

ANRT – DESTINATION MOON WORKING GROUP

**FOR A EUROPEAN LUNAR CONSTELLATION: EUROPE SUPPORTING MOON EXPLORATION,
EUROPEAN KNOW-HOW FOR SPACE COOPERATION**

STRATEGIC NOTE

ABSTRACT: The new lunar ambitions all share two major features: their desire for a permanent installation and the variety of projects to be conducted on and around the Moon. These new needs must be met by new services. The use of a common communication and navigation service would reduce the complexity and cost of missions while benefiting from improved performance, thus freeing up resources and budget for optimized and more ambitious missions. Europe has historical and recognized expertise in the fields of observation, navigation, and telecommunications, on which Project Moonlight can leverage for the Moon.

Since 2019, the ANRT and its Destination Moon Working Group have been supporting the development of a sustainable lunar and cis-lunar economy, and within this framework, any initiative for new cross-cutting European services, drawing on European industry talent. This note focuses specifically on ESA's Moonlight Constellation project - it will be followed by other notes on projects as described above.

The Moon is once again at the heart of the scientific, economic, and geopolitical agendas of space-faring nations. Whether they are historic states or newcomers to the space sector, multi-decade companies or start-ups, they all share the same desire to establish themselves permanently on the Moon. The common denominator of their projects is to consider the Moon as an outpost for future goals - especially for Martian exploration - but also as a training ground for developing and testing new space exploration techniques. Humanity is returning to the Moon to settle and engage with the future. The Moon is not only a stage before going to Mars, but the primary stage itself, and French and European actors must play a significant role in these future missions. **It is therefore a fundamentally renewed ambition that presides over the return of humans to the Moon in the coming years.** And this new logic is the source of new needs requiring innovative responses. **Designing a sustainable and expanding base on the Moon to serve new and bold ambitions requires a reliable navigation and communication system as a service support, a keystone for the efficiency and promise of any lunar project.** These services of a new "Lunar Logistics" can be a French or European contribution to international missions such as ARTEMIS.

The decade 2020-2030 will see the first phase of humanity's return to the Moon, with dozens of robotic missions under development around the world. **Each of these missions plans to embark its own means of telecommunication with the Earth, representing a shortfall in terms of design, flexibility, and interoperability.** Moreover, while the first missions will focus on the South Pole, where most of our natural satellite's water resources are concentrated, exploration ambitions will soon extend to the far side of the Moon, where the need for external telecommunications and navigation resources will prove indispensable.

This is the interest of a dedicated lunar constellation: working together in orbit around the Moon, its specific satellites associated with a network of Earth stations will be able to accompany the lunar missions with positioning and communication services over its entire surface without any transmission interruption.

In the development of these services, **Europe can play a strategic role and to find here an essential lunar application to develop and expose its full potential.** These services are complementary to the American ambitions of the ARTEMIS program: while the United States is focused on a successful return to the Moon - "Boots on the Moon" - Europe can position itself as a provider of multiple services: communication and navigation with Moonlight, Earth-Moon transport with EL3 or NYX or secondary

habitats such as EUROHAB, or finally the mastery of oxygen, water and hydrogen production from lunar resources for transport, life support and energy management from space.

THE MOONLIGHT CONSTELLATION, AN OPPORTUNITY FOR EUROPE

An ambition at the heart of ESA's Moonlight project. The agency is currently concluding two evaluation studies with two consortia of companies from different countries, to then call for a competition for the implementation of the system and the provision of services.

For Europe in space, committing to a project such as Moonlight means putting at the service of the Moon a **historical, recognized, and complete European know-how in Earth observation, navigation, geolocation, and telecommunications**. By transforming this terrestrial know-how into lunar skills, our continent would become the provider of an elementary brick for the lunar missions of partner states. This is the central ambition of the program: to allow the implementation and the provision of a European capacity of communication and cislunar navigation through services that will support the current and future generations of institutional and commercial explorers.

Reducing the cost and complexity of missions

Providing communication and navigation services thanks to a dedicated constellation of satellites in lunar orbit presents a double interest for the reduction of the cost and complexity of lunar missions.

Firstly, many missions are currently limited by the volume of spacecraft, their capacity to transfer data from the Moon, or by difficulties in communicating in real time with the Earth. At the same time, many missions already suffer and will continue to suffer from limited precision in terms of navigation during the descent to the Moon or during the conduct of missions on and around the Moon. The equipment, the safety of the astronauts and the durability of the missions are then at risk. **Therefore, the preliminary installation of a constellation in lunar orbit appears to be the prerequisite allowing to permanently provide a range of services solving the problems mentioned, but also to ensure the diversity of future missions for a large international community.**

And it is precisely this last element which serves the second interest of such an infrastructure that is **the reduction of the cost of the lunar missions**. The installation of a lunar constellation will enable space nations or companies of the sector with a reduced space budget to aim at the Moon; while limiting the costs of the missions already planned by the space powers. This is one way that a Moonlight constellation for navigation and communication around the Moon can serve as a catalyst for the emergence of new players and the strengthening of established players.

The other effect for the missions benefiting from improved communication and navigation performances is to **increase the range of the missions**. These services will make it possible, for example, to land or navigate in rugged areas of interest that are not accessible today because they require a high degree of precision, or even to completely redefine more efficient mission operating modes thanks to high-speed, real-time communication.

Acting in favor of cooperation and intersectorality

The logic that has just been explained also finds its *raison d'être* beyond the purely technical aspects of organizing lunar missions. Indeed, the lunar service constellation is also a formidable vector of international cooperation and industrial intersectorality.

Cooperation

Several nations already cooperating in space matters are on the new starting line for the Moon. **Maintaining and preserving international space cooperation on the Moon mutual use of services and competences between cooperating States**. Thus, a European lunar constellation could provide

communication and navigation to partner missions, including the American missions of the Artemis program. In return, the partner programs would offer Europeans other essential services in terms of astronaut transport or equipment. **Cooperation through mutual services has been the essential logic of space cooperation since its origins; preserving it and stimulating it on the Moon must be a priority.**

By providing the first permanent lunar communication navigation service, Space Europe and its member states position themselves as a strategic and essential player in the international lunar landscape. **The Moonlight constellation would actively contribute to the exploration of the Moon and space at large by providing essential functions** for a more efficient robotic exploration, but also for a truly sustainable human presence, with a natural need for very dynamic social interactions on the Moon and with the Earth. Considering that cooperation between space agencies is primarily through the reciprocal provision of services, **ESA thus benefits from an additional service to be inserted in barter agreements with other space agencies.** This means that the return on investment for the Member States goes far beyond the provision of communication and navigation services and could allow significant ESA participation in other programs in many areas

The cooperation by services finds its technical declination in the interoperability between the systems of the various projects of return of the human on the Moon. **A constellation such as Moonlight will be part of this interoperability scheme: the operator of the constellation and its users will have to share technical data allowing its operation.** Interoperability is a technical bet on the future and a vector of cooperation. It is the technical expression of equality between partners through technical transparency.

But the interests for the Member States do not stop there. **Indeed, an infrastructure such as Moonlight gives Europe a strategic autonomy regarding the needs of communication and navigation of European missions.** If we project ourselves towards Mars, demonstrating from the Moon the European capabilities in the design and implementation of a constellation beyond the terrestrial orbits will be a powerful showcase of European know-how for the red planet.

Intersectorality

This effort to work together is also found in the other interest of a European lunar constellation: **the ability for industry to mobilize in an intersectoral manner.** The new lunar ambitions are taking place in a renewed geo-economic context. Two major aspects of these new landscapes are of particular importance for lunar constellations. The first one, that of a new space economy where the private sector is now able to execute space exploration missions. The space agencies can thus turn to public-private partnership modes for services in support of the agencies' missions. **This renewed cooperation between agencies and industry will undoubtedly find a particularly important application in the design of lunar constellations, especially since it calls upon know-how acquired on Earth in the fields of telecommunications and navigation.** It is from this same transfer of know-how from Earth to the Moon that another crucial element of the industrial analysis of lunar constellations emerges: the importance of mobilizing non-space sectors for the development, maintenance or research and development of this lunar constellation. The mobile network providers are undoubtedly the first ones concerned. Moreover, who knows what uses the non-space sector could envisage in the future by taking advantage of the services provided by this lunar constellation which, after all, is an extraordinary means of bringing the Earth and the Moon closer together.

This cross-sectoral approach will have to be applied to the development of all new European service capabilities, for example the implementation of the space resources value chain

(e.g. H₂O/O₂/H₂/regolith, serving space transportation - O₂/H₂, intermittent energy storage - H₂, life support - O₂, infrastructure construction - regolith). These new European service capabilities are based

on the integration of the skills of many players in the ground and space industry, and will guarantee Europe's strategic independence, while enabling it to promote international collaboration, through the provision of services needed by all.

The international influence from which Europe's space industry would benefit is just as important for the Member States as for their industries. **By being the first to position themselves on a permanent communication and navigation infrastructure, European entrepreneurs will take a considerable and leading edge for new services around the Moon in an emerging lunar economy.** The Moonlight constellation, by its complexity and the unprecedented nature of its construction, will involve space and non-space companies from all member states in sectors as concerned as launch, telecommunications, maintenance, services, networks, etc.; on and around the Moon, of course, but also on Earth. Permanent, the Moonlight constellation will ensure a predictable and long-term commitment to the companies involved, offering the temporality necessary for non-space companies to invest towards and in space.

A European lunar constellation would also be a start to create a new market for lunar services with Europe as a supplier. The two essential functions of communication and navigation constitute an important source of income for the stakeholders of the project and **if initially the customers of such a constellation are institutional, high growth prospects are to be expected with an increase in the number of purely private customers.** The latter include primary users (objects and people present on the Moon or directing them from Earth) but also users of future applications to be invented in the fields of education, entertainment or media. The creation of a stable and reliable connection bridge will strongly link the Earth to the Moon.

Moonlight is much more than a lunar constellation, with an emphasis on service provision; it is a vector of innovation, strategy, excellence and cooperation for Europe.

The Europe of lunar services to the surface of the Moon

Another element of the lunar services that Europe could provide in this future "Lunar Logistics" concerns surface elements: NASA's Human Landing System (HLS) would be able to deliver large quantities of equipment to the surface. According to the figure announced by SPACE-X - manufacturer of the HLS - this system could provide between 50 and 100 tons of material on the lunar surface. It is clear that the United States will not need Europe as a supplier of equipment. But missions with systems like NYX and EL3 bring high benefits. On the one hand they affirm a certain European autonomy to have the capacity to reach the lunar surface. On the other hand, the medium size lunar landers can also be used to transport material on strategic sites which cannot be reached by the HLS (for example sites too risky for landings with crews on board). EL3 and NYX can transport material to sites of high potential such as the crests of lunar craters at the South Pole, or the dark side. The objective here will be to develop complementary services to the US ARTEMIS program, not to compete with it.

The EUROHAB concept is also part of this perspective. Since there is a large gap between safe crew landing sites (with HLS) and sites of interest (such as crater crests with high solar exposure during lunar nights; or crater bottoms where ice-like amounts of water have been measured), NASA will need Secondary Habitats placed between the landing sites and the sites of interest. These habitats can be in the form of a payload on EL3 or NYX, such as EUROHAB, and would be positioned before the astronauts arrive. Unlike the American HLS, they will remain in place. The first permanent habitat on another celestial body could be European.

EUROHAB is designed as a payload for an EL3 or NYX type lander. Considering the mass available on these systems it is important to design a system that is limited to one functionality: to allow a crew to survive on the lunar surface. These islands can be an advanced exploration base, or a storage place for

samples recovered by robots or instruments that will be passed from one crew to the next. EUROHAB will need this lunar logistics for its re-supply with the elements necessary to the life support systems, and also Moonlight for the tele-operation and tele-monitoring when no crew is on board.

NASA has just signed on June 16, 2022 an agreement with the Italian Space Agency on the study of the supply of lunar surface habitats. This shows on the one hand the American interest in surface housing systems and on the other hand that NASA is ready to have such systems delivered by international partners. But it is important that France and French actors mobilize so that this project becomes European!

France and Europe now have a unique opportunity to place our expertise, our technological solutions and our talents on this new race to the Moon. We have a historic duty to ensure that the European continent continues to play a significant role in exploration - it is the DNA of our culture.

But this race is on, and we must have the courage to choose new methods and the speed to make bold decisions to face the challenge of the American New Space.

Mr. Josef Aschbacher, the DG of the European Space Agency said at the Space Forum in May in Toulouse that we should have the courage to dream. It is up to our engineers and scientists to make dreams about Europe's lunar future come true; but it is up to the agencies and governments to make sure that the dreams become reality.

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