 07/10/16**	**mié 02/11/16**
17	**4.1**	**Vehicles**	**15 días**	**mar 25/10/16**	**mié 02/11/16**
20	**4.2**	**Satellite Deployer**	**2 días**	**mar 25/10/16**	**mié 26/10/16**
23	4.3	Replacement Strategy	34 días	vie 07/10/16	mar 25/10/16
24	**5**	**OPERATION**	**88 días**	**vie 07/10/16**	**mar 22/11/16**
25	5.1	Communication protocol	34 días	vie 07/10/16	mar 25/10/16
26	5.2	Ground Stations	27 días	mar 25/10/16	mar 08/11/16
27	5.3	End of life strategy	27 días	mar 08/11/16	mar 22/11/16
28	**6**	**FINANCIAL PLAN**	**18 días**	**lun 12/12/16**	**mié 21/12/16**
29	**6.1**	**Costs**	**9 días**	**mié 14/12/16**	**mar 20/12/16**
30	**6.1.1**	**Fix**	**9 días**	**mié 14/12/16**	**mar 20/12/16**
31	6.1.1.1	Maintenance Cost Analysis	3 días	lun 19/12/16	mar 20/12/16
32	6.1.1.2	Insurance Cost Analysis	5 días	vie 16/12/16	mar 20/12/16
33	6.1.1.3	Administration Cost Analysis	5 días	vie 16/12/16	mar 20/12/16
34	6.1.1.4	Taxes Cost Analysis	9 días	mié 14/12/16	mar 20/12/16
35	**6.1.2**	**Variable**	**4 días**	**vie 16/12/16**	**mar 20/12/16**
36	6.1.2.1	Manufacturing Cost Report	4 días	vie 16/12/16	mar 20/12/16
37	6.1.2.2	Launching Cost Report	4 días	vie 16/12/16	mar 20/12/16
38	**6.2**	**Income**	**9 días**	**mié 14/12/16**	**mar 20/12/16**
39	6.2.1	Price Analysis	9 días	mié 14/12/16	mar 20/12/16
40	6.2.2	Revenue Forecast	9 días	mié 14/12/16	mar 20/12/16
41	6.3	Economic Feasibility Report	14 días	lun 12/12/16	mar 20/12/16
42	6.4	Marketing Plan	7 días	lun 19/12/16	mié 21/12/16
43	7	PROJECT EXHIBITION	20 días	mar 06/12/16	vie 16/12/16
44		Project Delivery	0 días	jue 22/12/16	jue 22/12/16



Proyecto: NANOSATELLITE CON
Fecha: mié 05/10/16

Tarea		Resumen del proyecto		Tarea manual		solo el comienzo		Fecha límite	
División		Tarea inactiva		solo duración		solo fin		Progreso	
Hito		Hito inactivo		Informe de resumen manual		Tareas externas		Progreso manual	
Resumen		Resumen inactivo		Resumen manual		Hito externo			

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