DOI: 10.13009/EUCASS2023-690
Aerospace Europe Conference 2023 – 10TH EUCASS – 9TH CEAS

Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: SUSTSP / REUSYS
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Type: Oral
Status of corresponding author: Student
For student corresponding author: student member of one of the following:
3AF / AAAR / AIAE / AIDAA / CzAeS / DGLR / FTF / NVvL / PSAA / RAeS / SVFW / EUROAVIA

Title

LEONEEDS - A space debris removal and recycling project

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Full paper publication date :09/07/2023.

Abstract

The threat posed by space debris, at all altitudes, has become a big subject of research for the space industry, especially for young startups. The space sector is always on the lookout for more projects and solutions towards space debris removal. We could mention ESA and ClearSpace SA's efforts to bring together new types of missions and demonstrators, being one of the most advanced space debris removal projects.
LEONEEDS, named after the Leonids meteor shower, is a space station concept aimed directly at the treatment of space debris in Low Earth Orbit (LEO). The main goals of the project are the use of a permanent Low Earth Orbit space station, in collaboration with space tugs startups, to remove or recycle space debris. Its objective is to recycle, in orbit, space debris that could serve a new use, for example in collaboration with the future Lunar Orbital Platform-Gateway (LOPG). A second use would be the deorbitation, under thermal shields, of inactive satellites or satellite parts, which would be flight-proven (Technology Readiness - Level 9) and less expensive to produce for young startups or new space programs. Partnerships on the subject of space tugs could allow the new space economy to evolve towards reusability. This reusability would allow the space sector to develop a circular economy, by bringing back previous space missions, either to refuel and re-launch them, or to gain access -either for students, startups or emerging countries – to older space missions, to gain valuable data on the ageing of such missions and the effects of the harsh space environment. LEONEEDS could also serve as a technology enabler, to allow on-orbit testing while still being able to gather data from the mission as it comes back to Earth.
The options for such a space station are almost limitless. Any space actor could benefit from a circular economy. This station has the potential to reinvent on-orbit services, using on-orbit recycling and potential refueling in the long term. The proposed services could first reduce the numbers of new debris through life extension missions, but also reduce the current amount of debris in the short term, while allowing a circular space economy, by letting space debris to come back to Earth for a second life.
Would you throw away your phone once it runs out of battery? This is more or less what's currently done in space with old satellites – why not change the way we treat debris in space?

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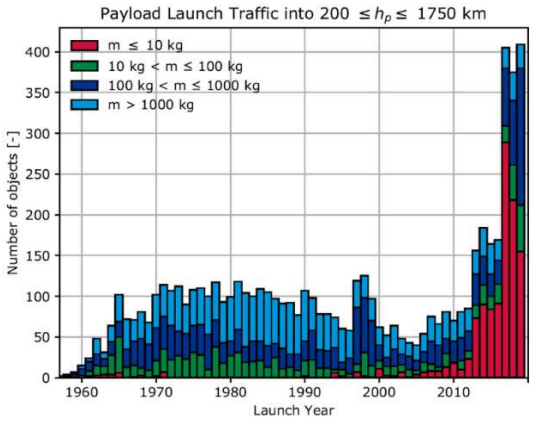
1.Introduction

"The Black Waffles team welcomes you on board. Your destination? A circular and sustainable space future!"

The LEONEEDS (Low Earth Orbit NEw Experiment For DebriS) project was conceived and proposed in 24 hours during a space hackathon organized by CNES: ActInSpace 2022. This hackathon is one of the initiatives put forward by various companies in the space market (Airbus, Thales, EUSPA, ESSP, Sopra Steria) under the aegis of national and European space companies (CNES, ESA), to open new renewable solutions market to space.

The proposed solution, a subtle blend of technological and economic considerations, was put forward in response to a challenge: invent public space services. The chosen topic had the modest ambition of serving more general objectives of common interest. To be a player in NewSpace today means applying technical skills to improve society, to promote better use of space for the benefit of the Earth and mankind.

Since 1957, a large number of launchers, satellites and instruments have been sent into space. At the time, there was no provision for what to do with them once they reached the end of their life. Their numbers have continued to grow, and explosions and collisions in space have created hundreds of thousands of pieces of dangerous debris. In addition, the number of small satellites launched into near-Earth orbit has increased dramatically over the last ten years, partly due to the growing number of constellations.



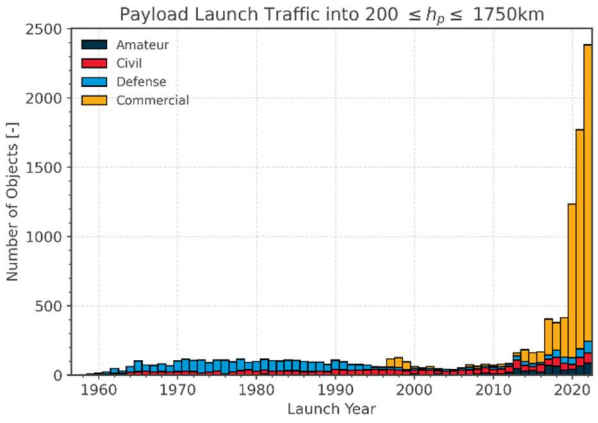


Figure 1 and Figure 2-Payload Launch Traffic evolution in 60 years according to their mass and their application domain. Source : [Space Environment Statistics · Space Debris User Portal (esa.int)]

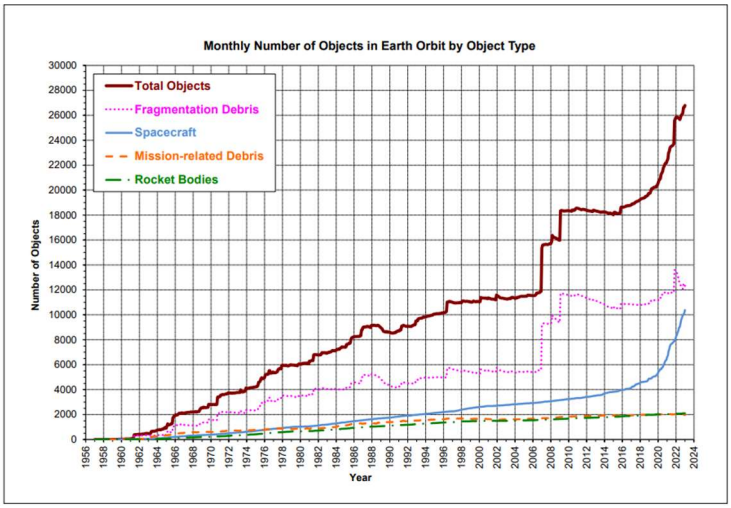


Figure 3 - Monthly Number of Objects in Earth Orbit Cataloged by the U.S. Space Surveillance Network. Source: [Orbital Debris Quarterly News 23-1, 2 (nasa.gov)]

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Around 80% of small satellites launched into low orbits (around 2,000 km altitude) will naturally comply with space debris mitigation measures, as their low altitude ensures that they will disintegrate in the atmosphere. But at least a third of them do not comply with end-of-life rules. The growing congestion of the orbit increases the risk of collisions, fragmentation and chain reactions that can lead to chaos. We're all familiar with the incident on June 11, 2007, following China's anti-missile tests, which led to the destruction of the FY-1C satellite in the Fengyun series. Similar events tragically improve the probability of that scenario to become reality. This pessimistic situation is known as the Kessler Syndrome.

This catastrophic scenario could permanently hinder both safety of active satellites and access to space for future missions. Eager to curb this pessimistic scenario, which would spell disaster for a space industry that is currently flourishing, we came up with a solution for this at the latest ActInSpace hackathon: this solution is called LEONEEDS.

2.1 Context around space debris de-orbiting and space stations

The LEONEEDS solution is mainly based on a few key technical functions, which could be summed up as followed: The construction and deployment of a space station, the use of technologies for manipulating and machining debris, the assembly of the debris with a thermal shield and reentry handling. The technology that's brought by our solution is mainly the segment about thermal shield equipment. Indeed, we can find in space exploration history and beyond plans for future space related programs, solutions that were or will be successfully used concerning the others technical functions.

The construction and the deployment of space stations have been achieved by several organizations throughout space exploration history. The Salyut stations were the first to be successfully constructed and deployed, for civil (DOS-1 to DOS-6) and military (OPS-1 to OPS3) manned and unmanned missions, between 1971 and 1986. Those stations where usually constituted of one structure that could fit a Proton rocket's fairing. The experience acquired through failures and successes of the Salyut program led to the configurations of DOS-7 and DOS-8 modules, that respectively served beyond MIR and ISS modules. The Skylab station was then the first American space station made from one Saturn V third stage. This station managed to go through early breakdowns, that hindered energy production and space station on-board temperature. This station enabled three manned missions and brought several useful data that would then be useful for ISS design.

MIR happened to be the first space station constructed in several modules, enabling collaboration at the international level, especially around the end of MIR's life, as well as multiple EVA and experimentations. The ISS is the well-known main space station permanently in orbit, and conveys all experiences acquired in history on the previous space station missions, as well as the contribution of a plethora of countries across the world. Nowadays, we know that two main projects of space stations which are Tiangong station and Lunar space Gateway are currently either in orbit or in design.

Those several projects heavily involved space agencies and were ruled with States as main contractors. However, more humble recent projects on the European scene are now undertaken by private companies. Those constitute the firsts ambitious missions managed by private companies that could enhance space as a service through the deployment and the use of permanent stations.

First, we can mention the EROSS IOD (European Robotic Orbital Support Services In Orbit Demonstrator), led by Thales Alenia Space. This program has the ambition to demonstrate and validate several of the main function that are planned to be used for space-servicing solutions (satellite rendezvous, capture, docking, refueling and payload exchange capabilities). One of the features of this station is a robotic arm, which has gone through several steps of development. Another project also conducted by Thales Alenia Space as a project contractor and his subsidiary company Space Cargo Unlimited. This project is constituted of a station, constituting the container of a module enabling on board experiments for several months. The module made from an already existing spacecraft module is planned to be refueled and recharged by a reusable service module. We can finally mention the project lead by Clearspace with the support of ESA and other institutions, for the use of a module of space debris de-orbiting. Those mission are planned to be launched in a few years, which gives an optimistic eyesight for the innovation in those domains.

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2.2 Context around NewSpace project funding

First and foremost, the France 2030 plan is designed to provide financial support for French and European companies. This support is provided for companies involved in sustainable development, and for those developing solutions in the space sector. The objectives of this plan are in line with those of the LEONEEDS project:

Objective 9 (Investing in the new space adventure, in particular with the production of reusable mini-launchers and micro- and mini-satellites) translates into an investment of two billion euros for space and the seabed. France also aims to be home to several of the major players in New Space by 2030. With this in mind, the plan is built around four pillars, of which the following are the most relevant. The first pillar of the French strategy is to strengthen France's competitiveness and space sovereignty (scientific and industrial), by investing in projects with both established and new space players. The development of new market segments (in-orbit services) is also under consideration, as we shall see later.

The LEONEEDS project is fully in line with the third pillar: making space a place to protect a common good by promoting regulatory standards. A European model for space traffic management must also be defined. Finally, the fourth pillar encourages research, particularly for environmental purposes. The quantified objective of this plan is as follows: "Within 5 years, to develop a French offer for reusable launchers, New Space players and connectivity constellations (€1,550 million)". We can mention that other institutions as ESA and BPI France emits calls for tender and calls for project to financially support those kinds of projects, as well of solutions brought by CNES (through the “Connect by CNES” initiatives) and a great number of clusters and start-up incubators.

3. LEONEEDs, a new recycling solution for low earth orbit (LEO)

The project is motivated by a context of environmental consideration concerning activities related to the space domain. Several initiatives at different levels are enabling private-sector players to take action on issues such as recycling, product life-cycle management and space orbit liberation. The latter is the focus of the LEONEEDS project. With the rise of Space Traffic Management in France and around the world, there is an urgent need to position ourselves as leaders in space debris recycling.

The aim of LEONEED is quite clear: in the short term, it involves implementing a module for de-orbiting and recycling on the ground the small debris cluttering up low-Earth orbit. In the longer term, the project aims to make any object sent into space recyclable. Utopian? Certainly, but necessary, even indispensable, for the harmonious and sustainable management of future launches and therefore the future of the space sector. This station would be based on a multi-stage implementation and incremental services over time.

1. The basic station: this would enable a large satellite (Hubble, for example) to be captured and transported using a heat shield equipped with a robotic arm. The project would be financed through calls for tender. We expect to benefit from aid provided under the France 2030 plan and the space stimulus plan launched at the same time.

2. The second service increment involves the recovery and resale of ground components. In the short term, the project targets small pieces of debris (10 to 1,000 kg) that have reached the end of their life cycle, are faulty or dysfunctional, in order to relieve LEO orbit congestion.

3. The third increment consists of a set of partnerships that will enable us to support the end-of-life of current and future spacecraft manufacturers. Several standardized format sockets adapted to the station would make it easier to pick up modules and redirect them. Sockets, improved heat shields adapted to satellites... will be developed over the long term.

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Figure 4 - Proof of concept of the LEONEEDS station – Joshua Benarroch

It is important to underline the influence that the LEONEEDS project could have on the space industry from a legal point of view, as well as the legal constraints that could stand in the way of the project's development. The ISO 24113 standard is designed to ensure that the design, operation and disposal of spacecraft and the launch vehicle stages used to place them in orbit (and ejected after propulsion) do not generate debris during their life in orbit. The station provides an unequivocal response to the end-of-life aspect of spacecraft, which spacecraft manufacturers will have to consider, on pain of financial penalties. Space law is not precise on prohibitions and is flexible on the sanctions applied in the event of transgression of the prohibitions it contains.

However, the implementation of an effective solution, considering all the solutions present in orbit, could encourage the introduction of and compliance with new standards in this area. The legal hurdle concerns the notion of ownership of high-altitude debris. Because of the grey areas in space law, we can't know whether a piece of debris still belongs to the company that created it, or for how long if it does, and to what state of integrity.

Our business model already makes it possible to identify the interests of the various stakeholders at different stages in the product's life. We have already mentioned some of them. But some additional players have an important economic role to play. Space debris removal companies play a role in the deployment of the station in the early years. It will be necessary to transport debris to the station, at least initially. Companies producing heat shields ensure that debris is transported from the station to the ground in a condition similar to that of space debris. NASA was able to demonstrate an inflatable LOFTID heat shield, which could be used to land heavy loads on Mars. The technology therefore already exists, and it will be possible to use such a solution for atmospheric re-entry at varying cost.

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4. Conclusion

There is undoubtedly an opportunity to be seized in the Space Traffic Management sector. With the growing number of launches in recent years and in the future, consideration of satellite end-of-life, orbit-freeing solutions and material recycling are becoming essential to preserving space for future missions. LEONEEDS is exploiting these opportunities by working with committed players motivated by the desire to circularize space. The project also benefits from a monopoly, and will take advantage of an organized short-, medium- and long-term strategy to flourish and rapidly establish itself as the orbit recycling solution.
Where reusable launchers are a prequel to a more sustainable space, LEONEEDS extends the reuse of spacecraft components to the entire space ecosystem and its stakeholders.

Figure 5 - "LEONEEDs YOU!"

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Illustrations Table

Webography

ActInSpace Challenge:
ActInSpace Challenges || An international innovation contest lead by CNES and ESA

ESA's space debris dossier:
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Norms and laws for space:
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https://fr.wikipedia.org/wiki/Droit_de_l%27espace

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Other projects evoked in this paper:
Space Cargo Unlimited and Thales Alenia Space unveil details of their alliance for the development of “REV1”, the first space factory | Thales Alenia Space
Home - Space Cargo Unlimited (space-cu.com)
Thales Alenia Space to lead Eross IOD, on-orbit servicing project | Thales Group
Les stations spatiales passées, présentes et futures – Société astronomique de France (saf-astronomie.fr)
ClearSpace - A mission to make space sustainable

Participation in the « Colloque de l'Armée de l'Air et de l'Espace », Monday 9/01/2023
Participation in ActInSpace 2022, discussions with engineers from CNES and MaiaSpace.
Participation in the “Assises du NewSpace” 2nd season, exchange with several Newspace actors.