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ESEIAAT

CleanOrbit: Laser-based Space Debris Deorbiter

(CO-LSDD)

Deliverable 1
Project Charter

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1 Project Charter

This document presents the project proposal, based on a laser-based space debris deorbiter. The following sections describe the idea, requirements, risks, objectives, estimated budget and distribution of roles in the team in charge of the project.

1.1 Project Purpose and Justification

In this section, a general vision of the project is presented, along with the objectives and scope of the work.

1.1.1 Vision

Since the early days of space exploration, the aim and attention have been set in getting equipment out in space without actually considering what happens when it isn't useful anymore. That is why most satellites and systems have been forgotten once they have reached the end of their service life.

According to ESA, in recent years there has been a noticeable increase in the number and size of launches performed. This fact combined with some in-space collisions and other events, has led to an enlargement of the amount of debris humankind has left on orbit. If this trend continues, the safe operation in space will become increasingly harder, making space exploration unsustainable.

While missions in higher orbits are usually successfully disposed of, more than half of the operators with equipment in Low Earth Orbits (LEO) take no action in that direction. Although the tendency is to increase, it is not fast enough and therefore some action must be taken to address that.

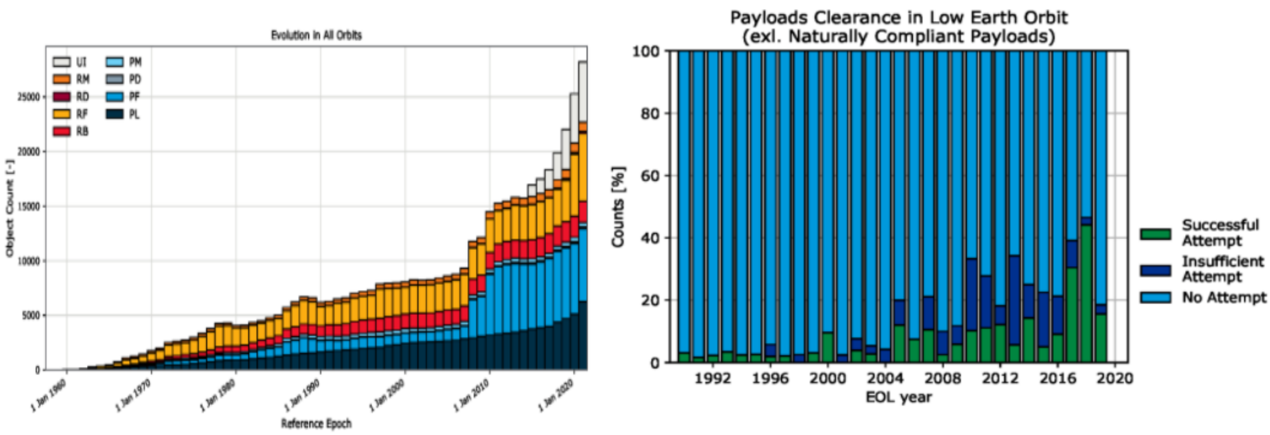

Figure 1: Number of launches along the years (left), deorbiting attempts with time (right) [1]

Although ESA has been promoting actions to clean the space environment, most of them have stayed in a test phase, without promoting their comercial distribution. An example of that is the laser operated by ESA at the Teide Observatory, which is used for detecting, tracking and observing satellites.

Whereas most of the actions taken to date are in terms of avoiding the existing objects in space, this proposal is intended to bring forward a technology that, once developed, will provide an easy and fast solution to eliminate space debris in Low Earth Orbits. The main concept is a a ground-based laser system to deorbit all sorts of debris.

The main outcome is to contribute to the protection of the in-space future ecosystem by fostering the EU's space sector competitiveness with a system that all the space users will demand so they can be able to operate in the near future when we reach an excessive level of debris.

1.1.2 Objectives

The key objectives for this project are the following:

- Creation of a passive and active system that monitors anticipates the potential danger towards orbiting satellites and acts accordingly using laser technology.
- Design of a high-powered ground-based plasma laser technology as a means of acting on targets with the aim of deorbiting them or reducing the risk of impact on other objects of interest.
- Develop this project efficiently in order to became a potential European resource in the competitive market of the aerospace sector.
- Built and construct the laser system with the latest technology while guaranteeing the least environment impact.
- Implementation of a prototype and testing protocol as a means of guarantee the security and the efficiency of the laser system and its software.
- Definition of documentation and maintenance information to ensure the correct behavior of the system.
- Design a service model for European users and different operators (as well as public entities) capable to protect the physical integrity of the current satellites in orbit using the laser technology designed through this project.
- An extensive study of the feasibility and its relation with ESA regulations and other legal concerns regarding environmental parameters and airspace coordination.
- Create a marketing plan strategy to bring visibility to this project and promote its vision toward possible investors from companies out of the consortium.

1.1.3 Scope

In order to accomplish all the objectives declared in the previous section, the following processes and analysis will be included:

Background

- An extensive study and preliminary design of the laser system based on Laser Orbital Debris Removal (LODR) technology, and its characteristics.
- A feasibility study that justifies the existence of a laser system of this characteristics at a competitive price.
- A brief study of the ESA regulations in order to broaden the market possibilities of this new concept of technology.

Project Management

- Project planning in order to establish a schedule, dividing Work Packages (WP) and defining Deliverables.
- Definition of Risk Assessment and Risk Mitigation with the aim of containing potential deviations or setback.
- Periodic reports to stakeholders and weekly meetings with CleanOrbit staff.

Technical Solution

- A justification on the general configuration selection aiming on being optimal in different laser types adapting to various densities and materials of space debris.
- The laser system designed in this project will be ground-based with a maximum re-targeting time of 1 minute in order to be fast-response.
- An analysis of the software required for tracking and its development by an specialized entity described in forward sections in order to automatize and monitoring the laser system and tracking the targets.
- The LODR system will be capable of removing objects up to 1000 kg at a maximum of 900 km of apogee (LEO orbit).
- The optical system shall use mirrors which with be able to target large and small debris.
- A prototype will be built in order to test and analyse the output data to ensure the correct behavior of the system.
- Implementation of technical documentation and maintenance protocol after testing the prototype.

Marketing

- A market study that analyses competitive status of this technology and growth trend taking into account similar solutions in other countries.
- Marketing strategies shall be considered in order to promote and commercialize the LODR system before the prototype implementation.
- Marking plan shall be developed in order to promote and gain visibility of potential investors.

Legal concerns

- An environmental and legal study that ensures that this project meets the standards imposed by ESA and does not become in conflict with European airspace.
- A legal study concerning data protection and competencies regarding tracking of satellites.

The following aspects are considered to be out of the scope of this project:

- Second-phase data collecting and analysis of satellites ecosystem and their behaviour tendencies.
- The maintenance work on the laser system to ensure its correct behavior is out of the scope of this project and belongs to a second phase of a long-term work.
- Space debris allocated in High and Medium orbits are out of scope of this project.
- Super-large objects (more than 1000 kg) elimination is not taken into account trough this project in order to focus in smaller debris, which are the ones that presents a potential danger for orbiting satellites.
- Space-based laser system is discarded.
- Possible remain rests collection and removal that could be achieving the Earth surface are not considered inside this project but a second-phase service implementation.

1.2 Project Description

The aim of this project is to develop a ground-based laser system to deorbit satellites which are no longer in use, as well as other sorts of debris.

In recent years the increase of launches and accidental collisions has led to a noticeable rise in the amount of debris that has been left in outer space, specially at low orbits (LEO). The laser developed in this project will contribute in successfully deorbiting satellites and equipment that is no longer being used, and dispose of it safely.

For that purpose, said laser system will track with precision the object to be deorbited and it will slow it down. Ultimately, it will burn down while reentering the Earth's atmosphere, thus being no longer an issue.

The main target of this kind of technology is going to be equipment up to 1000 kg which is located in lower orbits, in particular within a maximum altitude of 900 km.

During the early stages of the project, the focus will be set on research so as to assess the state of the art and further expand the knowledge in the field. Additionally, an in-depth assessment has to be performed on the impact that operating this kind of laser is going to have in the area where it will be located, so as to avoid any disruptions to the surrounding air operations or the environment.

Later on, the necessary equipment will be developed by the members of the consortium as stated in the following sections, along with the required software, especially for tracking.

Every area within the project is covered by the universities and companies of the consortium. They are experts in the field, with a remarkable background in laser systems, the specific mirrors they require and in satellite observation and tracking.

All in all, the expected outcome of this project is an on-ground laser system which is capable of tracking in-orbit objects with precision, so as to be able to slow them down and dispose of them safely. This will contribute to reduce space debris and promote a cleaner environment, making future operations easier, as the probability of collision will be significantly decreased.

Additionally, a paradigm shift is also expected to be derived from this initiative, as it will set the grounds for a more sustainable space infrastructure, and it will promote the protection of the Earth's orbit.

1.3 High-Level Requirements

The project must fulfil a set of requirements in order to be considered successful. In the matter of the project general requirements, the following aspects must be met:

R-G01: The project shall develop and balance 4 areas of technological interest: acquisition and tracking of the object to deorbit, illumination[1] of the targeted debris, analysis and clearance of the re-entry location and assurance of the laser clearing and tasking approval.

R-G02: The project shall reach a minimum Technology Readiness Level of TRL5 by the end of the project duration.

R-G03: The estimation of the overall duration of the project shall not exceed 4 years.

R-G04: The consortium shall be formed by a minimum of 3 independent partners from three Member States.

R-G05: According to the H2020 requirements, the budget contribution provided by the EU commission shall not exceed 2 million euros.

R-G06: The subcontracted activities shall not exceed 15% of the direct costs.

As regards the technical specifications the project must meet, these are:

R-T01: The debris-deorbiter system shall be based on a Laser Orbital Debris Removal (LODR) technology.

R-T02: The system shall be capable of slowing-down debris targets such that they are burnt up when re-entering the atmosphere.

R-T03: The LODR technology system shall be ground-based.

R-T04: The maximum re-targeting time of the LODR system shall be less than 1 minute in order to enable quick response against debris.

R-T05: The system shall be capable of removing small and large category objects. These are defined according to [2] as:

- Small debris: objects up to 0.75 kg and located at a maximum apogee of 700 km (LEO orbit). Minimum elevation of 30°.
- Large debris: objects up to 1000 kg and located at a maximum apogee of 900 km (LEO orbit). Minimum elevation of 60°.

R-T06: The optical system shall use mirrors according to the following specifications:

- Mirrors up to 13 m of diameter to target small debris.
- Mirrors up to 25 m of diameter to target large debris.

R-T07: The technical solution developed shall be modular and capable of mounting different types of laser according to the characteristics of the debris target to be deorbited.

[1]The process consisting in aiming and shooting with the laser at the debris target.

1.4 Acceptance Criteria

In order to make sure that all the project requirements are fulfilled the following methods will be followed:

RA-G01: As advances are made in each department, a process of verification and review will be performed by the coordinator of each department to ensure it works correctly.

RA-G02: A Technology Readiness Assessment (TRA) will be performed to ensure that the TRL5 level is achieved.

RA-G03: Ensure the fulfilment and the viability of a four year calendar comprising all the different stages the project must fulfil. Every week an organisation meeting will be held in order to verify that all deadlines are respected.

RA-G04: An external audit will be performed in order to verify the independence of the members of the consortium and to identify possible incompatibilities.

RA-G05: The accounting manager will deliver a document specifying the economic contribution from each member of the consortium. The treasury will periodically verify that funding is provided on time.

RA-G06: The treasury will verify that all expenses are tracked accordingly to the established budget and that there is no presence of cost overrun regarding subcontracting activities.

As regards the technical specifications these will be checked by:

RA-T01: The viability of the usage of Laser Orbital Debris Removal (LODR) technology will be assessed in the Preliminary Design Review (PDR) document.

RA-T02: The operating principle of the deorbiter system will be studied in the Preliminary Design Review (PDR) document.

RA-T03: The LODR technology system will be installed in a ground base located in the Canary Islands as specified in the PDR document.

RA-T04: The capability of re-targeting debris in less than 1 minute will be verified in the First Prototype Building and Operational Test & Evaluation (OT&E) document.

RA-T05: The system will be tested to see if it is capable of removing objects from 0.75 kg to 1000 kg located at a maximum apogee between 700 km and 900 km (LEO orbit) with a minimum elevation between 30° and 60°. The results will be presented in the First Prototype Building and Operational Test & Evaluation (OT&E) document.

RA-T06: The specific sizing and technical details of the mirrors will be determined in the Critical Design Review (CDR).

RA-T07: The modular architecture of the the system will be proposed in the PDR and assessed in the CDR.

1.5 High-Level Risks

In order to define the high level risks of the project, five different areas will be analyzed: Technical, Business, Management, Impact and Quality.

1.5.1 Technical risks

Risk	Description of the Risk	Level of risk
Optical system / laser failure	Physical problems such as the aberration or nonalignment of the components may lead to several problems in the efficiency of the deorbiting system	High
Dependence on predictive models and statistics	As the speed of light is finite, it is not possible to aim the laser beam to the actual coordinates of the object. Thus is required to predict the position and trajectory, if this prediction is not good enough, the laser beam will not find the orbital element	Medium
Atmospheric transmittance dependence	In average the atmosphere transmits 85% of the laser energy. But there are a lot of events (storms, clouds, wind, solar activity) that can modify this factor and thus the efficiency of the system	Low

Table 1: Technical risks with their description and level of risk

1.5.2 Business risks

Risk	Description of the Risk	Level of risk
Business / Technological competitors	There are other business interested in developing the same technology such as NASA and the Japanese Space Agency that may want to lead the sector	High
Construction and operations budget	As the construction and operation of the system is not yet performed, there may be upcoming increases in the budget stated due to some difficulties faced in future stages of the project	Medium

Table 2: Business risks with their description and level of risk

1.5.3 Management risks

Risk	Description of the Risk	Level of risk
Partnerships delays	As there are different business that will be developing some technologies or services for the project, if any of them has an important delay in their duties, the overall project will be delayed	High
Continuous communication	This project has several areas that may need to be communicating each other due to the tasks that are developing may need of results of other tasks	Medium

Table 3: Management risks with their description and level of risk

1.5.4 Impact risks

Risk	Description of the Risk	Level of risk
Technological impact	As the technology is being developed faster each year, there could be a technological gap with future technologies that may be more efficient that the selected one	Medium
Deorbiting impact	It is very important that the system have a long life of utility as the deorbiting process with this technology is slow compared to other technologies being used nowadays. Thus the impact of utility of this project needs to be fulfilled in a long time-scale	Low

Table 4: Impact risks with their description and level of risk

1.5.5 Quality risks

Risk	Description of the Risk	Level of risk
Quality of deliverables	As the project requires different groups working in parallel and it will be presented in an Horizon 2020 call, all the documents must be accurate and formal	High
Quality of deorbiting system	All the systems developed in order to be combined must have a minimum quality ensured in order to develop its purpose in the most effective way. As the purpose is to deorbit space elements, the accuracy of the optical systems and the laser beam must be excellent, thus the quality in the manufacturing process needs to be ensured	High
Environmental quality	The environmental quality must be ensured in order to keep the ecosystem unaltered and to ensure that the production process is taking into account the environmental free damage policy	High

Table 5: Quality risks with their description and level of risk

1.6 Project deliverables

In this section the documents to be delivered at the completion of the project are listed in Table 6. It should be noted that the estimated due date of the deliverables is defined with respect to each year. In this way, T0 refers to the day in which the first kick-off took place and T1 to one year after T0. For instance, the Project charter will be delivered three weeks after the kick-off meeting, i.e., T0+2w, and the Software Design Report of the tracking system, one year and 10 months after the kick off meeting (T1+10m).

Code	**Deliverable name**	**Description**	**Estimated due date**
PC	Project Charter	Document with the description of the core aspects of the project, such as the purpose, objectives, stakeholders, requirements, risks and internal organization, among others.	T0+2m
PSS	Project Scope Statement	Document that will detail the scope of the service and the project, the main deliverables and the assumptions, accepted criteria and constraints to take into account before starting to develop the project.	T0+4m
WBS	Work Breakdown Structure	Hierarchical diagram in which the main activities will be itemised in sub-activities, work packages (WPs) and tasks.	T0+4m
RBS	Resources Breakdown Structure	Hierarchical diagram of identified resources to plan the development of the project. It will mainly include: human resources, tools, equipment, materials, licenses and facilities.	T0+4m
OBS	Organisational Breakdown Structure	Hierarchical diagram that will define the internal organisation of the consortium in terms of roles and the relationship with the external companies (subcontracted activities).	T0+4m
GD	Gantt Diagram	Detailed schedule with the duration of the tasks and their sequence, which defines the relationship between them.	T0+4m
B	Budget	Document focused on the estimation of the costs and the funding requirements and a forecast analysis.	T0+4m
RMP	Risks Management Plan	Document focused on (a) the identification of individual and overall risks related to different dimensions of the project (e.g., technical, business, management); (b) the qualitative and quantitative analysis (probability and impact) of the previous risks; (c) the response, in each case, in terms of type, resources, costs, timing and responsibility.	T0+5m
QMP	Quality Management Plan	Analysis of the main aspects in terms of quality, such as the necessary tools to carry out an effective control of the service, the costs associated or the possibles improvements of the process.	T0+5m
H2020	Standard Application Form (2020 Horizons Call)	Document to apply to the 2020 Horizons Europe Program. The main aspects that will be detailed are divided in two parts: the application form itself and the technical description of the project.	T0+6m

LD	Legal Documentation	In-depth study of the legal aspects associated to (a) the tracking of space debris; (b) the affectations and limitations of using a laser in terms of its effect in the airspace; and (c) possible certifications and licenses required.	T0+9m
ES	Environmental study	Analysis of the environmental impact that the production and usage of the system designed could imply and proposal of alternatives if necessary.	T0+9m
MR	Market Research	In-depth analysis of the market in which the service will operate, focusing specially on the offer and demand and its evolution. In addition to this, a forecast of the future situation of the industry will also be provided along some conclusions that could be drawn from the study.	T0+11m
TechR	Technological Research	Document elaborated by the universities of the consortium describing the in-depth research carried out of the technology necessary to develop the project and offer the service. It will be focused specially on lasers, mirrors, de-orbit techniques, tracking and space debris, taking into account the current state of the art. This report will be essential to design the components and integrate the system.	T1+3m
SDR-T	Software Design Report: Tracking	Document in which the design and creation of the software necessary to monitor space debris is described in detail.	T1+10m
SDR-LODR	Software Design Report: LODR system	Document in which the design and creation of the software necessary to operate the LODR system space debris is described in detail.	T1+10m
DPR-L	Design and production report: Lasers	Report with in-depth explanations of the design of the laser/s that will be part of the LODR (e.g.,properties, materials, geometry, physical principles), as well as of the production procedure (e.g., techniques, equipment).	T2
DPR-M	Design and production report: Mirrors	Report with in-depth explanations of the design of the mirror/s that will be part of the LODR (e.g.,properties, materials, geometry, physical principles), as well as of the production procedure (e.g., techniques, equipment).	T2
PR-E	Partnership Report: Electronics	Document in which the electronic aspects of the LODR system will be discussed. As the production and supply of these type of elements will be procured, the report will include, among others, the necessary products by the consortium to create the system and their requirements; the relationship between the consortium and the company (e.g., type of contract); and the departments of the consortium involved.	T2+2m

PR-I	Partnership Report: Integration	Document focused on how the integration of the different elements that are part of the LODR system will be managed. As the assembly of the elements and subsequent supply of the system will be carried out by an external company, the report will include, among others, the elements and components to be assembled; the requirements that have to be fulfilled in terms of the integration; the relationship between the consortium and the company; and the departments of the consortium involved.	T2+4m
PR-L	Partnership Report: Logistics	Document focused on explaining the aspects related to the logistic of the project, such as the terms in which the supplying of components or systems will be carried out. In this way, it will include, among others, the requirements of the services that the consortium needs to be fulfilled; the relationship between the consortium and the company (e.g., type of contract); and the departments of the consortium involved.	T2+5m
MKP1	Marketing Plan 1	Document focused on planning the marketing actions that will be carried out to advertise the service once the project is finished but also slightly before its completion.	T2+6m
PTR	Prototype Report	Document in which the main aspects involving the creation of a prototype of the LODR system will be stated.	T2+7m
TCR	Test Results and Conclusions Report	Document with the results of the tests conducted with the prototype and the conclusions that can be drawn from them. This report will dictate if the system and/or the components designed have to be modified because they do not meet the established requirements.	T3+1m
MKP2	Marketing Plan 2	Report focused on the long term to increase the visibility of the service in the market and gain more potential clients.	T3+4m
MP	Maintenance Plan	Document with the actions that have to be carried out periodically on the LODR system to ensure a good functioning and the accomplishment of the requirements established in the Quality Management Plan.	T4
TS	Technical Specifications	Document in which the main technical data of the core elements, such as the laser or the mirrors, and the performance of the system are collected.	T4
MCR	Monthly Control Report	Report with the progress of the project that will be send every month to the institutions and companies of the consortium and the stakeholders with high power and interest on the project (see Figure 5), so they can monitor and be informed of the work and results obtained throughout the different phases.	Every 1m

BCR	Biannual Control Report	Report with the progress of the project that will be send every six months to the stakeholders with medium and low interest and power on the project (see Figure 5), so they can monitor and be informed of the work and results obtained throughout the different phases.	Every 6m

Table 6: List of deliverables.

1.7 Project milestones

Milestone name	Description	Estimated due date
Project Feasibility Definition	Statement of the budget available for the project so that it ensures economic feasibility alongside the foreseen period of operation. Establishment of the stakeholders share and agreement of payments method of the overall contribution. It will be stated following with the Budget deliverable.	T0+4m
Tracking Data Legal Certification obtainment	Statement of the compliance of current regulations regarding deorbit and clean space debris. They need to be identified and ensured to be certified in order to begin activity.	T0+8m
Laser Design and Production	Report with in-depth explanations of the laser design which ensures that the technological requirements are met. The rest of component designs have to be done in tune with the laser design. Furthermore the laser system performance will be determined by the laser design.	T2
System Requirement Review (SRR)	Formal review conducted to guarantee that all system requirements have been entirely and properly identified in order to achieve the stated necessities.	T2+8m
Preliminary Design Review (PDR)	Technical assessment that establishes the Allocated Baseline of a system to guarantee it is operationally effective.	T3

Critical Design Review (CDR)	Multi-disciplined technical review to guarantee that the system go on test, fabrication and demonstration and thus meet asserted performance requirements inside schedule, cost and risk.	T3+2m
Test Readiness Review (TRR) and Technical Acceptance Review (TAR)	Formal review conducted to settle whether the system under review is ready to go on formal testing by deciding if the test methods are done and verify agreement with descriptions and test plans. Formal review directed to evaluate the technical aspects of the whole system so that they settle the technological requirements are in in agreement with all tasks tested.	T3+4m
First Prototype Arrangement, Operational Test and Evaluation (OT&E)	Arrangement of prototype and fielded test under realistic operations conditions of the system with the goal of establishing its operational effectiveness and operational suitability for activity and evaluate the performance of the overall systems. It is concluded with the results exposition of the activity offered to possible costumers.	T3+5m
Stakeholders Feedback and Approval and Marketing Plan	Exposition of the project to the stakeholders in order to receive their feedback and meet with their requirements and suggestions so that they approve with the setting of the systems. Marketing report in which potential clients are identified and the actions necessary to publicize the service and enhance its visibility in the market.	T3+8m
Final Approval	Consent of the operation of the product so as to start its operation on the expected date.	T3+10m

Service Launch	Initiation of the operation of the service ensuring effective execution and meeting the stated requirements.	T4
Maintenance Service Launch	Initiation of the maintenance systems needed to ensure functioning for the expected period of operation so that required modifications are performed in order to continue with safe and effective performance.	T4

Table 7: List of milestones.

1.8 Project objectives

This section presents the main objectives of the project, taking into account the criteria that will be followed to verify that they are successfully met, and the person or institution responsible for carrying out said verification.

	Project Objectives	Succes criteria	Approval responsible
Scope	An extensive study and preliminary design of the laser system and its characteristics.	Presentation of the current advanced techniques suitable for the product along with contrasted and approved studies.	Consortium researchers R+D (CleanOrbit)
	A feasibility study that justifies the existence of a laser system of this characteristics at a competitive price.	Find verified studies on laser technology, its capabilities and current cost.	Purchasing and Production (CleanOrbit)
	A brief study of the ESA regulations in order to broaden the market possibilities of this new concept of technology.	Comply with all legal requirements imposed by the ESA and equivalent organizations.	Direction (CleanOrbit)
	A preliminary study on the needs of this project and an analysis of companies and suppliers that can meet the requirements.	Identification of stakeholders, establishment of relationships with producers and suppliers.	Direction (CleanOrbit)
	Periodic reports to stakeholders and weekly meetings with CleanOrbit staff.	Presentation of the minute meetings and follow-up of the stakeholders.	Project secretary (CleanOrbit)
	A justification on the general configuration selection aiming on being optimal in different laser types adapting to various densities and materials of space debris.	Submit evidence of the operation of the laser in the requested operating situations.	Production (CILAS)
	The laser system designed in this project will be ground-based with a maximum re-targeting time of 1 minute in order to be fast-response.	Submit evidence of operation at the requested speed.	Production (CILAS)

Table 8: Project objectives, success criteria and approval

	Project Objectives	Succes criteria	Approval responsible
Scope	Offer European users and different operators as well as public entities a service capable to protect the physical integrity of the current satellites in orbit.	Establish a sales plan and a marketing campaign to sell the product and service.	Direction (CleanOrbit)
	Implementation of an eco-system oriented both to tracking and analysis of orbit debris to de-orbiting action of light and heavy objects which could present a hazard to the orbiting satellites and their trajectory.	Develop the software and manufacture the product that satisfies a safe and effective de-orbiting.	Production dept. (DIGOS)
	Creation of a passive and active system that monitors space debris, tracks its trajectory and anticipates the potential danger towards other orbiting objects and acts accordingly using laser technology created through this project.	Tracking verification with information provided by the companies that own the satellites. Successful tests in deflecting the object with laser technology.	Production dept. (DIGOS)
	Approach and design of a high-powered ground-based plasma laser technology as a means of acting on targets with the aim of de-orbiting them or reducing the risk of impact on other objects of interest.	Manufacture of the device and verification of the power supplied by the laser at long distances.	Production dept. (CILAS)
	An analysis of the software required for tracking and its development by an specialized entity to automatize and monitoring the laser system and tracking the targets.	Verification of the software used for tracking objects in orbit.	Electronics technical Manager (DIGOS)

Table 9: Project objectives, success criteria and approval

	Project Objectives	Succes criteria	Approval responsible
Scope	Offer European users and different operators as well as public entities a service capable to protect the physical integrity of the current satellites in orbit.	Establish a sales plan and a marketing campaign to sell the product and service.	Direction (CleanOrbit)
	Creation of a passive and active system that monitors space debris, tracks its trajectory and anticipates the potential danger towards other orbiting objects and acts accordingly using laser technology created through this project.	Tracking verification with information provided by the companies that own the satellites. Successful tests in deflecting the object with laser technology.	Production dept. (DIGOS)
	Approach and design of a high-powered ground-based plasma laser technology as a means of acting on targets with the aim of de-orbiting them or reducing the risk of impact on other objects of interest.	Manufacture of the device and verification of the power supplied by the laser at long distances.	Production dept. (CILAS)
Time	Development of all stages of this project in a maximum period of 4 years.	Follow the established milestones in order to start the operation of the service on the expected date. A maximum delay of 4 months is allowed.	Purchasing and production (CleanOrbit)
	Project planning in order to establish a schedule, dividing Work Packages and defining Deliverables.	Creation of a Gantt chart planning the duration of the tasks.	Direction (CleanOrbit)
Cost	Develop all parts of the project with a maximum of 3 million €.	Allocate the correct amount of the budget to each corresponding need. A 10% excess of the budget is allowed.	Accounting managers (CleanOrbit)
Quality	Create and offer a legal service with the latest technology and the least environmental impact.	Conduct a pollution study and technical inspection of the product.	AENOR

Table 10: Project objectives, success criteria and approval

1.9 Estimated Budget

In this section are clarified the different categories of the budget (management (including meetings and travels), materials, human resources, equipment (amortization), subcontracting), and the budget share amongst the consortia partners. To properly structure the funds, the budget is divided into research and design tasks and, on the other hand, the manufacture of the prototype and its respective tests.

1.9.1 Research and design budget

Institution/company	Research expenses	Material and equipment	Human resources	Management	Total
Consortium partners					
DLR (Bremen)	102.600 €	25.650 €	64.125 €	12.825 €	205.200 €
ISAE-SUPAERO	102.600 €	25.650 €	64.125 €	12.825 €	167.152,5 €
TU DELFT	102.600 €	25.650 €	64.125 €	12.825 €	205.200 €
IAC	25.650 €	205.200 €	64.125 €	25.650 €	320.625 €
CleanOrbit/DIGOS	102.600 €	25.650 €	85.500 €	166.725 €	380.475 €
CILAS	76.950 €	205.200 €	85.500 €	25.650 €	327.037,5 €
	393.300 € (30%)	513.000 € (30%)	427.500 € (25%)	256.500 € (15%)	1.710.000 €
Contingency reserves (5%)					90.000 €
Final budget					**1.800.000 €**

Table 11: Research and design budget decomposition

The research and design budget is divided into the institutions and companies that make up the consortium, being this part 81% of the total budget; and some contingency funds, which represent 5% of the total, to allow flexibility and reduce risks of budget overruns.

Within each recipient, the funds have been classified according to four categories: Research expenses, Materials and equipment (those that are amortized during the project), Human resources and, finally, Management, which includes management tasks between companies, transfer of information and its respective meetings and travels. Figure 2 shows the percentage distribution of funds among the members of the consortium.

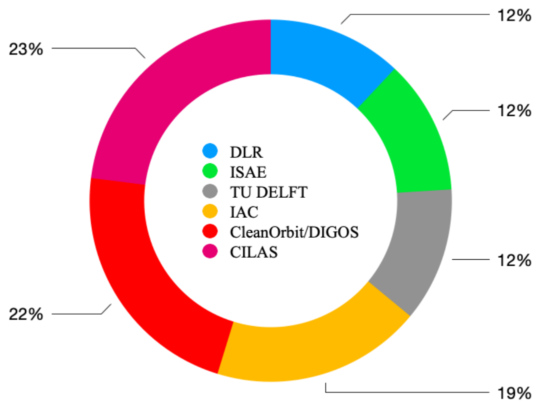

Figure 2: Research and design budget distribution

1.9.2 Prototype budget

Institution/company	Prototype building	Prototype testing	Human resources	Management	Total
Consortium partners (60%)					
DLR (Bremen)	0 €	0 €	0 €	0 €	0 €
ISAE-SUPAERO	0 €	0 €	0 €	0 €	0 €
TU DELFT	0 €	0 €	0 €	0 €	0 €
IAC	21.600 €	86.400 €	60.000 €	36.000 €	204.000 €
CleanOrbit/DIGOS	75.600 €	43.200 €	60.000 €	36.000 €	214.800 €
CILAS	118.800 €	86.400 €	60.000 €	36.000 €	301.200 €
	216.000 € (30%)	216.000 € (30%)	180.000 € (25%)	108.000 € (15%)	720.000 €
Subcontracting (35%)					
OHB System AG	25.200 €	84.000 €	49.000 €	14.000 €	172.200 €
RUAG International	25.200 €	42.000 €	49.000 €	14.000 €	130.200 €
Maersk	12.600 €	42.000 €	49.000 €	14.000 €	117.600 €
	63.000 € (15%)	168.000 € (40%)	147.000 € (35%)	42.000 € (10%)	420.000 €
Contingency reserves (5%)					60.000 €
Final budget					**1.200.000 €**

Table 12: Prototype budget decomposition

Subcontracted companies are involved in the prototype manufacturing and testing budget, accounting for 35% of the prototype budget and 14% of the total budget. As can be seen, the funds allocated to universities in this part of the budget are zero, since manufacturing is carried out by companies specialised in each component of the product (Lasers, mirrors, software, hardware, etc.).

The budget is classified into two new sections: prototype building and prototype testing, which will allow the components to be created and assembled, and subsequently, to carry out the certifying tests (endowed with enough power to deorbit objects and with the minimum environmental impact). Figure 3 represents the percentage distribution of the budget allocated to each institution in this prototyping part.

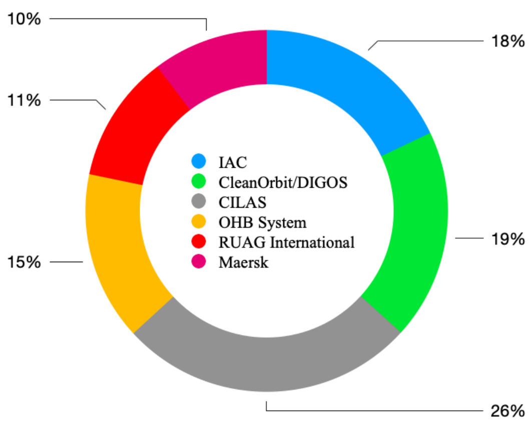

Figure 3: Prototype budget

1.9.3 Total budget

Finally, taking into account the two parts of the project, research and prototyping, the total budget of the project is presented in the following table.

Institution/company	**Total**
Consortium partners (81%)	2.430.000 €
Subcontracting (14%)	420.000 €
Contingency reserves (5%)	150.000 €
Final budget	**3.000.000 €**

Table 13: Final project budget decomposition

The total budget is divided into the budget allocated to the institutions and companies that make up the consortium, being this part 81% of the total budget; the budget allocated to subcontracted companies, which occupies 14%; and finally some contingency funds, which represent 5% of the total, to allow flexibility and reduce risks of budget overruns.

With the analysis of the stakeholders, it is determined that apart from the funds contributed by the H2020 program, two external investors must contribute the necessary funds to reach the total estimated budget. These external investors are EIF Venture and Ace Aerofondo. Supposing that 2 million euro will come from H2020, these two investors are expected to contribute the remaining 33% of the budget.

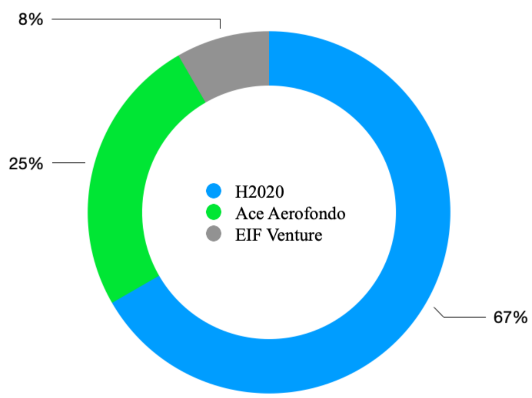

Figure 4: Budget investors

1.10 Project organization

1.10.1 Customers

The following customers are defined for this project:

Table 14: List of customers groups.

Customer group	Customer representative
European Comission	Pau Nualart Nieto - National Contact Point
European Space Agency	Holger Krag - Responsible of Space Debris Office
NASA*	Jer Chyi Liou - Responsible of Space Debris Office
JAXA*	Mayumi Matsuuri - Responsible of Space Situation Awareness System

*: If their previous work and technologies are not good enough compared to our solution, they will become potential clients.

1.10.2 Stakeholders

The following groups and organization are the key stakeholders in this project:

Stakeholder name	Roles/Responsibilities
CleanOrbit	Includes the members of staff, PM & engineering in the company
TU Delft	Design mirrors for laser cone direction control
ISAE - SUPAERO	High-power laser design, in collaboration with CILAS
Universität Bremen	Mechanical design of the laser
IAC	Placement provider for laser infrastructure & Space Debris tracking in collaboration with DIGOS
DIGOS	Electronics design and validation
CILAS	High power laser & mirror manufacturing
OHB Systems AG	Main laser assembly responsible
RUAG	Main laser electronics manufacturing
AP Møller - Maersk	Logistics of main parts of the laser and its infrastructure
NASA	Main competitor for space debris removal, may have their own project. Possible client if the project succeeds
ESA	Main sponsor for the project, with funds from the H2020 proposal
JAXA	Secondary competitor due to lower capital. May also be a client if project succeeds
Roscosmos	Possible future client. They are currently not developing any technologies in this sector
EIF Venture	Possible investor. Involved in breakthrough technology R&D
Ace Aerofondo	Possible investor. Specialized in aerospace sector, especially in projects based in Spain and France

Table 15: List of stakeholders, roles and responsibilities.

* Names in bold letters mark the consortium members.

1.10.3 Roles and responsibilities

The following key roles have been defined for this project:

Role	**Resource name**	**Dept (Organization)**	**Responsibilities**
Project Sponsor	Pau Nualart	European Commission	National contact point (NCP) and supervision
Project Manager	Rubén González & Alexander Gratch	Direction (CleanOrbit)	Leading and organising the overall project and the different phases
Project Secretary	Abel Vilanova	Direction (CleanOrbit)	Support for the project leaders and documentation
Accounting manager	Gerard Rius & Abel Vilanova	Finance (CleanOrbit)	Control and track the project's revenues and expenses
Quality manager	Teresa Peña	Purchasing & Production (CleanOrbit)	Control the project's advances quality and technical documents' consistency as well as the work done by subcontractors
Electronics technical manager	Alexis León	Production (DIGOS)	Supervise DIGOS' involvement and assist the electronics' development team
Electronics engineer	Alexis León & Joan Massons & Pablo Navarro	Production (DIGOS)	Develop the electronics technology and manufacturing
Laser technical manager	Delia Gamboa	Production (CILAS)	Supervise CILAS' involvement and assist the engineers during the laser's development
Laser engineer	Jesús Durán & Delia Gamboa & Oriol Luján	Production (CILAS)	Develop the laser and mirror's technologies and manufacturing
Test manager	Alexander Gratch	Production (CleanOrbit)	Supervise the testing phases
Test engineer	Rubén González & Alexander Gratch & Orlin Mihov	Production (CleanOrbit)	Carry out the testing of the different advances and general assembly in order to certificate them
Universities connection	Laura González	R+D (CleanOrbit)	Supervise the universities involvement and progress within the research areas

Table 16: Roles and responsibilities.

2 Stakeholder identification

This section presents the analysis of the main stakeholders for this project.

2.1 Stakeholder analysis matrix

The location of each stakeholder in Figure 5 represents their interest and power they have over the proposed project. Depending on the quadrant where they are, they should be treated differently, trying to keep it in the area of interest, especially those that have greater power.

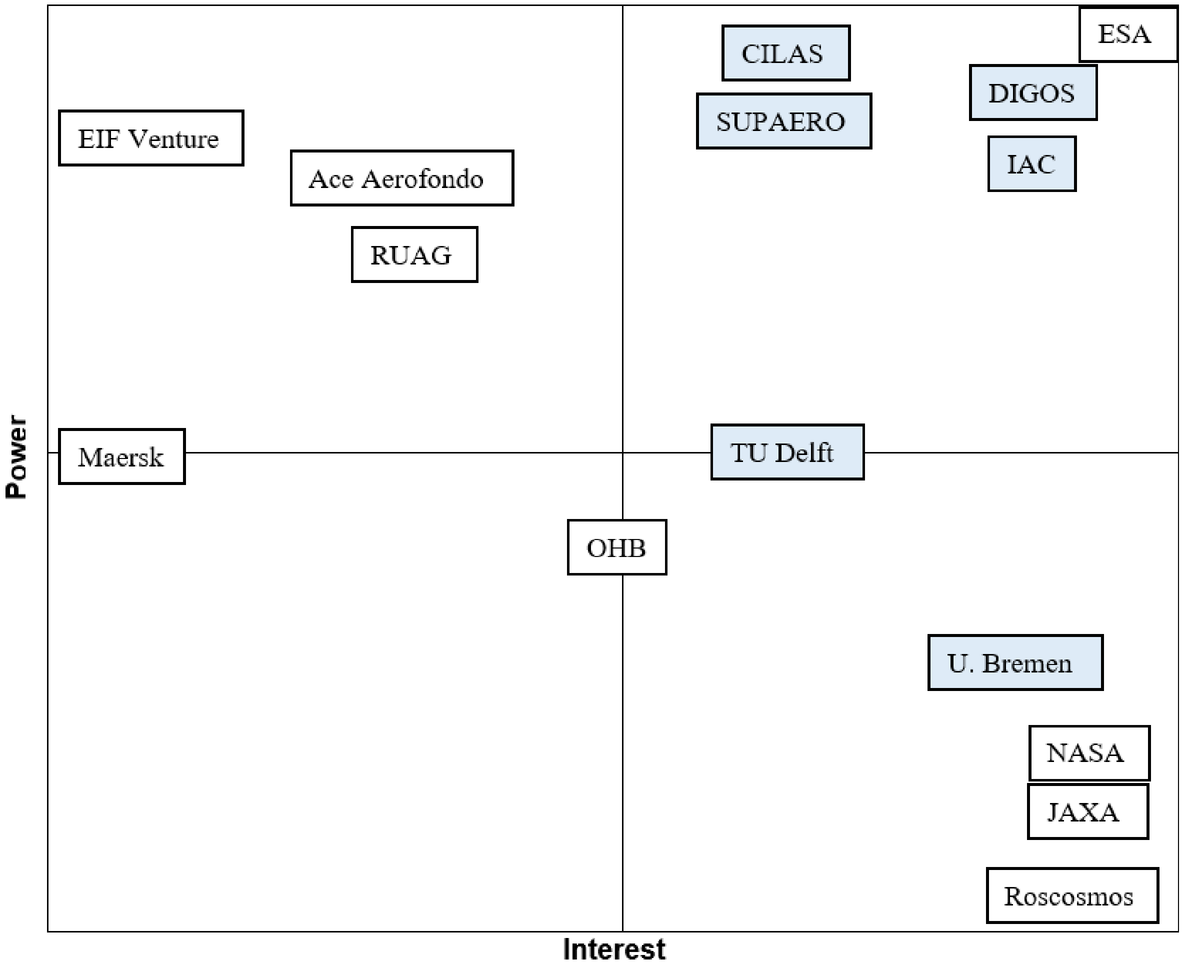

Figure 5: Stakeholder Analysis Matrix

2.2 Stakeholder Register

Name	Position	Role	Contact Info	Requirements	Expectations	Influence	Classification
JM Kuiper	Optical & Mechanical Engineering Leader	Opto-mechanical design	j.m.kuiper@tudelft.nl	Main responsible for the mechanical design of the laser movement systems	Achieve maximum movement precision through state-of-the-art technologies	High	External / Supporter
Nisrine Arab	Optical Engineer & Researcher	Laser design	linkedin.com/in/nisrine-arab-427021a5	Main responsible for laser design & development	Achieve a laser design capable of hitting a target withstanding atmospheric turbulence	High	External / Supporter
Kerstin Kracht	Mechanical Engineering	Main mechanical system engineer	kkrahl@uni-bremen.de	Mechanical & structural design, production methods	Achieve maximum structural performance with minimal weight and price	High	External / Supporter
José Alfonso López Aguerri	Instrumentation area	Instrumentation area chief leader	secins@iac.es	Responsible for instrumentation department and subdepartments (optics, software…)	Full coordination between IAC and DIGOS / Clean Orbit	Medium	External / Supporter
Steffen Zeidler	System Engineer	Tracking system responsible	linkedin.com/in/steffen-zeidler-581607176	Development and correct functioning of the DIGOS tracking system	Achieve space debris tracking with relatively good precision	High	Internal / Supporter
David Sabourdy	Laser Engineering Leader	Laser design leader	d.sabourdy@cilas-ariane.fr	High power laser design and state-of-the-art technology implementer	Provide previous knowledge in the world of high-power lasers from CILAS	Medium	External / Supporter
Franco Ruggiero	Assembly, Integration & Test Electrical Engineer	Main assembly & integration responsible	linkedin.com/in/franco-ruggiero-a9515625	Integration of electronics inside the mechanical assembly	Correct assembly of the laser system	High	External / Influencer
Peter Sinander	Chief Engineer Electronics	Main electronics production & verification responsible	linkedin.com/in/peter-sinander-3761196a	Check validity of electronic the electronic systems built by DIGOS / Clean Orbit	Manufacture, validate and verify the correct assembly of the electronic systems	Medium	External / Influencer
Mahesh Nair	Master Mariner / SCM	Logistics management	linkedin.com/in/mahesh-nair	Logistics management	Make sure all the equipment is successfully sealed and sent to the chosen location	Medium	External / Neutral
Pau Nualart	Spain Contact Point	European H2020 Proposal Contact Point	pau.nualart@upc.edu	Answer questions regarding funding, management and HR	Provide knowledge from previous projects	High	External / Supporter
Bjorn Tremmerie	Head of Venture Capital and Impact Investing at EIF	Possible investor	linkedin.com/in/bjorn-tremmerie-1998861	N/A	Provide funding	Low	External / Influencer
Miguel Cavero	Head of Ace Aerofondo	Possible investor	contact@ace-cp.com	N/A	Provide funding	Low	External / Influencer

Figure 6: Stakeholder register

References

[1] Esa's space environment report 2021. (2021). https://www.esa.int/Safety_Security/Space_Debris/ESA_s_Space_Environment_Report_2021

[2] Phipps, C. R., Baker, K. L., Libby, S. B., Liedahl, D. A., Olivier, S. S., Pleasance, L. D., Rubenchik, A., Trebes, J. E., George, E. V., Marcovici, B., Reilly, J. P., & Valley, M. T. (2012). Removing orbital debris with lasers. *Advances in Space Research*, *49*, 1283–1300. https://doi.org/10.1016/J.ASR.2012.02.003