DOI: 10.13009/EUCASS2022-6108
9TH EUROPEAN CONFERENCE FOR AERONAUTICS AND SPACE SCIENCES (EUCASS)

A sustainable and affordable access to space

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Abstract

NewSpace is turning to be a new era for the Space Market as actors are initiating new projects and innovations to democratise access to space. It is not only a complete economic transformation but also a technological and human revolution. Among many other values that are new to the space sector, NewSpace is changing the economic philosophy to drive sustainability and affordability : Solutions must be found to preserve the environment and foster the growth of NewSpace's activities. It is essential to remind that sustainability should not leave aside development considerations and has to be the core of the product life-cycle management definition.

If those environmental considerations are to be applied for developing a mini-launch vehicle for the NewSpace's industry, there is a need to rethink entirely the life cycle of a mini-launch vehicle to guarantee a sustainable project development. It is necessary to consider environmental impact and carbon footprint for all development activities : Conception, raw material extraction and processing, test campaigns, qualification, transportation for launcher parts. As for the operational phase, mini-launchers can be more ecological as it is possible to promote the use of bio and green propellants and aim for a no-debris policy : The development of 100% reusable launchers should be supported to foster more responsible space projects and limit the amount of debris on ground and in-orbit. At the product's end of life, it should be defined that the launcher's parts must be recycled for sustainable purposes.

As much as sustainability has become highly important in the NewSpace industry, the first need on the space market for a mini-launcher is to be affordable for clients and partners. To propose low-cost access to space, it is recommended to develop a mini-launcher as demonstrated in a document published by the Air and Space Academy [1] : The architecture of the launcher must be simple, with many reproducible and adaptable systems as possible, for example, the same engine can be used for all the stages to reduce the development cost and it is highly recommended to aim for a two stages launcher. To guarantee an affordable price, the use of COTS (Components-Off-The-Shelf) and non-space systems that can be qualified during the development phase is also highly recommended as it can drive cooperation with non-space industries and lower the development cost. To minimise the launch price for a mini-launcher, it is also recommended to aim for a fully reusable system, to lower costs and support sobriety and sustainability in the production phase.

With NewSpace evolution, competitiveness has been increasing between the actors on the space market, and it is crucial to identify the main requirements for the development of mini-launchers. At Sirius Space Services, the project development is inherent to the space market evolution and requirements : The company is focusing on conciliating the needs of the clients and low-cost rides with ecology and is proposing to submit an abstract on sustainability meeting with affordability. The presentation will be about proposing new methods of development at early stages for conception, production, tests and operations to guarantee the sustainability of all activities in the space sector.

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Introduction

With the NewSpace evolution, space actors are supporting the development of small private and low-cost entrepreneurial projects to develop innovations and easy access to space. Regarding NewSpace launchers activities, it is now crucial to consider sustainable and reusable architectures to provide for tailored and dedicated rides.

Today at Sirius Space Services, there is a need to support NewSpace activities and define with space actors a new way of considering space missions. To that end, it is recommended to support developing simple products, using low-cost and COTS systems to guarantee affordable services. Partnerships with renowned space companies are promoted to adapt small launchers to the market's evolution : Simple and flight proven technologies combined with new space innovations. The objective is to reuse 100% of launchers Sirius before 2035 while developing innovative systems for recovery and reusability purpose. In this article, it will be shown that reusability is mandatory for future space program and crucial to support sustainable space missions. A proposition of recovery system will be presented here to address the reusable market needs, including upper stages, fairing and booster recovery.

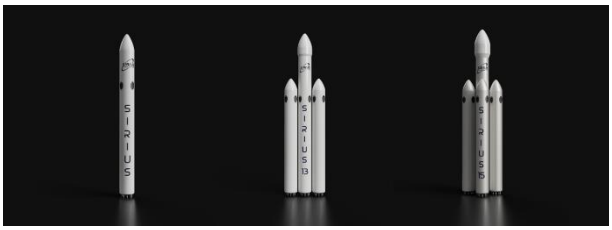

Figure 1 : Sirius launchers @Sirius Space Services

Regarding the space development, it is also crucial to consider the life cycle of the product, here small launchers for sustainable space. Circular economy should be fostered, as it guarantees low carbon footprint emissions to drive a new model of production and consumption of space products. To that end, it should be prioritized to develop reusable and recycling phases to lower needs for raw materials extraction and processing. Space companies could also consider supporting partnerships to sell retiring components to non-space companies to support new life cycles.

This article is dealing with sustainable and new space innovations to support low environmental impact for space missions. There are propositions of space product management to support circular economy processes and lower the carbon footprint of NewSpace activities.

1. Small satellites market's needs

1.1. Small satellites market's evolution

In the document published by the Air and Space Academy in 2021 [1], it has been shown that the number of satellites available on the market from 2024 to 2028 should be significant and shows that launchers of 800kg capacity is consistent with the needs for launch services, as shown in the next figure.

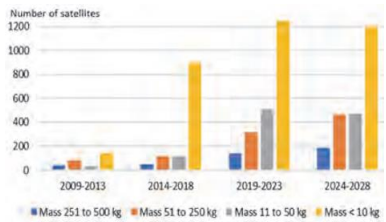

Figure 2 : Number of small satellites (excluding broadband connectivity) @AAE

In the figure above, the number of satellites between 51 and 250kg will grow in the next years which is perfectly addressing the needs of agile and affordable rides to space. There is also an important volume of heavier satellites, almost 200 satellites of 251 to 500kg, which is matching the capability of larger launchers with a payload capacity up to 800-1000kg and a significant development for new constellations that requires to launch multiple medium satellites through batches. Constellations like those are the perfect opportunity to address the space market and aim

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for long-term agreements. The figure below shows the number of launchers that are currently targeting the space market of small satellites. There is a lack of small launchers with a payload capacity from 400 to 1000kg that few projects under development are currently targeting, which could perfectly address the need of tailored launches for small satellites constellations. However, this payload capacity could be perfectly addressing the market needs shown on figure 2.

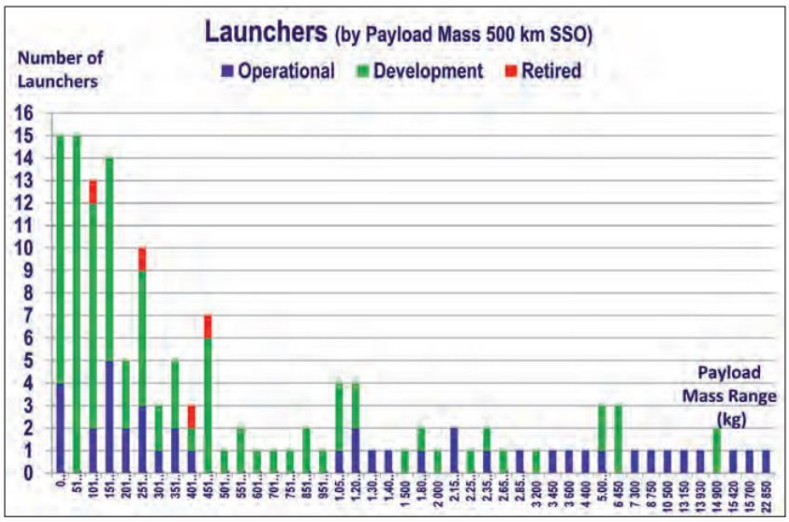

Figure 3 : Number of launchers to come on the space market @AAE

Today, what is important for satellites manufacturers is to get tailored launch services at low-cost and high flexibility options. Launch plannings are expected to be shorter and satellites can be sent all over the world depending on the mission needs and operations requirements so one of the main objectives would be to launch from multiple launch sites. To that end, it is necessary to support for agility and flexibility considering launch services requirements : A family of small reusable launchers is perfectly addressing the needs of the market.

1.2. Agility and affordability

The competition on the space market will be rough between the wide range of small launchers companies, but the most important requirements for satellites manufacturers are the same for all : Cost, agility and reliability. Micro-launchers can pretend to have similar reliability objectives than heavier launchers and the capacity to be more agile. Indeed, agility is about planning, a great variety of launch sites and the opportunity to adapt launchers to the clients needs in terms of mission configuration and management. But the major aspect to consider for the micro-launcher competition is about prices.

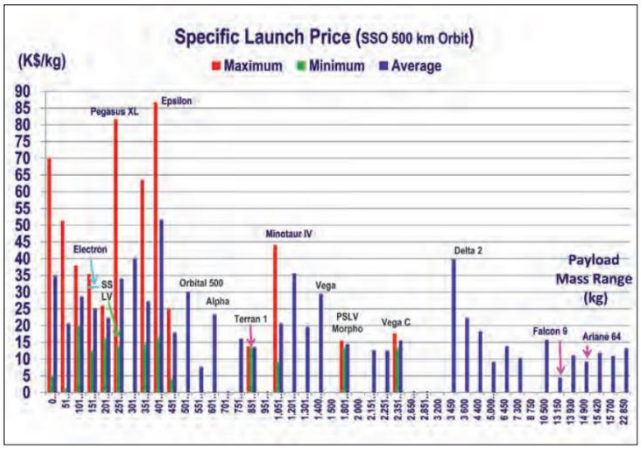

Figure 4 : Launch price range on the space market @AAE

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As shown on figure 4, the launch price range is wide considering smallest launchers to the most powerful ones, Ariane 5 and Falcon 9 with prices from 5K$/kg up to 86K$/kg for Epsilon. To compete with the lowest prices on the market, small launchers companies need to determine disruptive technologies and manufacturing processes to lower the space access cost to the ones of Falcon 9. Combine with more agility and if possible equivalent reliability, small launchers companies would be able to secure the small satellites market estimated in figure 2.

For launcher manufacturers, there is a need to anticipate the evolution of future space market and to target a commercial development logic, which implies to adapt to the evolution of the NewSpace activities. Small launchers development should be agile and constantly evolving with the market needs to guarantee that it is providing one of the best services to target space.

2. Modular launchers and simple architecture

There are more advantages to develop a family of launchers than considering the market's evolution, including cost optimisation and simpler development phases. Developing a family of launchers guarantees an agile and innovative development organisation and requires determining new technologies and manufacturing processes to optimise the design, production and test phases.

2.1. Modular launchers

For launcher manufacturers, it should be supported to develop highly modular and adaptable launchers, in order to easily adapt and reconvert some parts for one launcher to another. For example, the first stage of one launcher could meant to be easily integrated as a booster for a heavier version. Doing so, and by using the same architecture, propulsive and fluidic systems, it will be significantly easier to lower costs and development phase duration. To optimise the production of the cryogenic stages, it could also be considered manufacturing same tanks structures for propellants to lower the costs and production times.

The fairings should also be adaptable and suitable for each launcher, depending on the mission needs and capabilities. Three versions could be available considering at least one larger expended version for constellations rides or institutional and heavier satellites launches. As for the adaptors and dispensers, it is necessary to design and develop various and modular systems to be suitable for multiple mission's variations such as constellation rides, rideshares, piggyback and dedicated launches. Using flexible platforms and configuration is one way to optimise the number of satellites and cost of launches.

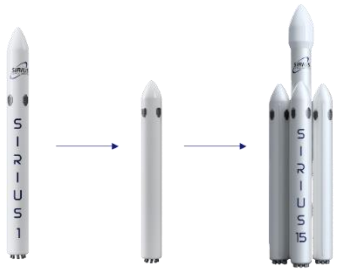

Figure 5 : Sirius modular launchers (Left : Sirius 1, Middle : Sirius booster inspired from Sirius 1's first stage, Right : Sirius 15 with 4 boosters @Sirius Space Services

Using modular and adaptable systems for a launcher's family is the opportunity to provide for tailored services and simplified operations : Combined with a standard price for all of the launchers, this is the opportunity to target for more flexibility in filling launchers with satellites dedicated to the same orbit and having the same launch date target. Inspired for the highly modular launcher Ariane 4, a range of small adaptable launchers would be providing for a wide range of mission capacities using an adaptable number of boosters. The main objective is to optimise the satellites launch flexibility and filling configuration under the fairing to optimise cost and operations. Promoting modular systems and simple architecture is the opportunity to optimise the development, qualification and production processes of the launchers.

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2.2. COTS components

To optimise and target a competitive launch price, launcher manufacturers could aim to use as much as possible space and non-space COTS components. There is a need to support collaboration opportunities and to work with numerous partners with various backgrounds to support the project's development.

To guarantee affordable launch services, launchers providers should be aiming to use as much as possible COTS and generic components, which can be adapted or integrated on other systems. For example, separation systems for the inter-stage and fairing separation phases could be using the same technology to guarantee lower development and production costs. It should not be limited to consider only space systems, as there is today great collaboration opportunities for non-space companies to provide for new innovations and possibly affordable systems. To reduce the qualification times and increase chances of success, it is also necessary to select components and systems that have already a high maturity level considering a minimum TRL of 6 or 7. Some systems can have a lower TRL, but it will require a particular integration to ensure qualification of those systems.

Some innovative processes can also be highly supported, for example metal additive manufacturing is a new manufacturing process that most of launcher manufacturers are developing and integrating within their teams to support new technologies.

2.3. Metal additive manufacturing

At Sirius Space Services, we are promoting agile and simple architecture for our launchers, and a new manufacturing process: Metal additive manufacturing.

This innovative and challenging technology is the opportunity to lower the production cost while maintaining great performances and guarantee reliability for our systems. For example, because we are using the same engine for the first stage, second stage and boosters, it is crucial to develop metal additive manufacturing in-house to optimise development cost and duration for our pieces. The main advantage for this manufacturing process is to promote rapid prototyping, with a time of production that is easy to estimate. It is more adequate for multiple iteration processes, where modifications can be easily made in shapes and designs without impacting manufacturing tools and process. Also, the additive manufacturing process allows complex geometries to save mass while maintaining good mechanical properties, so it is possible to design infinite geometry and shapes. For example, Sirius Space Services designed multiple pieces part of the cryogenic fluid components that would not be possibly manufactured using traditional manufacturing processes.

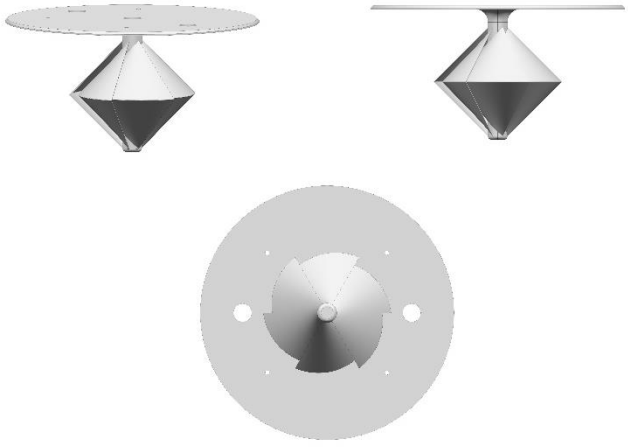

Figure 6 : Gas diffuser to be printed using metal additive manufacturing process @Sirius Space Services

Additive manufacturing is also an innovative process that guarantees a lower environmental impact while reducing the waste production, the energy requirements and transportation needs to have at least identical or even better thermo-mechanical properties than traditional manufactured pieces.

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3. Reusable launchers and circular economy for sustainable access to space

Today, there is a huge opportunity considering reusability for small launchers to target modularity and agility in space. Recovering small launcher parts can provide for shorter and diversified operations configuration to access space in a more responsible way.

3.1. Reusability for small launchers

Developing small reusable rockets is the opportunity to catch up launcher parts and to brought them back to technical facilities for maintenance. There are multiple solutions to study in order to recover elements depending on the size of the launchers.

To accommodate with small launchers and systems, the recovery system could provide at least a parachute reuse kit to aim at first for small launcher part's recovery. Indeed, the development of a parachute reuse system should be significantly more affordable than other systems as it is simpler to design and to aim for using COTS and non-space systems with high maturity products. This solution would be combined with the use of a helicopter to hook in mid-air the line between the pilot parachute and the main parachute. After this operation, the launcher's elements are brought on a boat to return to the spaceport and start tests and qualification phase. Considering the performances of a standard helicopter, this solution only applies to pieces with a mass of less than 2 tons and would not be suitable for heavier launchers like Sirius 13 and Sirius 15.

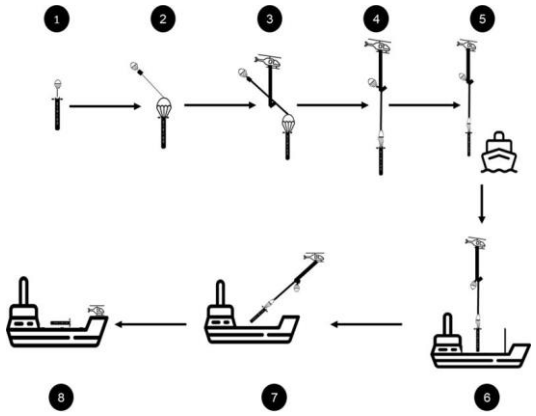

Figure 7 : Concept of operations (1 Deployment, 2 Deployment of the main parachute, 3 Hooking of the launcher parts, 4 Locking of the hook, 5 Back to the boat, 6 Placing the launcher on deck, 7 Securing the launcher, 8 Landing) @Sirius Space Services

For heavier launchers, parachute might not be suitable and reverse thrust combined with intelligent recovery system could be considered. The development of a versatile drone ship is highly recommended, as it would allow to recover parts of the launchers together to be shipped to the nearest harbour for recovery and qualifications. The drone ship system could be easily combined with the use of reverse thrust to catch the stages of the reusable launchers and is compliant with the use of multiple spaceports. The most challenging aspect here is that the engine must be re-ignitable, which is difficult especially considering the second stage.

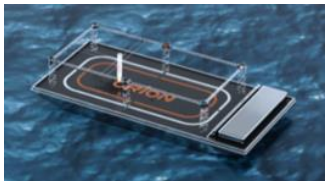

Figure 8 : Sirius recovery solutions developed in partnership with @Orion Space System

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Recovery systems and reusable launchers are part of a strong initiative to support the development of sustainable space activities. It is possible to provide for solutions to lower the environmental impact of space missions and to minimise the amount of debris into orbits. By integrating recovery within operations of micro-launchers, manufacturers would be able to reuse up to 20 times some parts of the launchers.

3.2. Circular economy and sustainability

To support sustainable activities, Sirius Space Services is looking for initiating a sustainable life cycle to lower the environmental impact and carbon footprint for all development activities: Conception, raw material extraction and processing, test campaigns, qualification and transportation for launcher parts.

Space has always been a sector with a high impact on the environment, whether because of the pollution of its activities, or the important amount of debris in orbit that are endangering space. But it is crucial now to redefine completely the way of launching satellites. To do so, launch services providers should have a zero-debris in-orbit policy, to ensure a safer and more responsible use of the space area.
There is also responsibility in defining new responsible approach to limit our environmental impact by minimizing for example shipping needs: Space companies could manufacture most of the launcher's parts in-house or locally, and limit as much as possible transportation needs and range. Solutions can also be found to support more sustainable transportation means like railway, sailing boats or even flying air cargo.
For test, qualification and production phases, sustainable processes should be supported using more ecological raw materials considering the pollution generated not only by the extraction but also transformation and manufacturing processes. Combined with recovery ad reusability purpose, small-launchers development and operational phases could be highly optimised to minimise both environmental impact and costs.
SpaceX recently set a new world-record with the 13th landing and recovery of a Falcon 9 first stage in 2022. This means that we already have technology and knowledge to reuse some parts of micro launchers at least up to 20 times and this is a ground-breaking innovation that will allow us to truly minimize pollution regarding space activities.

Regarding circular economy principles, it is crucial to define a new model for developing small launchers, involving reusing, repairing and recycling of the raw materials, internally or by fostering partnerships with space and non-space companies. Using metal additive manufacturing for example could be the opportunity to recycle internally launcher parts by melting and processing existing materials. If it is not possible to reuse or recycle some systems to manufacture new parts at Sirius Space Services, it should be supported to enable partnerships with local companies once launcher parts are recovered, in French Guiana for example. It could be the opportunity to minimise the waste production and offer a second life cycle to the products.

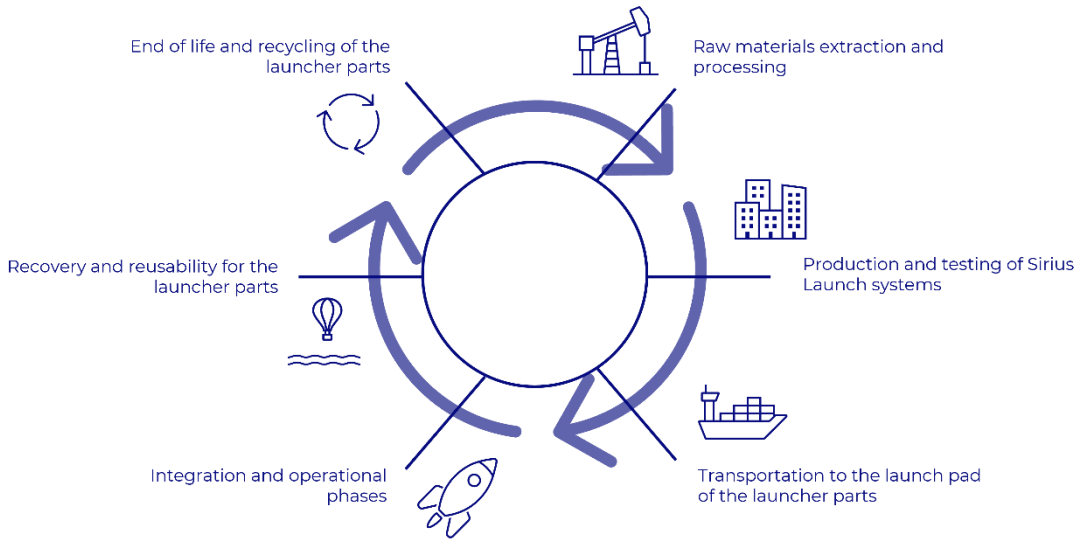

Figure 9 : Life-cycle of Sirius @Sirius Space Services

As sustainability is at the heart of our mission, Sirius Space Services has the ambition to certify our activities with international standards to promote a lower environmental impact, considering ISO standards for energy systems management, environmental management or limitation of the space debris.

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4. Conclusion

At Sirius Space Services, there is a need to support a new era for the space activities and guarantee a more responsible and sustainable approach to access space. The main goal is to focus on providing affordable and agile access to space, while supporting new innovations and technologies to develop sustainable space and NewSpace evolution. To target being one of the most competitive small launcher operators on the space market, there is a need to understand and follow the evolution of the small satellite market needs. To combine both affordability and sustainability, it is necessary to aim for using as much as flight-proven components, with a simple architecture and as much as possible generic and adaptable systems to optimise greatly the development of a range of small launchers.

At Sirius Space Services, there is also a need to certify the launchers development and operational phases with international ISO standards and to promote innovations like metal additive manufacturing and reusability to ensure a low environmental impact. The company aims to perform a complete environmental impact study applied to all activities and phases of a launcher's life-cycle from conception to retiring of the launcher's parts. The objectives of this study are to identify the most polluting activities of a small launcher development and to initiate a continuous improvement process at Sirius Space Services.

Considering small launchers development, there is a need to challenge space accessibility and drive NewSpace ecosystem to evolving for more responsible services with the lowest possible price level.

References

[1] J. Ackermann, C. Bonnal, G. Bréard et al. 2021., SMALL LAUNCHERS : A European perspective. AAE file 52/DGLR file 2021-01.

