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POLIFEMO DEVICE BUSINESS PLAN

Panoramic Multifunctional Sensor for Small/Micro Satellites

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Summary

1. Introduction 2
2. Market analysis & requirement definition 3
   2. 1 Space 3
   2.2 UAV/RPAS/HAP: 5
   2.3 Deep Space Rover 6
   2.4 Ground Systems 6
3. Technological feasibility of the POLIFEMO 9
   3.1. The Lens 12
   3.2 Image Detector 14
   3.3 Proximity electronics and control unit (PE&CU) 15
   3.4 Software 15
4. Strategy for commercialization 16
   4.1 Pricing 16
   4.2 Channels of Distribution 17
   4.3 Promotion 17
5. Economic statements 17
6. Definition of the development plan and business plan 18
   6.1 Design and development plan 18

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PU	Public	x
PP	Restricted to other programme participants (including the Commission services)	
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1. Introduction

Spacecrafts continuously need for low cost and weight sensor easy to integrate in a plug-in approach and capable to improve platforms versatility while reducing integration time and complexity. This is particularly true for the new generation of small and micro satellites to be launched in constellation and formation. Controlling small satellites cooperation and protecting the space assets from debris are two important issues of current and future missions. The cost reduction and safety of space missions is a key issue for further expand European leadership in the Earth Observation and Communication sectors.

The POLIFEMO (Panoramic Multifunctional Sensor for Small/Micro Satellite) is a unique solution for an integrated sensor capable to replace by one single unit the functions of Sun sensor, Earth sensor and Star tracker and, additionally, providing external situational awareness.

POLIFEMO is based on an innovative lens with a very wide angle (with a hyper-hemispheric field of view) able to look at a field of view of 360° in azimuth (panoramic omnidirectional lens) and 270° in elevation (hyper-hemispheric capabilities), designed and patented by the Italian National Institute for Astrophysics (INAF). POLIFEMO, with that extremely high field of view and unique imaging detection capability, results in a small, low weight, low cost and reliable (no moving part, potentially failure point) space sensor. It is unique in the market of space sensors and suitable for many spaces and non-space missions (e.g., communication, weather, imaging, surveillance, deep space but also UAV/HAP). Progetti Speciali Italiani s.r.l., a SME active in developing microsatellite and space applications, has set up, during the phase 1 project, a very experienced team of engineering and commercial specialists for carrying on the proposed project. University of Napoli (Parthenope) is expert on developing satellites star trackers solutions.

This paper reports a summary extracted from a more detailed BP (Doc: ECSME-PSI-POLIFEMO-BP-2016) which has been prepared within the EU-H2020 contract framework. The full BP is available on request.

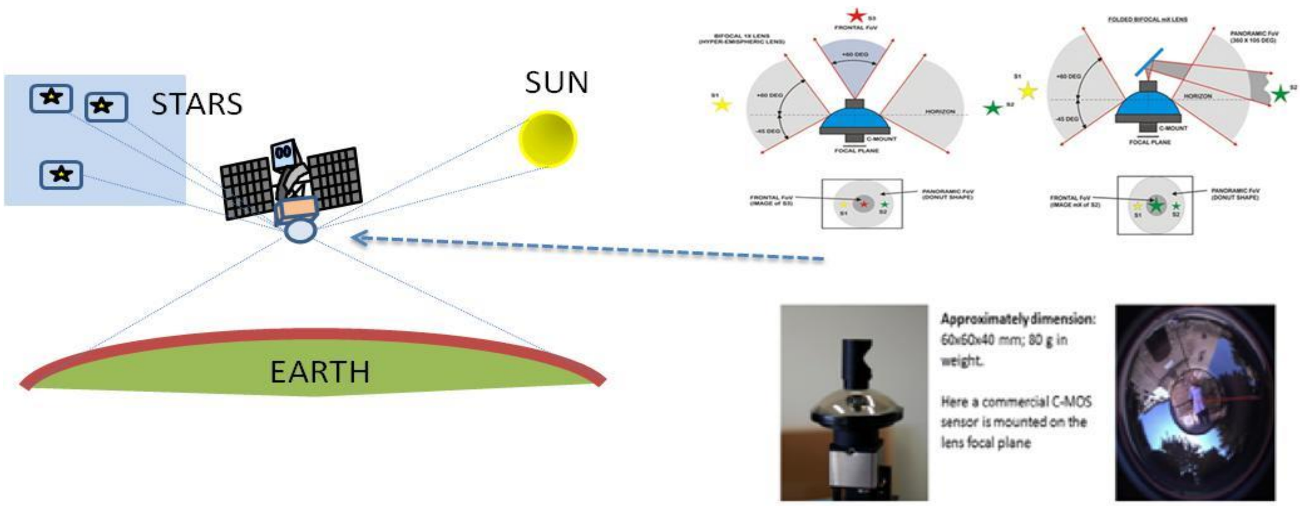

Figure 1: The POLIFEMO product reference context.

2. Market analysis & requirement definition

POLIFEMO technology can be adapted to several fields of including wide commercial applications. Its market segments are:

- SPACE
- UAV/RPAS/HAP: anti-collision & swarm operations
- DEEP SPACE ROVER
- Ground System for monitoring and control

2. 1 Space

Space market for POLIFEMO can consist of many applications:

- LEO/MEO satellites: small and large, EO (earth observation), science and telecommunications
- GEO satellites: mainly for telecommunication with same meteo
- Deep space: planet exploration
- Space station: mainly for external awareness
-

Interest in small satellites typically defined as those under 500 kilograms (1,100 pounds) has grown over the years based on a number of factors working in tandem: The miniaturization of once-bulky satellite components, standardization of many satellite parts, and other factors have trimmed costs substantially. That has made the building, launching, and operation of "smallsat" constellations increasingly feasible***.***

What investors are betting on is nothing short of the future of big data, the Internet, and global market intelligence all rolled into a suite of orbital technologies. While National Agencies mostly look for continuous Earth data collection (Copernicus) and new science.

From Euroconsult's analysis of the satellite based EO Market Prospect to 2024[1], the number of EO satellites expected to more than double in the next decade to 427 (2015-2024), from 179 (2005-2014). The number of countries that are expected to launch EO satellites should increase from 36 (2005-2014) to 44 (2015-2024). More than 50 countries are investing in EO programs with a spend that was forecast to exceed 10 B€ in 2015. The EO satellite manufacturing revenues are expected to increase by 80% in the next decade to a total of just under 39 B€. An earlier study of Euroconsult[2] highlighted that traditionally most of the satellite operators were operated by governments or national space agencies, but that the number of commercial operators were emerging. Another trend was the blurring between data distribution entities (typically contracted by government) and commercial EO value-added service providers. They estimate the value of commercial EO data market to be in the order of 1.3 B€ in 2014, part of which represents the revenues to commercial operators. According to an EO21 study[3], the value of EO data, when separated from value-added products and information services, was just under 800 M€ in 2013.

On the other hand, also LEO communication is growing with several constellations under design.

In January, Google and Fidelity announced a $1 billion investment in SpaceX to help the company build out its own constellation of Internet-beaming satellites. That same month, newcomer OneWeb announced that it would likewise put in orbit a constellation of 648 smallsats capable of supplying Internet to points on the ground below (the estimated $2 billion project, set to begin launching in 2018, is not accounted for in

[1] http://www.euroconsult-ec.com/earthobservation
[2] http://www.e-geos.it/news/meeting12/presentations/24-Re%81Lvillon-Euroconsult.pdf
[3] http://congrexprojects.com/custom/15C12/D1_A1_06_1130_Osullivan.pdf

NewSpace's $2.5 billion number cited above).

According to the public information given by a small/microsatellite market assessment overview of 2019 made by SpaceWorks Enterprises, Inc, (http://www.sei.aero), in 2019 hundred of commercial nano satellites (1-50kg) have been launched, with an increasing trend over the next years (left panel in Figure 2). Recent multi-million up to multi-billion-dollar investments in various ventures confirm the commercial sector has continued interest in the small satellite industries.

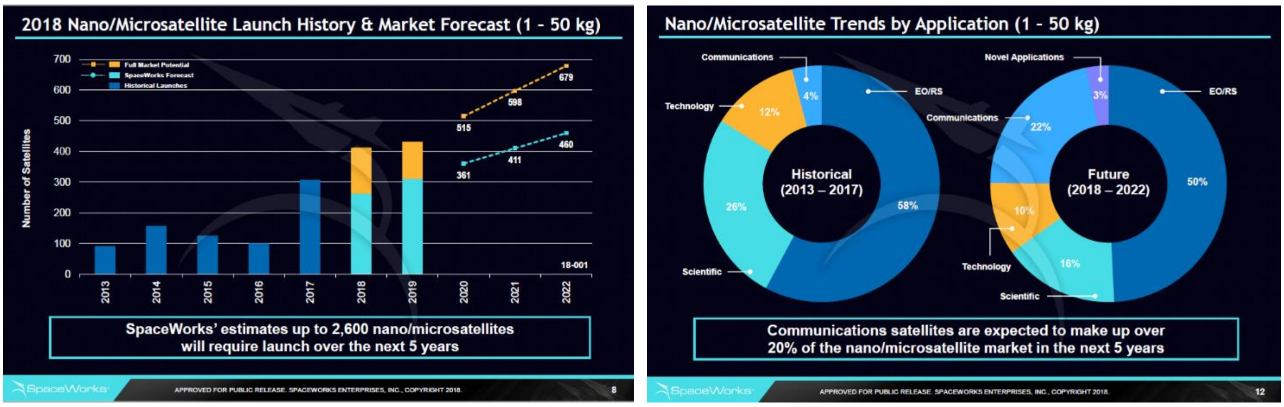

Figure 2: Satellite market trends up to now.

Another interesting research, "Prospect for the small satellite market" in the 2019 edition made by Euroconsult (http://www.euroconsult-ec.com/shop/space-industry/64-prospects-for-the-small-satellite-market.html) gives a global supply and demand analysis of government and commercial satellites up to 500kg. It is reported that a total of 510 smallsats are to be launched in the next five years, a two-third increase in the average number of smallsats per year versus that of the past decade. This total includes constellations of different sized and capabilities that represent a total of 140 satellites. It is expected a further exploitation of constellation and swarm/formation architecture where tens of satellites are needed to get revisit time and coverage. For instance, the microsatellite telecommunication market appears the most interesting looking at satellite of 50-150 Kg to be built in tens of units to provide mobile communication smart phone like. Indeed, this market is growing with the use of microelectronics, and other technology development, private initiatives and furthering of applications.

The market value of these future 510 smallsats is estimated at $7.4 billion (at 2014$ prices to develop and launch the satellites). Market growth will remain strong (+17% vs. the past five years) as the small decrease over time in prices and in launch masses (for satellites greater than 50 kg) is offset by more satellites to be launched. The U.S. is by far the most active country in smallsat deployment with almost half of the 620 satellites launched in the past 10 years; it will remain the largest country for smallsats over the next five years, with Europe as the second-largest region. Finally, four countries are at the forefront of smallsat development in the Middle East, whom together have launched or will launch 27 satellites, i. e. about half of the total of the MEA region.

Recently Satellogic Company, a small satellite startup announced the launching of 300 EO microsatellites to get near real time data (http://www.satellitetoday.com/technology/2016/03/17/satellogic-on-its-way-to-launching-300-satellite-constellation-for-earth-observation/) with the first non-prototype launches slated to occur in 2016.

The nano and microsatellite market however constitutes of revenues from hardware, software and services required for the development and launch of satellites. Among the enabling technologies for this kind of satellite, the ADCS are a main component: new generation of ACDS products with better performances and with added capabilities, respect the only magnetic determination and control (e.g., star tracker determination, earth horizon sensors, and integrated ADCS packages including CPU) are required. In synthesis, we can state the future global market might consist of 300-500 satellites in the next three-four years where at least 100 one can be accessible for a sensor like POLIFEMO.

In addition, the geostationary expensive satellites need same protection against the change to impacts with other bodies during orbit setting and to monitor external situations. This market values another 50/60 satellites.

Another report (Nano and microsatellite markets 2nd edition published in June 2015, http://www.nsr.com/research-reports/commercial-space/nano-and-microsatellite-markets-2nd-edition/) available only for a fee, analyzes the rapidly evolving and increasingly competitive sub-100Kg satellite market, providing an assessment of such market considering mass range, region and application and thus could be used as a reference for the market analysis of POLIFEMO.

In the following same picture extracted from SpaceWorks Enterprises, Inc, from where it is possible to extract the data above reported.

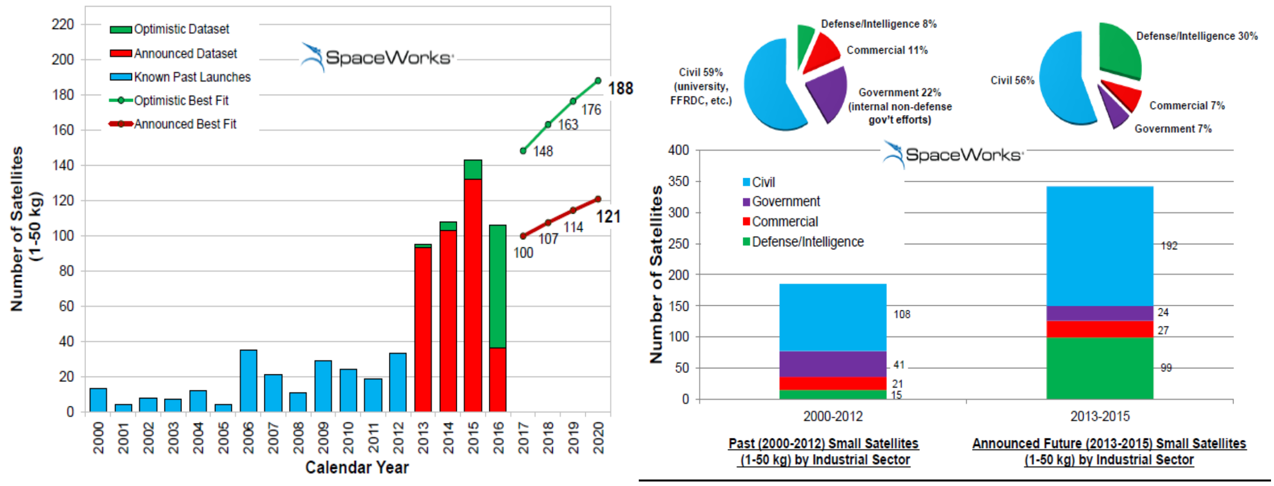

Figure 3: Market forecasts.

It is well assessed that the space segment is moving towards:

- Constellations of small satellites (Earth Explorer type missions) rather than large Envisat-type missions
- On-board instruments that are technically flexible and can be flexible in their scheduling
- Plug in sensors and units to reduce integration cost
- Flexible and modular platforms capable to be reconfigured for the various mission typologies

In conclusions from SpaceWorks and above-mentioned references:

"Thousands of commercial small satellites (100-500 kg) are planned for launch over the next fifteen years. Recent multi-million and multi-billion-dollar investments in various ventures confirm the commercial sector's continued interest in the nano/microsatellite and small satellite industries." The Mega Constellation deployment is expected for 2020.

The large communication satellite market will moderately increase of 20% per year.

Deep space missions will remain almost constant in number unless the Moon or Mars raid will be launched. However, for this mission a high level of reliability and resilience to space environment is requested.

2.2 UAV/RPAS/HAP:

Several attempts have been already done to produce anti-collision system capable to allow UAV/RPAS operations however no operational system still exists. The Unmanned Aerial vehicles (UAV) market is another market that is expected to show a strong growth (http://www.marketsandmarkets.com/Market-Reports/unmanned-aerial-vehicles-uav-market-662.html) with the increase in functionality and demand in the civil and commercial sector. The UAV market has been segmented based on class (e.g., small, tactical, strategic & special purpose), based on payload (e.g., sub-systems –GCS-ground control system), data links, and software, and applications (e.g., defense, commercial and homeland security).

Moreover, with the use of UAV in climate and pollution monitoring, border security operation and maritime operations, the demand of UAV is expected to drive this market. Currently, the global UAV market is valued at USD 10.1 Billion in 2015 and is expected to show a robust growth in future accounting for USD 14.9 billion by 2020, thereby registering a CAGR of 8.12% from 2015-2020. The US accounts for nearly 65,53% of the global UAV market in 2015, but countries such as Russia and the U.K. in the European region are proving to be the emerging markets.

PSI has contacted CIRA and other UAV stakeholders verifying that the availability of a panoramic sensor is considered very important in the design of such systems.

The future market is looking very promising considering the UAV size bigger than 100 Kg.

2.3 Deep Space Rover

Ground rovers and probes exploring other planets and celestial bodies need of the awareness of the surrounding environment to head on safe.

In addition, even here there can be the possibility to operate swarm of vehicles and therefore the need to reciprocal control. However, this market is for the time being very small but might increase in case of massive exploration of moon and Mars.

The market is small but very lucrative because of the high quality standards requested.

2.4 Ground Systems

Finally, in the Earth environment POLIFEMO can find several applications even if this is not the focus of the BP it is worth to mention them:

- Situational awareness and visibility conditions in special sites such airports
- Anticollision systems for vehicles
- Monitoring of areas for security applications

This market can provide hundreds of products to be sold.

POLIFEMO can address several needs of both small and large spacecrafts and specifically:

- Low attitude accuracy requirement

Here the attitude requirement can be achieved by a combination of Sun and Earth sensors.

POLIFEMO can replace those sensors.

- Medium attitude accuracy requirement

Here the attitude requirement is obtained by the addition of a medium accuracy star tracker or high accuracy sun sensor.

Even here POLIFEMO can act alone.

- High attitude accuracy requirement

In this case star tracker is essential but POLIFEMO can support most of the operative modes but not the very high accuracy.

However, POLIFEMO has important advantage advantage w.r.t. conventional sensors: it can keep tracking even if satellite changes its asset because of maneuvering.

- Spinning satellites

They need only single axis sun sensor but with a panoramic sensor their accuracy is improved.

- Orbit transfer & rendezvous

During orbit transfer and maneuvering in general it is very important to keep attitude tracking and of course the availability of an omni directional sensor it helps. At same time during spacecraft nearing other objects the environment availability is important.

- Roll rate measurement

A possible utilization of a star tracker is in the spacecraft roll rate measurement based on the star streak in the images.

- GEO satellite

The availability of an optical sensor such POLIFEMO would be very useful because they can look at sun and Earth.

- Space awareness

Here simply there is a holistic vision of satellite outer space in order to detect threats or support maneuverings

- Formation monitoring/controlling

In case of flying formations, it is important to monitor reciprocal behavior of vehicles both for space and aeronautics.

- Collision avoidance

Collision avoidance is managed by ground however something may suddenly happen in the space that can't be timely managed from ground. This need Is very important for UAV/RPAS

- Science

In same application may be important to get a holistic vision of big phenomena such for instance atmospheric evolutions.

- Rover

A panoramic situation awareness /vision is very important in many situations

If a single sensor can comply most of the above need the advantage became evident for the spacecraft platform designer because he would be only tailor, the sensor to the mission without changing system design.

POLIFEMO will be designed to be a competitive product in the space product arena considering both performance and cost to get the best value.

Integrated sensor main requirement

Performance	**Value**	**Remarks**
Operation functions	Star tracker, Earth sensor and Sun sensors	Always in combination with overall FOV view availability
FOV total	360°x145°	
FOV lens nadir for Star tracker	20°x20°	Magnification factor 3
Pupil	2 mm	
Detector matrix	2Kx2K	
Star track accuracy	50 arcsec (max target, 150 arsec min)	Star > 4/FOV 20°/number of star: TBD
Earth +SUN sensors	0, 1°	For tre axis pointing
Rate meas.	4/5 Hz	
Weight	350 gr	
Power consumption	2 W (target)	Depending on operative mode and measurement rate
Dimensions	10x10x8 cm	
Radiation hardness	10 KRad	Low end but for Up to 100 Krad for Deep Space

Table 1: POLIFEMO product characteristics.

In the following table the potential expected accessible market is summarized per segments.

Market sector	**Units**					**remarks**
	Y1	Y2	Y3	Y4	Y5	
Spacecraft	10	40	60	100	100	
UAV	10	30	60	100	100	
Space Rovers and deep space missions		1	2	4	4	
Ground systems	50	100	100	100	200	

Table 2: POLIFEMO potential market.

3. Technological feasibility of the POLIFEMO

As said POLIFEMO is a multifunctional space sensor that integrates different capabilities (e.g., star tracker, sun sensor, and earth sensor for attitude control, awareness features for anti-collision or anti-debris), with the aim to provide a compact, low cost, autonomous equipment that can support any kind of spacecraft orbits and simplifying spacecraft design, integration and testing while introducing new capabilities. Its integration in small satellites could reduce design cost and provide attitude control and space awareness functionalities using a single multifunctional sensor with lower mass and size and better flexibility and versatility.

In Figure 4 the block diagram of a classic ADCS system is compared with POLIFEMO block diagrams, and its capabilities are sketched. The same figure describes the sensor basic block diagram in the most complex configuration (bifocal with star tracker embedded).

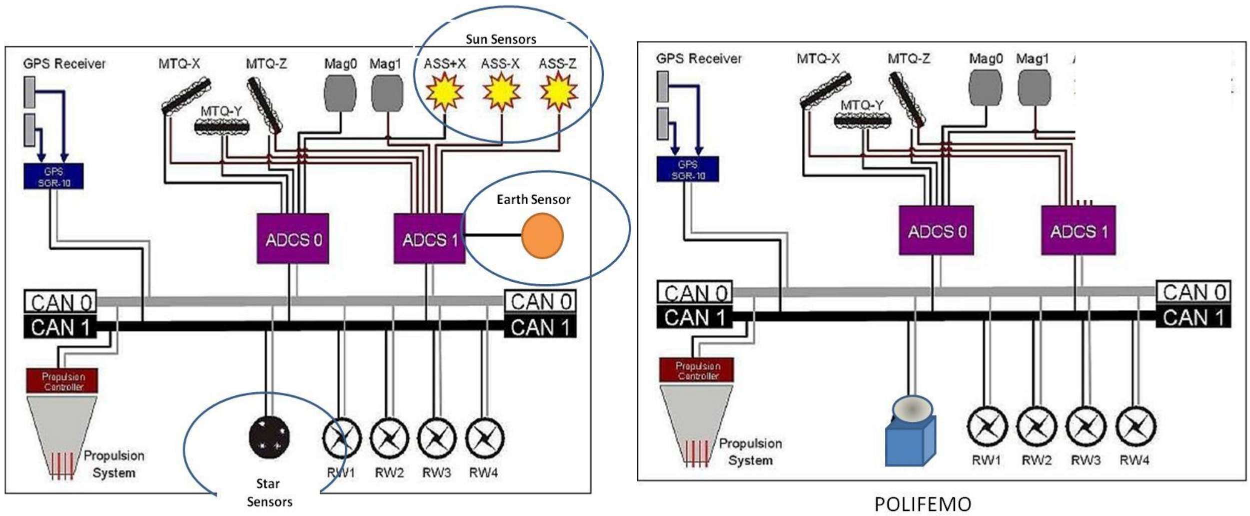

Figure 4: ADCS and POLIFEMO block diagram.

The POLIFEMO sensor is compact and low resource consuming: the basic version with embedded processing may be outlined with a weight of 350 g unit, a power consumption of about 3 Watt depending on the operative mode and measurement rate updating, and accommodation requirement of about 10x10x8 cm.

The equipment can be easily reproduced because, basically, it consists of a lens and a CCD (or others) sensor matrix, which is easily available on the market. The data processing can be locally integrated by adding a dedicated processor (Field-Programmable Gate Array, FPGA or Application-Specific Integrated Circuit) or can be remotely running with the same firmware function on the On-Board Computer (OBC).

The core of the equipment is an innovative optical head with a "hyper-hemispheric" FoV, i. e. 360° in azimuth and up to 270° (105° basic configuration) in elevation. To achieve the sensor, the optical head is then integrated with other components such as a relevant detector matrix, proximity electronic and a miniaturized processing device for signal and data processing.

The POLIFEMO sensor can be arranged in different configurations depending on the mission requirement. In Figure 5two possible improved solutions are shown. On the left the field of view is additionally extended by a second lens on the top, while on the right it is added an optical truss to embed a high-resolution star tracker that will use the same detector matrix of the panoramic camera. In a classic panoramic lens, the image of the Field of View (FoV) has a "donut-shape" format.

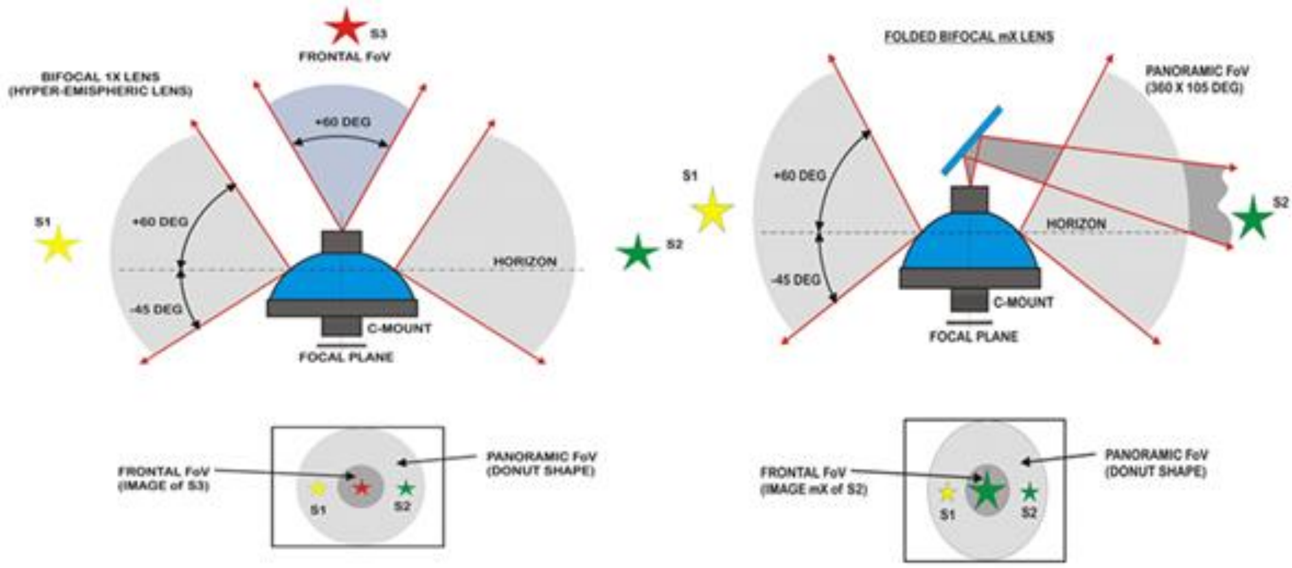

Figure 5: POLIFEMO configurations.

It is worthwhile to remark that the central part of the "donut" can be designed to meet different applications and requirement. In fact, it’s possible to implement a lens with a 20° x20° FOV typical of a star track with a magnification factor of 3 or a 60°x60° lens with a magnification factor of 1. Clearly the POLIFEMO lens provides much better performance compared to a fisheye and reduced complexity respect to four cameras configuration systems.

In

Figure ***6*** the POLIFEMO operative modes are depicted. A few modes can operate at the same time. The operations also include sensor auto check and calibration. While the first fix/safe mode is devoted to the acquisition of sun pointing when tracking is lost, or spacecraft goes in safe mode.

In Figure 7 the block diagram and sketch of the POLIFEMO are presented to outline its main components.

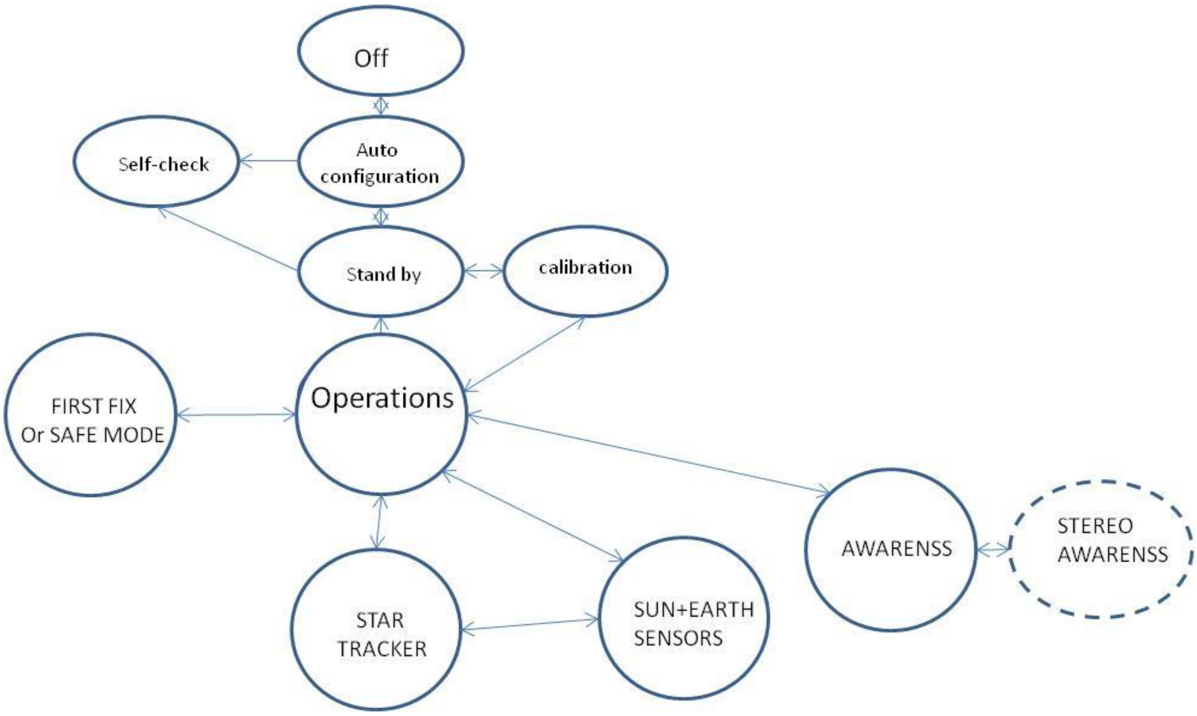

Figure 6: POLIFEMO operative modes.

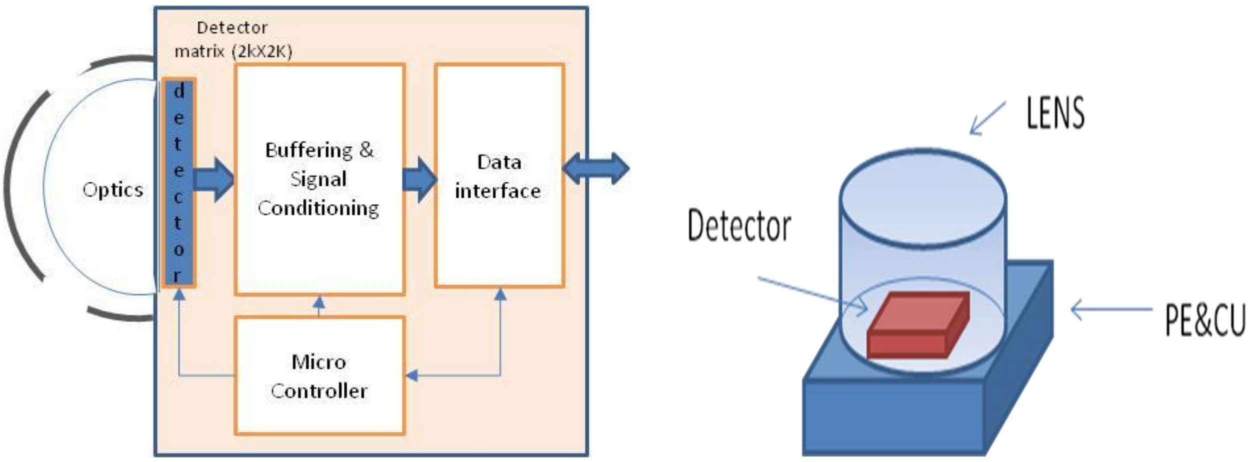

Figure 7: POLIFEMO Sensor block diagram.

The POLIFEMO design will take into consideration the following aspects:

- Improved and more efficient Algorithms:

Both to improve star tracker performance even with the specific lens used and to reduce processing complexity and power consumption.

- Reduced star tracker catalog

To reduce processing time and memory occupation.

- <u>Reduced fix acquisition time</u>

The panoramic vision of the sensor should allow fast acquisition of tracking at least with the sun sensor mode: In addition, the capability of acquiring the stars over the panoramic FOV could allow to solve the lost in space condition.

- <u>Flexible update rate</u>

POLIFEMO because of its multifunctional capability may reduce the need of high data rate redings by star tracker mode keeping pointing by other modes. This should reduce power consumption.

- <u>Tracking mode</u>

POLIFEMO can implement a tracking mode keeping pointing of same celestial bodies.

It can measure the tilting of a spacecraft complementing or replacing the gyros.

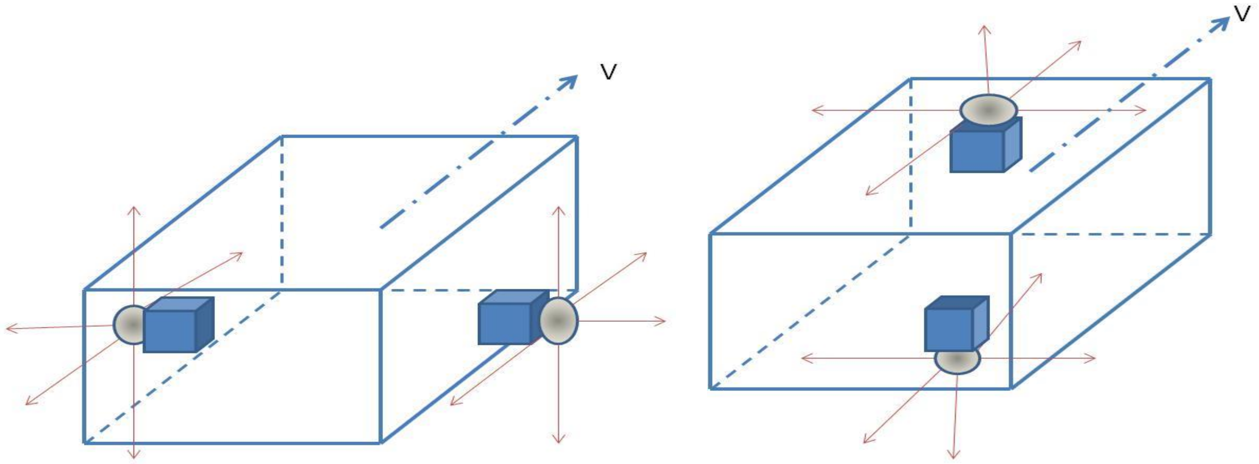

Figure 8: POLIFEMO accommodations on a satellite as function of the application.

In the Figure 8 a couple of possible installation of POLIFEMO sensor on a spacecraft are depicted. The configuration on the left is better suitable for attitude control while the right one can manage satellite formation control even with a stereo computation.

The main components of POLIFEMO consisting in hardware and software elements summarized in Figure 9 are here below described.

<u>3.1. The Lens</u>

The innovative "hyper-hemisferic (HH)" panoramic lens (owned and international patented (i.e, EU, US, Russia and China) by PANVISION s.r.l), is a very wide angle lens, compact (e.g., approximately dimension are 60x60x40mm and 80g in weight), robust, autonomous and low cost.

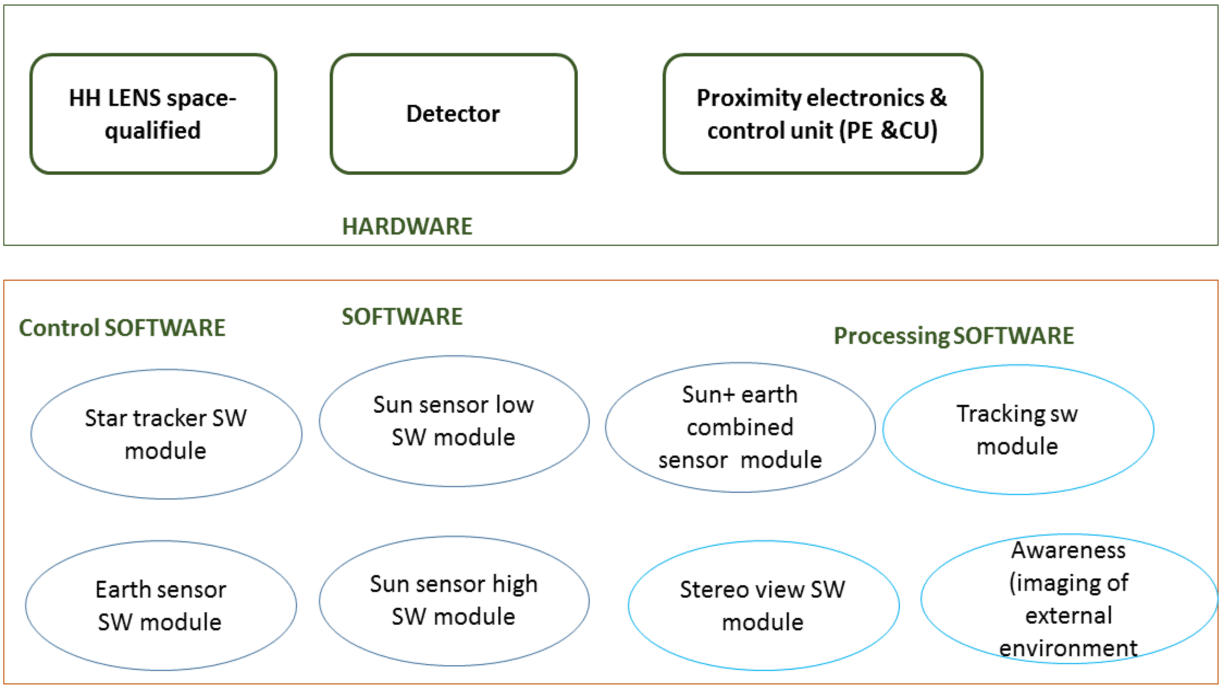

Figure 9: POLIFEMO components.

Figure 10: HH lens picture (top left) and image recording.

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This lens (HH lens) is able to image a Field of View (FoV) of 360° in azimuth angle and up to 270° in elevation (0° < Z < 135°, see figure 1, left panel), the zenith angle Z going from 0° (zenith) up to 135°. The entire FoV is imaged by the lens on its focal plane in a way indicate in the right panel of the

Figure ***11***.

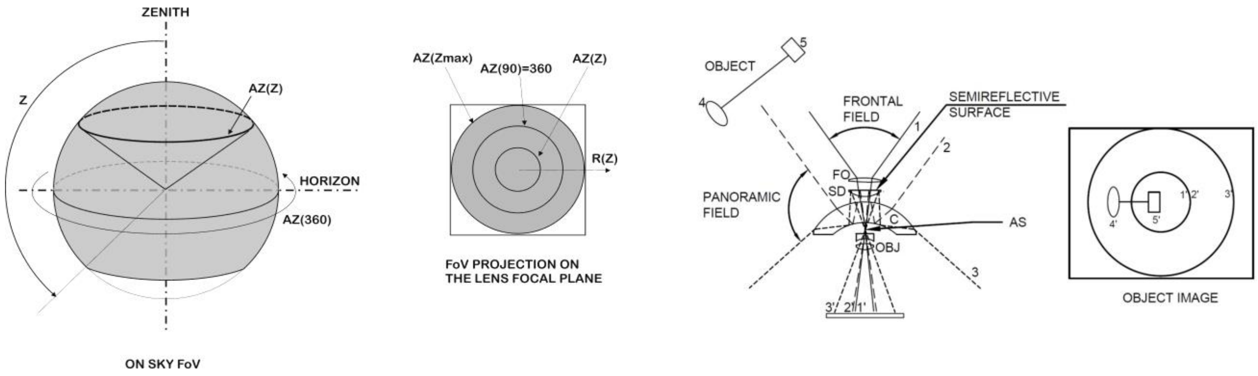

Figure 11: Field of view of the HH lens (left) and how the HH lens works (right)

The lens is composed by three logical segments: a fore-optics (the optics preceding the aperture stop AS), a lens for the frontal field (FO) and an objective lens following the aperture stop (OBJ) able to image the field on the focal plane. The fore-optics is composed by a catadiopter C with a reflective concave surface and a lens to speed-down the light beam (SD) making it slow enough when entering the OBJ through the stop AS. The panoramic field is comprised between the chief rays 2 and 3; they enter the catadiopter, refract on the first surface, reflect from the concave one and enter the SD optics. One surface of the SD is made semi-reflective and then half of the light re-enters back to the catadiopter and then it passes across the AS entering the OBJ block to be imaged on the focal plane. The frontal field is a cone with the axis pointing toward the zenith and extending down to the chief ray 1. The frontal field enters the FO, then passes through SD (also in this case only half of the light passes through SD, while the other half is lost back), C, AS, OBJ and is finally imaged on the focal plane, just on the donut hole. In the right panel the primed numbers show the imaged chief rays (1, 2, 3) and the objects reference points 4 and 5.

A picture of the currently realized lens is shown in figure 9 (top left panel). The dimension of the catadiopter is 60 mm in diameter and the lens has a standard C-Mount. The barrel containing the FO is visible on the top of the catadiopter. In the top right panel of the figure 9 a raw hyper hemispheric image is shown. In the bottom panel a dewarped image (solely for the panoramic field) is shown.

3.2 Image Detector

The detector is a CMOS or CCD matrix of 2Kx2K with a pixel size of 7,5 micron (5 micro ideal). Operating in the visible from 0,48 to 1 micron. This device should be a good compromise of several important parameters as spatial resolution, read out rate, dynamic range and the split-frame transfer architecture that allows a kind of shutter function as well. The detector will be selected among already existing devices but to be modified and specifically tested to make device space-capable.

It will be developed a special, adapted image sensor package that fits to the hyper-hemispheric and bifocal panoramic lenses and the aerial/space-environments.

3.3 Proximity electronics and control unit (PE&CU)

PE&CU (Figure 12) will be based on a FPGA with the suitable interfaces to the Detector to gather CCD o CMOS signals and with OBC to exchange data and telemetries.

The PE&CU functions are:

- Interface with detector matrix
- Signal ADC and conditioning
- Data extraction and compression
- Data elaboration for ES and SS or ST
- Interface with AOCS or OBC computers for commands and telemetries (Can bus or RS 422)
- Sensor control and status monitoring
- Functional modes implementations
- Store the onboard star catalog
- Self check

The unit dimension will be contained in 10x10x4 cm.

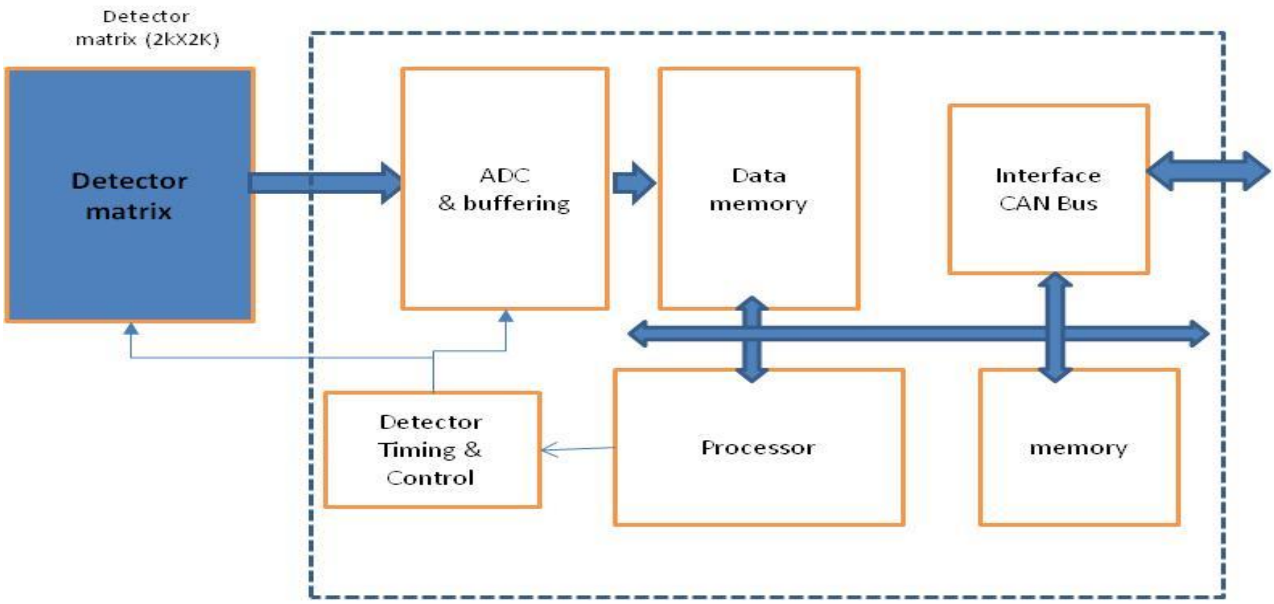

Figure 12 : PE&CU functional block diagram

3.4 Software

POLIFEMO SW is composed of two elements: the control SW and the Processing SW.

Sensor Control SW

The sensor control SW will operate:

- Interface with main computer
- Implement commands into operative modes

Application Processing SW

- Process data according to operative modes inside the PE&CU
- Process data in a service computer (OBC or other)

All the POLIFEMO components are for the time being considered feasible and no major criticalities are envisaged. However, the matching of detector characteristics with the lens design requests a careful attention, taking into account star tracker needs and it will be performed since the beginning of phase 2.

4. Strategy for commercialization

The effectiveness of POLIFEMO is clearly found in lower mass and size and integration cost into satellite compared to a legacy AOCS sensor suite. The product versatility and flexibility allows easy implementation of multifunctional applications and the utilization in other fields such aeronautic ones.
Its feasibility and marketing opportunities has *been demonstrated and therefore we assess the POLIFEMO value in the aerospace application scenario basing on its unique capabilities.*

THE SWOT analysis presented in table show how the product characteristics can match the opportunities while weakness and threats can be dealt with assuring product competitiveness in terms of cost and performance

STRENGHTS	OPPORTUNITIES
1. Versatility 2. Multi functionality 3. Reduced complexity for users 4. New applications (debris, formation, control, ect) 5. Multi applications (space , UAV, rover,ect) 6. Cost impact per satellite 7. Potential for growth (application, performance)	1. Small satellites AOCS sensor, formation control 2. Large satellite AOCS complementary sensor, situation awareness, collision alarm. 3. UAV anti-collision system 4. Rover situation awareness 5.No competitors on similar product
WEAKNESS	**THREATS**
1. Reduce performance in case of high pointing accuracy requirement requested 2. Sensor accommodation on satellite 3. No graceful degradation allowed from legacy sensor suite (however redundancy possible)	1. Market tradition and reliance in legacy sensors 2. Detector cost

Table 3: SWOT analysis

4.1 Pricing

Sensor Pricing will be tailored on the specific field of application and requested characteristics still looking to the market competition.

Of course, price is also particularly subject to the volumes of sales.

The initial price estimation is here below reported while in phase II more precise values will be defined also function of volumes.

- Space High quality product: 200k€, deep space applications, large satellites
- Space Medium quality product: 55k€ medium/small satellites
- Avionic version: 15k€

4.2 Channels of Distribution

POLIFEMO is a special product for specific aerospace applications and unless it will not be produced in tens of units the only distributor will remain PSI at least in Europe.

Two others entry/ distribution points are however considered:

- Brazil or Argentina to enter in Latin-America Market
- China for orient market.
-

4.3 Promotion

The Space community is quite small and the development of new technology and equipment is rapidly disseminated all along the world.

Especially, when as in POLIFEMO case it creates a breakthrough with respect the current status.

During this study have been contacted different satellite manufacturers:

In synthesis the overall business strategy will be based on a few simple steps:

- Qualify the product in-flight outlining the performance
- Identify a starting partner developing satellites and establish long term partnership
- Exploit all the product capabilities and performance possibly in flight
- Assess the market in order to dimension the product development chains
- Acquire European market share
- Expand product market to world customers

5. Economic statements

Considering the market perspective the POLIFEMO price and cost has been assessed allowing the preparation of the following economic tables.

Revenues	YEARS								
	2016	2017	2018	2019	2020	2021	2022	2023	Tot:
space sensor	0	0	0	550	2.200	3.300	5.500	5.500	17.050
UAV sensors	0	0	0	150	450	900	1.500	1.500	4.500
Rovers/deep space	0	0	0	0	200	400	800	800	2.200
Ground applicationz	0	0	0	300	600	600	600	1.200	3.300
Total revenues(€)=	0	0	0	1.000	3.450	5.200	8.400	9.000	27.050

	YEAR									
	2016	2017	2018	2019	2020	2021	2022	2023		
Investements										
system development	100	300	300	150					total=	850
application development	50	100	100	100					total=	350
marketing	10	30	50	50	50	30	30	30	total=	280
comercialization	30	30	30	30	30	30	30	30	total=	240
Total	190	460	480	330	80	60	60	60	total=	1.720
Revenues	0	0	0	1.000	3.450	5.200	8.400	9.000	total=	27.050
Product cost	0	0	0	800	2.750	4.200	6.600	7.100	total=	21.450
Yearly Cash Flow	-190	-460	-480	-130	620	940	1.740	1.840	total=	3.880
Cumulative Cash	-190	-650	-1.130	-1.260	-640	300	2.040	3.880		

Internal Rate of Return =	37%	
inflation rate=	0,03	per year
VAT(€)=	3.767	
ROI=	219	%

Tables 4: Economic forecast

Even if the prevision appears optimistic the expected huge expansion of the markets where POLIFEMO is aiming leaves a reasonably good opportunity to make a good business.

6. Definition of the development plan and business plan

6.1 Design and development plan

The preliminary D&DP has been outlined and the overall development team defined.

In addition to PSI the following partners shall contribute to POLIFEMO development:

- LOBRE srl , Lens manufacturer including PAN VISION the panoramic lens patent owner, whose scientists will provide the lens optical design. In the LOBRE team will be also involved the CISAS and INAF Reseach Centers
- UNINA Federico II whose heritage in low-cost space sensor design will be fundamental for developing the sensor algorithms.
- European SME's: a few small European companies (ANDANTA, etc) will provide complementary design and HW manufacturing.

In the next figure the POLIFEMO WBS for the development phase is depicted. All the tasks have been already assigned to a Company and quantified in economic terms.

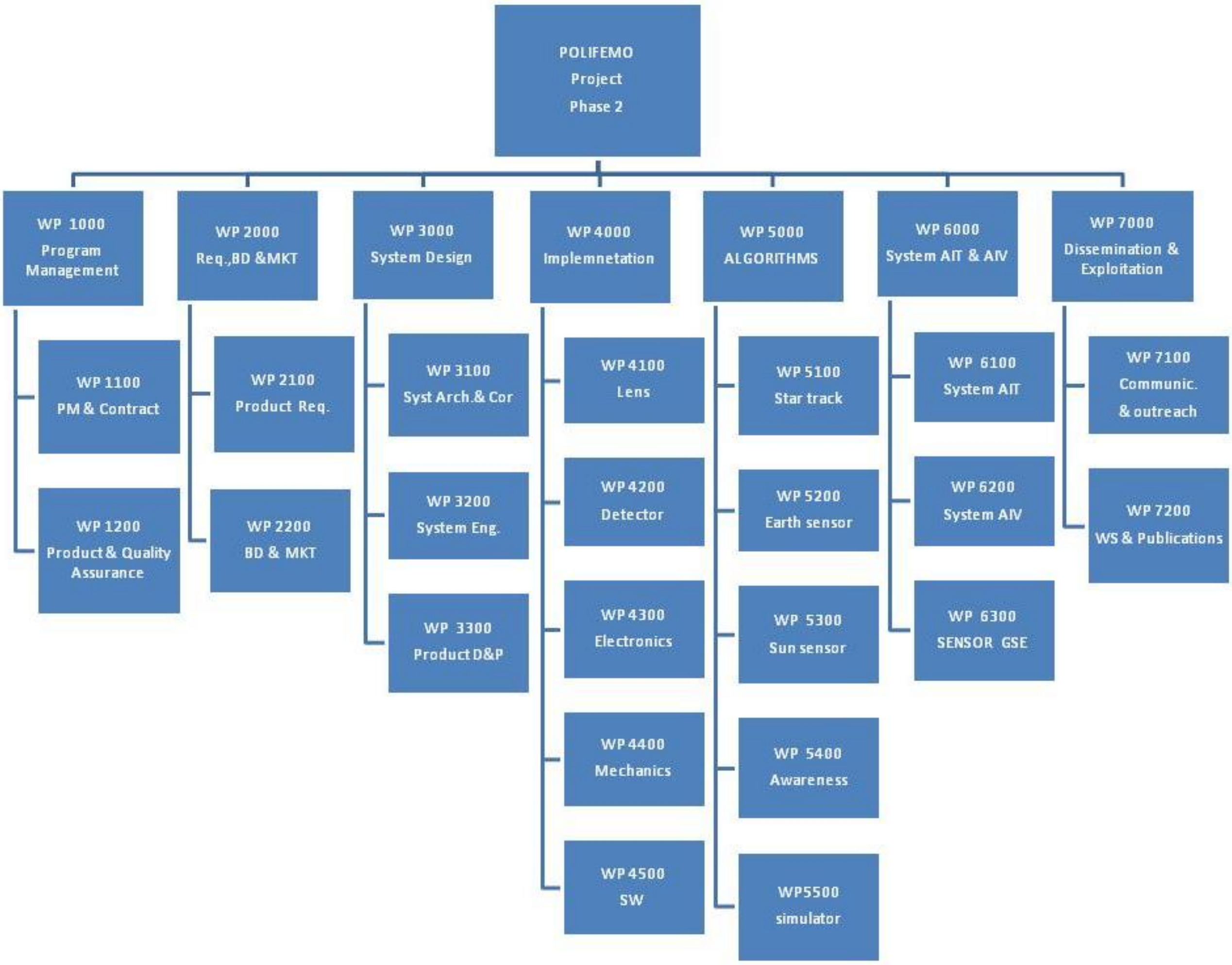

Figure 13: POLIFEMO WBS for phase 2 development

Basically, it is possible to distinguish three development phases:

1. Feasibility study: this one lasting 6 m.
2. Time to SME innovation phase 2 contract acquisition (or alternative funding solutions)
3. Prototype development: phase 2 of H2020 SME instrument project lasting 2 y

Plus, an additional Industrialization phase: charged to PSI and its strategic partnership, lasting 6 months.

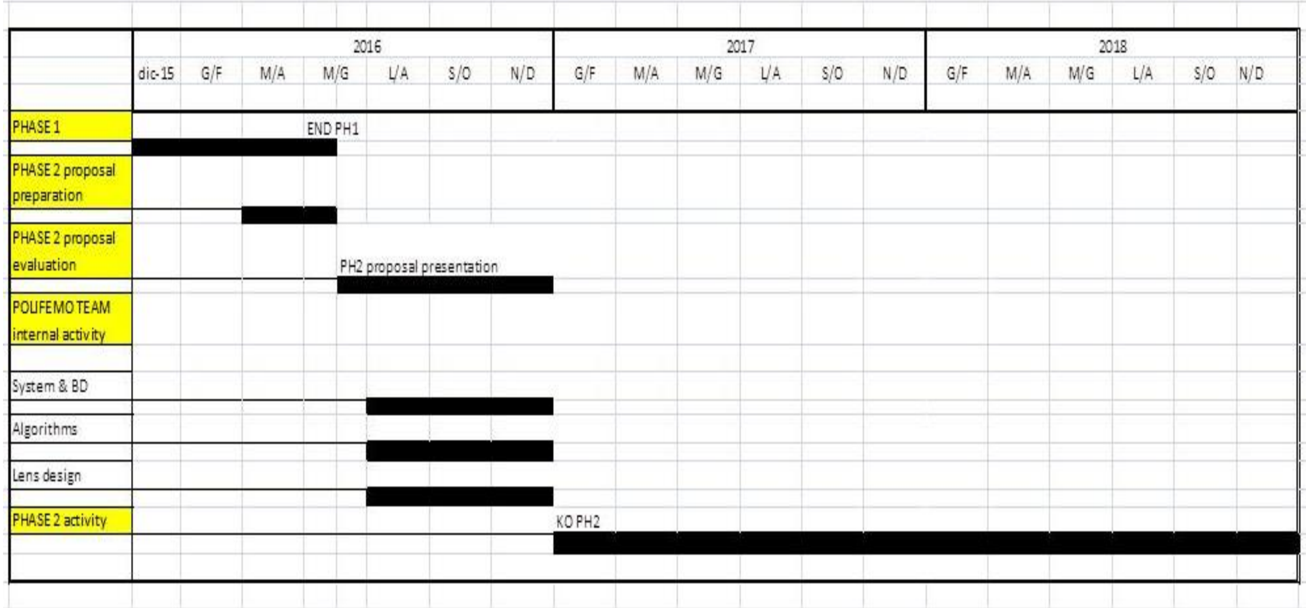

Table 5: Overall POLIFEMO Development plan

Table 6: Phase 2 POLIFEMO plan

Furthermore, the development team has been set up identifying the key personnel, facility and actors.

The system will be developed according to ECSS standards and verified on ground by dedicated test equipment and simulator and in flight by an in-flight demonstration opportunity.

6.1 Business plan

A completed and detailed BP (Doc: ECSME-PSI-POLIFEMO-BP-2016) has been prepared for this project within this contract framework , it is available for reading. From it we have derived the data included in this report.

As result in figure the expected cash flow behavior is plotted. The breakeven point is reached beginning of 2020 while ROI is positive one year later.

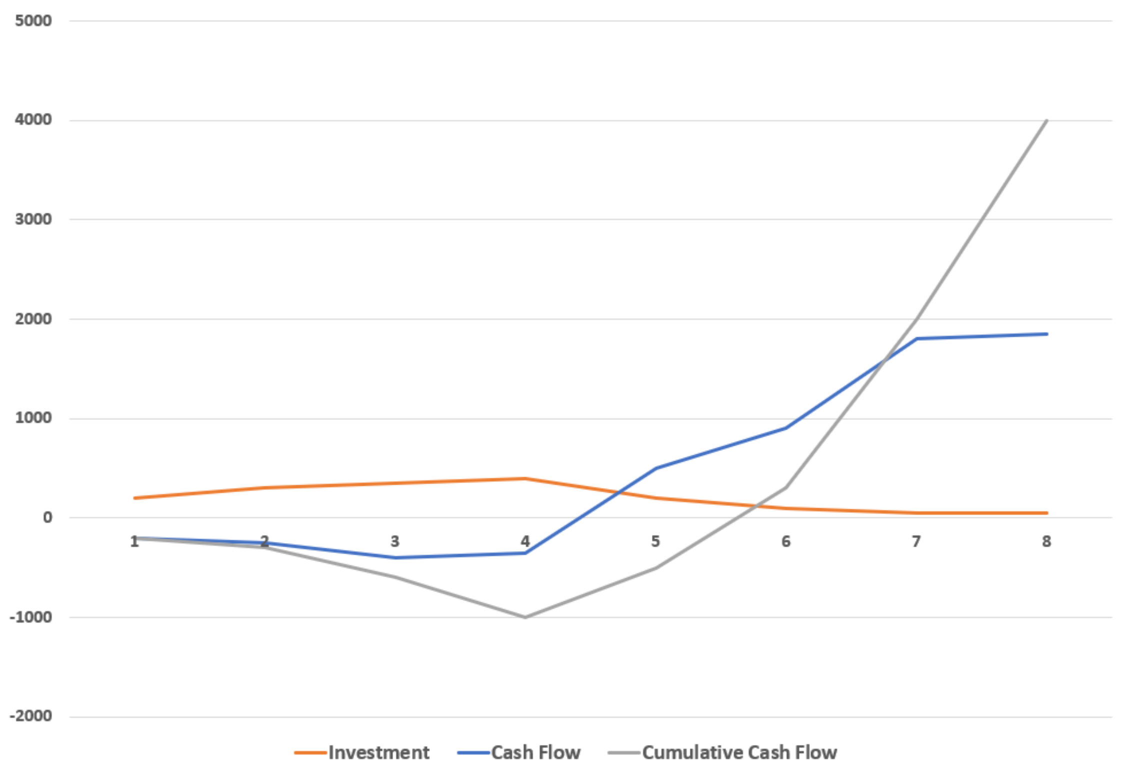

Figure 14: Business plan (flow vs. years).

7. Conclusion of the action

The Business plan for a new optical sensor for the increasing mini and micro-satellites market has been developed. The optical sensor is based on a hyper-hemispheric lens designed, realized (TRL4) and patented by INAF. The feasibility study has been performed by the University of Napoli (expert in star tracker algorithms development), while the industrial development has been studied by Progetti Spaziali Itailiani srl company (Rome). The final plan show as such sensor may take place profitably within the satellite's optical sensor market.