A SUSTAINABLE AND AFFORDABLE ACCESS TO SPACE

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PAPER

ABSTRACT: NewSpace is turning to be a new era for the Space Market as the actors are initiating new projects and innovations to promote and 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 Academy1 : 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 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.

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, we are aiming to support NewSpace activities and define with space actors a new way of considering space missions. To that end, we are supporting developing simple products, using low-cost and COTS systems to guarantee affordable services. We are working with renowned space companies, to adapt our launcher 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 proved that reusability is mandatory for future space program and crucial to support sustainable space missions. Our proposition of recovery system will be presented here to address the reusable market needs, including upper stages, fairing and booster recovery.

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 end-of-life cycle products 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. SIMPLE ARCHITECTURE AND COTS SYSTEMS FOR TECHNICAL SOBRIETY

There are many advantages to develop a family of launchers, including cost optimisation and simpler development phases. Developing a family of launchers guarantees agile and innovative development and requires determining new technologies and manufacturing processes to optimise the design, production and test phases.

1.1. Modular launchers

At Sirius Space Services, we are aiming to develop modular and adaptable launchers, where we can easily adapt and reconvert some parts for one launcher to another. For example, the first stage of Sirius 1 is meant to be easily adapted as a booster for the heavier Sirius versions,

S13 and S15. Doing so, and by using the same architecture, propulsion, avionic and GNC systems, it will be significantly easier to lower costs and development phase duration. To optimise the production of the cryogenic stages at Sirius, we are also considering manufacturing same tanks structures for liquid oxygen and liquid methane to lower the costs and production times.

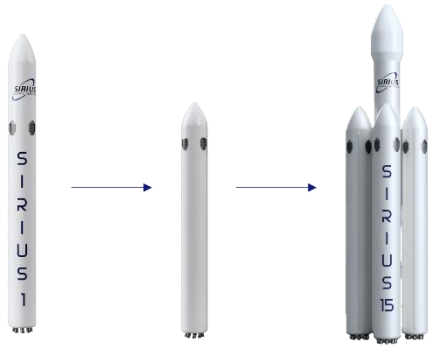

Figure 1 : Sirius modular launchers
@Sirius Space Services

The fairing should also be adaptable and suitable for each launcher, depending on the mission needs and capabilities. At least three versions should be available considering 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.

Promoting modular and adaptable systems is the opportunity to optimise the development, qualification and production processes of the launchers while addressing the market's needs for payload capacity and planning.

1.2. COTS components

To optimise and target a competitive launch price while minimising the development needs and cost, Sirius Space Services is aiming to use as much as possible space and non-space COTS components. We are working with numerous partners with various backgrounds to support our project's development.

To guarantee affordable launch services, Sirius Space Services is aiming to use as much as possible COTS and generic components, that can be adapted or integrated on other systems. For example, separation systems for the inter-stage and fairing separation phases should be using the same technology to guarantee lower development and production costs. To reduce the qualification times and increase our chances of success, it is also necessary to select components and systems that have already a high maturity level considering a TRL minimum of 6 or 7. Some systems can have a lower TRL, but it will require a particular integration at Sirius Space Services to ensure the qualification of those systems.

Some innovative processes will also be supported, for example metal additive manufacturing is a new manufacturing process that Sirius Space Services is developing and integrating within its teams to support new technologies.

1.3. Metal additive manufacturing

At Sirius Space Services, we are promoting reliable 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. 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 our development cost and duration. The main advantages for this manufacturing process is to promote rapid prototyping, with a time of production that is easy to estimate. 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.

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.

Figure 2 : Star0 printed engine @Sirius Space Services

2. REUSABLE LAUNCHERS AND CIRCULAR ECONOMY FOR SUSTAINABLE ACCESS TO SPACE

Today, most of the operational launchers have been designed to be used only once and it is endangering the activities of NewSpace as many debris are floating in low orbits or crashing back on Earth in the sea.

2.1. Reusable launchers

To foster the initiative of small reusable launchers, the development of a standard reuse system should be considered to address small launchers development as it could democratise sustainability and sobriety for Sirius launchers. The development of a generic system could be the opportunity to aim for 100% reusability at a global scale, by developing an agile solution adaptable to a various range of launchers and systems: Stages, boosters, fairings, adaptors, kick-stages, etc.

To accommodate with a maximum of 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. A helicopter is needed to catch the parachute in mid-air to recover systems and

bring them to a boat. Then, the recovered systems are shipped to French Guiana to be reused on the future. The concept of operations is shown below.

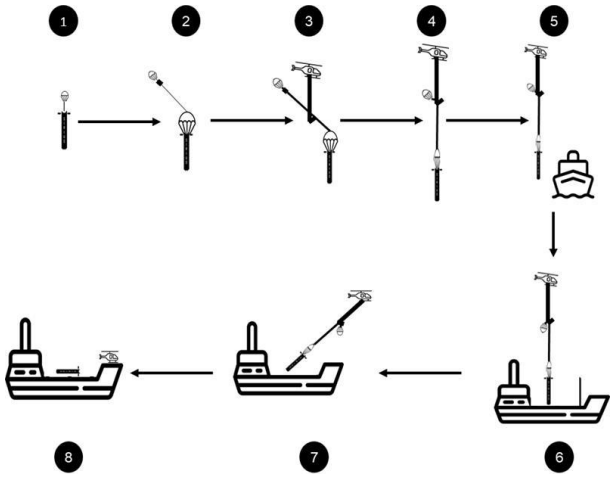

Figure 3 : Concept of operations

(1. Deployment of the pilot parachute, 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 the descent phase, two parachutes are needed to slow down systems: A pilot chute that is used to deploy the main parachute or other auxiliary parachute. It is the first parachute deployed. The main parachute is the most important one and used to slow down the fall so the helicopter can be catch.

To support the development of reusable systems, our target at Sirius Space Services is to reuse systems up to 20 times, to significantly lower our production cost and environmental impact. For Sirius, recovery systems and reusable launchers are part of our strong initiative to support the development of sustainable space activities. We want to provide for solutions to lower the environmental impact of space missions and to minimise the amount of debris into orbits.

2.2. 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 accessing space. To do so, Sirius Space Services aims to define a responsible approach to limit our environmental impact by limiting for example the transportation needs: The company will manufacture most of the launcher's parts in-house, and limit as much as possible transportation. During test, qualification and production phases, we will promote sustainable procedures and more ecological raw materials and propellants like bio-methane for propulsion to lower our carbon footprint. We have also a zero-debris in orbit policy, to ensure a safe and responsible use of

the space area. In the long term, it is planned to recover 100% of our launchers and to reuse some parts up to 20 times. If possible, at the end of life of the products, we will recycle some systems and materials to promote circular economy and more sustainable space industry. 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 at Sirius Space Services 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.

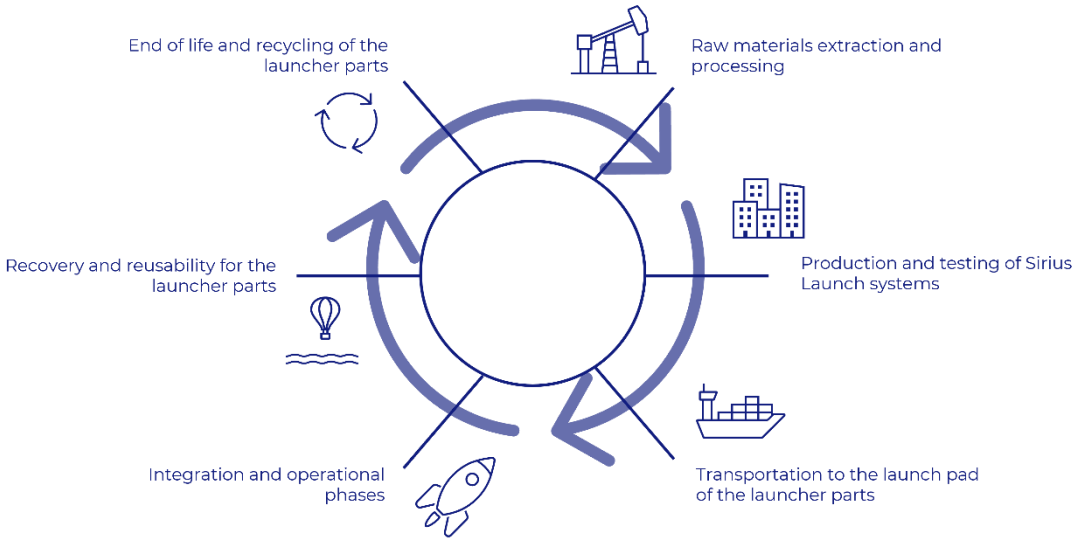

Figure 4 : Life-cycle of Sirius launchers @Sirius Space Services

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.

CONCLUSION

At Sirius Space Services, we want to support a new era for the space activities and guarantee a more responsible and sustainable approach to access space. Our mission is to focus on providing affordable and agile access to space, while supporting new innovations and technologies to develop sustainable space and NewSpace evolution.

We are aiming to certify our launchers development and operational phases with international standards and to promote innovations like metal additive manufacturing and reusability to ensure a low environmental impact. To achieve this goal, we are developing simple, modular and low-cost systems using essentially COTS components or non-space systems. We want to challenge space accessibility and drive NewSpace ecosystem to evolving for reliable services with the lowest possible price level.