THE LUNAR AMBITION

a strategic challenge for 21st-century Europe

FOR A SUSTAINABLE, RESPONSIBLE, COORDINATED MOMENTUM

ANRT
ASSOCIATION NATIONALE
RECHERCHE TECHNOLOGIE

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a strategic challenge for 21st-century Europe

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This publication is the result of collective work carried out during 2021 by Destination Moon group members and outside experts.

ANRT

ASSOCIATION NATIONALE RECHERCHE TECHNOLOGIE

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FOREWORD

by FRÉDÉRIQUE VIDAL

FRENCH MINISTER OF HIGHER EDUCATION,
RESEARCH AND INNOVATION

The publication of this "Destination Moon" white paper, which looks at the challenges involved in the long-term installation of humans on the Moon, opens the door to the future by bringing inspiration for research and innovation for many years to come.
I congratulate Claudie Haigneré and Clarisse Angelier for their remarkable work, along with all those who contributed to producing this publication, which stimulates our imagination, inventiveness, sensitivity, and even our spirituality.

Since the dawn of humanity, the Moon has kindled the collective imagination. The works of ingenious visionaries like Jules Verne, Konstantin Tsiolkovsky, Werner von Braun and Sergei Korolev have made us dream and led men to walk on the Moon a full fifty years ago.

Spatial exploration has suddenly accelerated, partly driven by private players, who have spurred the democratization of access to space. The staggering multiplication of exploration launches and projects opens our eyes to a reality: the Moon is once again an accessible destination for human beings. Beyond inhabited space stations, a Moon-centred ambition is a mark of progress that is not just about technical achievement.

This ambition, which is at once technological, scientific and societal, offers an opportunity for France and Europe to play a central role in space geopolitics and rally a sense of belonging to a community united by the same ambition, replacing competition with cooperation.

The challenges of establishing an inhabited base on the Moon are immense, and are related to basic living needs : supplies of energy, water, food and oxygen, data processing, and waste management. In fact, they are no different from our earthly needs, with particularly high stakes in terms of sustainability and circularity. Establishing a legal framework for a future Moon governance, collecting the agreement of nations, will be a factor for peace. The benefits of this kind of Moon project will be considerable for the Earth, and likely to encourage the general public keen to get involved in the space industry.

The Moon project as presented by "Destination Moon" is also an ideal way to promote science in society, particularly among young people. Future achievements and research stimulate the ecosystem of space industries and start-ups, which will find legitimate opportunities, including artificial intelligence and robotics.

The field has already been fertilised. The Moonshot Institute, created in early 2021 by the CNES and ANRT, led to the launch of the TechTheMoon initiative, which aims, via an incubator, to develop technologies that could be used every day on the Moon. Five start-ups have already been selected, and many others, at European scale, are more than ready to take part in the Moon adventure.

I heartily encourage you to explore this white paper, in the hope that it will make you want to discover the Moon and adhere to its key message : "Destination Moon" !

FOREWORD

by JOSEF ASCHBACHER

DIRECTOR GENERAL OF THE EUROPEAN SPACE AGENCY

The start of this decade has seen us enter a very dynamic phase of exploration of inhabited space. Europe must now join this historic acceleration, which will take us to the Moon for the long term by 2030, and open the way to the first inhabited mission on Mars by around 2040. I am determined to provide the necessary impetus, as indicated in my Agenda 2025. The question is Europe's positioning : join the major space powers, or remain on the sidelines forever. The question is eminently political and needs answering now.

FOREWORD

by PHILIPPE BAPTISTE

MANAGING DIRECTOR OF THE
NATIONAL CENTRE FOR SPACE STUDIES (CNES)

The exploration of the Moon is generating more interest than ever before. Whether to demonstrate power, tackle geopolitical, technological and scientific issues, exploit lunar resources, or develop space tourism, the major powers have many reasons to look towards the Moon. This enthusiasm of nations has been boosted by the arrival of new entrepreneurs and private funds that bring hope for the development of ambitious programmes with manageable costs.

Now more than ever, it is time to validate new means of propulsion, remote navigation, automatic landing, and types of habitat for future missions, both on the Moon and on Mars.

In this new race for exploration, NASA is the leader, closely followed by Russian and Chinese ambitions. France and Europe cannot aspire to keeping ranks with the big space powers if they do not take part; moreover, they undoubtedly have a duty to put forward the objectives of a universal space exploration that goes beyond state borders. It was to this end that France and Europe fostered international collaboration through the ISS. The new Moon target involves numerous solicitations from our international partners to participate in the exploration programmes that they are developing. The question arises as to how to remain an indispensable collaborator, avoid dispersal, and even envisage a real programme of European leadership. France, through the CNES and the ESA, is

already closely involved in the Artemis programme. The CNES maintains a long tradition of international cooperation, in which the United States has been a historic partner. At its space centre at Toulouse, the CNES is preparing its participation in future missions to the Moon.

As an agency, the CNES is responsible for building a strong vision of the future for the Moon adventure. We first need to anticipate by setting the horizon at 2060. To this end, the CNES has created and runs a space observatory for prospective work on the Moon and Mars. One of the targets is to evaluate the management of lunar resources and territory. This also involves orchestrating and promoting innovation to foster a taste for adventure among French companies, whether they are already active in space or not. The result is the recent launch of the first global incubator dedicated to the lunar economy : TechTheMoon. The incubator will be located within the CNES in Toulouse at Cadmos, which currently pilots Thomas Pesquet's experiments at the ISS. In October 2021, five innovative start-ups started benefitting from 12 months of support. The incubated projects receive technical support from experts at the CNES and SpaceShip France, and are coached by the business and entrepreneurship specialists Nubbo. The five selected start-ups include an inflatable lunar installation, modules for optimizing plant crops with minimum resources, and a camera capable of detecting defects in equipment launched into space. This is a formidable accelerator for French innovation, a unique way to inspire new generations and encourage careers in science and engineering, and an even greater incentive for our financial participation in international programmes.

It goes without saying that lunar missions are now part of a broader project to reach Mars. This intention spurs technological and scientific progress the benefits of which, let us not forget, will be reaped by those on Earth. Not only will knowledge of the Moon and Mars teach us a lot about our own planet, but the challenges to be overcome, starting with the survival of the crew, will impact us directly. It is highly likely that the experiments involved in these missions, on the human body and telemedicine, among others, will contribute more widely to medical progress on disease and ageing.

FOREWORD

by PATRICE CAINE

MANAGING DIRECTOR OF THALÈS, CHAIRMAN OF THE ASSOCIATION NATIONALE DE LA RECHERCHE ET DE LA TECHNOLOGIE (ANRT)

Since the first Greek philosophers in the 6th century B.C., the Moon has been a constant source of fascination for human beings and sparked our thirst for knowledge. Galvanizing enthusiasm and catalysing innovation, the exploration of our natural satellite has also been at the centre of major geopolitical and industrial interests since the second half of the 20th century. At the point where several powers are embarking on a kind of race to the Moon, it is vital to question Europe's role in this new setup. What are the continent's potential ambitions, what form should they take, and what means do they involve ? These are some of the questions to which ANRT's work provides some exciting answers for all of those interested in the place of the Old Continent in the future of the space age.

FOREWORD

by THOMAS PESQUET

ASTRONAUT AT THE EUROPEAN SPACE AGENCY

For the last ten years, I have witnessed first-hand the accomplishment of a major international space ambition : the Space Station. I see, in situ, space fulfil its potential, resulting in benefits for society beyond expectations for the nations that decided to embark on this incredible adventure twenty years ago. Today, it is time to make an even better future possible by ensuring that Europe takes part in this ambitious journey of discovery and exploration, for the sake of future generations. A return voyage to the Moon for the long term, with peaceful ambitions of scientific discovery, is the human adventure that will catalyse European technological capacities and accelerate progress in our societies. It is in tackling difficult but fascinating projects that European nations, countries of explorers, have excelled the most : tomorrow, European engineers and astronauts and all the people involved in these missions aimed at our satellite will have the chance to make the continent more unified, taking it further and higher than ever before – an opportunity that must not be missed.

EXECUTIVE SUMMARY

We are campaigning, with a sense of urgency, for a clear, immediate European commitment, not just to travel in the cislunar orbit, but to settle on the Moon for the long term. The race has already begun, the cards are being dealt, and the Moon is back at the centre of space geopolitics and on the agendas of established and emerging private companies in the sector.

Europe's future, both on Earth and in space, also centres on the Moon. The race is on, and Europe needs to rapidly secure its place around the table of lunar explorers. More than 50 years after the end of the Apollo era, our satellite is once again galvanizing the geopolitics of space : lack of involvement, or too little involvement, would undermine European influence in international relations, and diminish the sense of pride of belonging to Europe.

The Moon brings an inspiring, mobilizing, federating opportunity for our continent and its industry. Harbouring as-yet unknown resources, the Moon is both a challenge and an open door to numerous possibilities for European industry as a whole, extending way beyond the space sector.

Destination Moon can be part of the European economic and political recovery, acting to catalyse breakthrough innovations and respond in a totally new way to lunar and earthly challenges. At stake for Europe are its freedom of choice, its power, and its strategic influence in a scientific, technological, economic and geopolitical competition, along with its social model and its confident forward-looking towards the future and human values. Europe must take part and present itself as a power with a difference, based on synergy and inclusion, in line with its identity, and compatible with international cooperation, interdependent on equality.

This inspiring opportunity for the young generation can manifest the importance that Europe places on sustainability, peace, and a common effort for the benefit of mankind. Europe is demanding in terms of its positions, and has the capacity to temper the sovereign appetites of other space powers by proposing a new way forward that is more inclusive and holistic.

For Europe, the Moon is a project for the future that needs to mobilize young generations and European talents, attracted to the immanence of this new ambition, its demanding nature, and the way it meaningfully fits in with the times, acting to serve the times.

The recent multiplication of lunar projects raises the question of the collective governance of these ambitions, both on Earth and towards the Moon. The launch of a European lunar ambition and its sustainability call for more fluid European space governance. In the face of a compartmentalized, fragmented European space sector, both private and public, our collective recommends creating an Alliance for Lunar Europe. The aim is to offer Europe an area for dialogue and project creation involving stakeholders from different backgrounds – public actors, private actors established in the space sector or otherwise, along with citizens and civil society actors – gathered around the European lunar ambition.

As a challenge for civilization, the exploration of space involves analysing its ethical aspects and its relation to society. This perspective is all the more important given that the lunar ambition takes shape following a pandemic that has marred relations between science and society, further undermining expert opinions and conffience in progress. The pressing needs and challenges facing our contemporary societies mean that this lunar project is taking place in a very different society from that of the Apollo era. This lunar project will only make sense if it is global and responsible, and Europe can propose a different approach, and dare to ask why. Europe could make the lunar ambition a meeting ground of its key values : humanism, excellence, cooperation, peace, audacity, responsibility, durability and inclusiveness.

Moon bases on the surface spark the imagination, represent a challenge for science and engineering, and more broadly, raise societal questions. The design and implementation of the base are the technical, organizational and architectural translation of a social system based on cooperation and interoperability. The interoperability of the components installed will in fact be a critical point, to be unwaveringly defended with the establishment of standards covering all the material and functionalities of the living base. The design and implementation of the Moon base will imperatively integrate sustainability and circularity, centred on a holistic principle of coexistence integrating humans, technologies and environment. This same priority of sustainability also means designing the lunar habitat with an Earth-Moon outlook, in which lunar innovations have future earthly applications.

Sustainability should constitute the key value of the European lunar momentum, and the exploitation of the Moon's resources needs to be viewed from this angle. The most promising hypothesis of in situ resource utilization (ISRU) involves using lunar resources to produce fuel and supply space objects. ISRU thus limits the quantity of materials and equipment to be transported from Earth : to travel further, remain longer, refuel space vehicles and therefore increase their lifespan, and consequently reduce the overall cost of missions and space debris. The technological challenges of extraction and exploitation, and mapping, require the immediate coordinated involvement of interested industries (mining, refining, observation/prospecting, logistics, etc.).

Although massive public investment will initially be required, the development of viable economic models made possible by the exploration and sustainable exploitation of the Moon will mobilize space and non-space industries for durable presence on the Moon, facilitating the long-term construction of a true lunar economy that closely involves the private sector. Like recent developments in the space market, this economy will be the result of a synchronous movement to privatize and commercialize space applications. The future economic benefits generated from the

exploration and exploitation of lunar resources and from learning to evolve on an "extra-terrestrial" site, are one of the main motivations behind returning to the Moon.

The installation and utilization of an expanding human base on the Moon constitute a totally new strategic asset that needs to be made secure. This protection calls for a holistic conception of security. More precisely, the assets that need securing are the astronaut crew, the infrastructure that houses them and allows them to carry out their missions (habitation and working modules, lunar vehicles), and their scientific experiments, the means to carry them out, and their results. This security is not at all incompatible with peaceful, pacified exploration of the Moon. The protection of astronauts and scientific assets could also be a place for learning, anticipating and apprehending new conflicts generated by space exploration.

THE LUNAR AMBITION
A GLOBAL AMBITION

When the first missions of the 21st century land on the Moon in the near future, they will follow on from a dual heritage. An ancient heritage first of all : that of a very human desire to explore Earth and then space. And then a more recent heritage : that of the first human missions on the Moon in the last century, when a total of twelve astronauts put foot on the Moon. Since then, our relationship with space has changed considerably. Space is now indispensable for the operation of Earth activities through the numerous satellites positioned in low orbits, and it will continue to develop. The new lunar ambition, as in every major human era, fits in with its times and acts to serve the times.

LUNAR AMBITION AND THE 21ST CENTURY

On 20 July 1969, Apollo 11 landed on the Moon, and a few hours later Neil Armstrong joined the ranks of heroes when he uttered the most famous words in space history, *"That's one small step for man, one giant leap for mankind"*. Yet it was not just a small step for mankind, because it took thousands of years to get there. As Roland Lehoucq reminds us, the technique is easy, the difficult part is society. Broadcast live on televisions around the world, the first human step on the Moon took place in the midst of the Cold War. The Moon was certainly a key step in global space exploration, but for the United States, it constituted a demonstration of power to the Soviet Union. To achieve this economic feat, the Americans spent (almost) without counting. The Apollo programme was carried out

under great pressure and at phenomenal speed during a post-world war era that championed heroism, the value of risk-taking, and the race to conquer space.

Most probably – caution being the watchword – by 2024-2025 human beings will have returned to the Moon. But the situation is very different. The United States-Soviet Union Cold War ended with the fall of the Berlin Wall, and the world is no longer bipolar, but divided between several continental powers. Alongside the historical players, the United States, Russia and Europe, the geopolitics of space now includes new states in the shape of China, India and the United Arab Emirates. The fact that these powers are newcomers to space does not mean that they have less sophisticated technology : China, in particular, is entering into the new global space ambition equipped with top technological capacities and rigorous planning. At the same time, the economic parameters of the space sector have been upset by the dramatic entrance of New Space players. These include Space X, responsible for constructing the US landing system in the Artemis programme, and NASA's SLS space launch system, designed to launch the Orion spacecraft.

This new geopolitical and economic order is set against a background of critical challenges on Earth. Humanity, on its Earth ship, is facing the consequences of climate change provoked by its own activities. Young generations are calling for a fundamental questioning of how human activities impact nature. But this same situation establishes sustainability as a key value of space exploration, at a time when the space sector is becoming aware of the dangers that it has inflicted on itself by postponing the management of space debris. This new paradox between protecting the Earth and the desire for exploration means that democratic states are treading very carefully, and the space sector faces a conflict between societal and budgetary positioning.

These challenges should not be seen as obstacles to future projects. Audacity is the key factor of a desire for the future, a long-term vision that ignores neither the Earth nor remote exploration, a stimulus for human ingenuity in line with the times.

The spirit of the lunar ambition has thus been revived. More than a challenge, it is now a reasoned ambition – despite being rekindled by the most unpredictable of US presidents. The Moon is no longer a destination, but a place to explore with a potential for discovery. Human beings are returning to the Moon to stay. A testing ground a few days' journey from the Earth and a few seconds of radio signal away, the Moon is seen as the laboratory of human space exploration towards Mars and beyond. The establishment of a gradually expanding, long-term base camp is the common denominator of the two most promising lunar ambitions – that of the USA with the Artemis programme, and that of China and Russia with the ILRS. Go to the Moon to stay, go to the Moon to explore it, go to the Moon to go beyond, into orbit or outer space : these are the three main axes of the new lunar exploration.

LUNAR AMBITION WITH EUROPE ON THE START LINE ?

Artemis and the ILRS show that the space powers are globally positioning themselves on the lunar ambition. *"All of them ? No ! Because a continent of irreducible Europeans still hasn't positioned itself."* [1]

All eyes were turned towards the Moon when in 2019 the then US president, Donald Trump, proudly announced that the Americans would return to the Moon in 2024. Clearly a date chosen to correspond to the end of his coveted second mandate more than an official NASA estimation. A more detailed analysis of the history of US programmes

1. Liberally paraphrased from the Asterix comic books, inspired by the fact that one of the first French satellites was named Asterix.

nevertheless reveals that President Trump was reviving a project rather than initiating one. The US lunar ambition of the 2000s in reality dates from 2004, when President Bush announced the launch of the Constellation programme, which went on to be stopped by the Obama administration in 2021 just as the development of the Ares I and Ares V launchers was in full swing. The traditional US space industry was served a double blow : the halt of the space shuttle, and the end of the programme (giving a boost to Space X, which was making great headway). The US lunar programme was therefore at a standstill. But that was before the arrival of Donald Trump's Make America Great Again : returning to the Moon would put Americans ahead of China, whose space ambitions were firming up, and at the same time support the national space industry (reopening testing facilities like the Stennis Space Centre in Mississippi). Unlike Apollo, the new lunar ambition is driven by a stronger partnership between private companies and NASA. In April 2021, Space X was commissioned to produce a moon lander, which led Blue Origin, the space company owned by Amazon founder Jeff Bezos, to file a lawsuit against the decision.

The new US lunar ambition also involves proposals for bilateral signatures of the Artemis Accords. These agreements were drawn up by NASA and the US state department to establish a cooperation framework for the civil and peaceful exploration of the Moon. They lay down a number of principles accepted by both the signatories of the Accords and NASA, based on a US interpretation of the 1967 founding treaty. To date, Australia, Canada, Korea, New Zealand, Brazil, Ukraine, the Emirates, Japan, Luxembourg, Poland, Italy and the United Kingdom have signed. However, the bilateral Artemis Accords reveal a US ambition for leadership and hegemony in the new race to the Moon.

To the East, China and Russia have taken up a joint position.

US technological and space policies have always been highly mistrustful of China. The fear of technological transfer or Chinese industrial espionage has always led Congress and US intelligence to curb or even prohibit cooperation between China and NASA. When the two space powers do collaborate, it is generally to provide assistance (e.g. photograph by the USA for China of the Chang'e-3 probes in 2013 and Chang'e-4 in 2019). The Chinese have therefore launched a parallel, if not competing, lunar exploration project. The Communist power, sticking to a rigorous schedule, aims to establish a permanent base near the south pole of the Moon (not far from water resources). To do so, the Chinese space agency is developing a super heavy-lift launch vehicle, the Long March 9, the equivalent of the US Starship and SLS.

In pursuing its lunar ambition, China can rely on a solid ally that is a lot more willing to cooperate : Russia. This established space power, which inherited the Soviet space conquest, has moved away from its cooperation with the USA in recent years. Initially involved in the Lunar Gateway project, a lunar orbital station, Russia has opted to reduce its participation in a project presented as too centred on the USA, according to the director of the Russian agency, Roscosmos. At the same time, Russia lost its monopoly of conveying astronauts to the ISS when the USA entered the market of human transport flights with Space X.

The Russians and Chinese have thus joined forces to work on a project presented as an alternative to Artemis, called the ILRS. Announced at the Global Space Exploration conference in Saint Petersburg in 2021, the project presented by the agencies of the two countries aims to establish a research station on the Moon. Taking over from the Russian probes Luna (25 to 27) and Chang-e (6 and 7), the automated construction elements of the base are scheduled for installation on the Moon in 2025. The first cosmonauts and taikonauts are likely to land on the Moon by 2036.

Compared to these two ambitions, European efforts come across as somewhat feeble. Although back in 2015 the ESA, through its director general, promoted the concept of a Moon Village, for the moment the project remains pure conjecture. Yet European involvement in lunar projects is not inexistant. The ESA is contributing to the US spaceship Orion with its European Service Module (ESM). In addition, with Thales Alenia Space, the ESA will deliver its i-Hab and ESPRIT modules to the US and international Lunar Gateway station. These European programmes will also secure three places for European astronauts travelling to the Lunar Gateway.

Although some European states have already signed the Artemis Accords, many are still very hesitant. Their concern is that signing with the Americans would be seen in a bad light by the Chinese and Russians at a time when Europe is aiming to be a realm of space cooperation. The space sector continues to hesitate between a position of partner-contributor or leader of a European ambition. Nevertheless, positions are bound to change, and the different nations seem to want to reinforce Europe's role in the space domain, as shown by the reactions to Russia's destructive strike on one of its own satellites in November 2021, and the Matosinhos Manifesto of the same month, giving the ESA a mandate to develop a whole series of projects. In the words of ESA Director General Josef Aschbacher, the manifesto expresses the strength of *"a united Europe to deliver services to its citizens by accelerating space for the betterment and advancement of its people and of the planet overall"*. The manifesto commits the European space industry to focus on three initiatives, called "accelerators". The first involves starting to work towards *"space for a green future"*, the second involves developing a rapid, resilient crisis response system to decisively act on crises, and the third involves protecting European space assets. The manifesto also includes two *"inspirators"*: a sampling mission on the Moon and the inhabited exploration of space.

LUNAR AMBITION AN OPPORTUNITY FOR EUROPE

Committing to the lunar ambition is all the more important for Europe because our natural satellite represents a real opportunity for our continent. The reason that it is urgent for Europe to take part in the race to the Moon is not to imitate other space powers, but to contribute its talents, vision and values alongside already committed nations. This position requires a shared vision common to all European Member States following an ambitious roadmap, intelligently distributed throughout the value chain, from R&D to industrial policy and sound implementation. This ambition will require a legal and economic infrastructure capable of stimulating this new ecosystem, which has very high potential in terms of innovation and job creation, likely to inspire talented people, and particularly young people. The millennium generation is behind an essential requirement for the Moon project: What is the meaning of this project for today and tomorrow, for Europe, and for the world, in the face of current challenges? This same generation intends to take advantage of the European recovery, both economic and political, to think and act differently, including regarding space.

The challenges represented by the Moon create an occasion to mobilize scientists, innovators and entrepreneurs beyond the established actors of the European space industry. This involves increasing the scope of possibilities and generating collaborations between space and non-space industries, with double benefits for competitiveness, security and European sovereignty.

The European space industry possesses cutting-edge expertise and skills, both in sectors already involved in the space ambition and in sectors for which space exploration constitutes a market of the future. Mobilizing

these actors within a European lunar economy is a key dimension of the success of a European project. From launchers – on which France has valuable assets – to landers, and including observation of the Moon, telecommunications, health and nutrition, European industry will necessarily take a piece of the future Moon market and innovations useful for Earth. Obviously, establishing this kind of lunar economy will take some time. Nevertheless, Europe must urgently make a clear commitment to a lunar ambition in order to mobilize its research and industry to profit from the long-term benefits and ensure its sovereignty.

Europe benefits from top-ranking global scientific research that can be turned to innovations for the Earth and the Moon, cutting across disciplines and federating energies that are all too often compartmentalized or drained towards the USA or Asia. The Moon is also a scientific research opportunity in itself, including microgravity and its potential, improved knowledge of the Moon – a real open-air archive of our solar system – and space communication. Lunar exploration is therefore at once scientific, economic and geostrategic.

European strategic autonomy is also at stake. Committing to a European project, a European value chain, and the promotion of European companies means ensuring that the continent occupies a strong position vis-à-vis other space powers, today and tomorrow. But it also means possessing the necessary resources to drive an autonomous project that avoids export controls imposed by other commercial partners. This innovation autonomy would allow Europe to both maintain its freedom and put forward interoperability as a key principle of the design of space applications for the benefit of humankind.

We are campaigning, with a sense of urgency, for clear, immediate European commitment, not just to the cislunar orbit, but more precisely to land and settle on the Moon for the long term. The race is already on.

This white paper is about this commitment and this strategy.

APPROACH AND METHOD

The European lunar ambition must be approached at the interface of several strategic themes. This Destination Moon White Paper is situated at this interface, bringing together the following six core themes : governance, industrial and economic strategy, ethics and society, exploitation of resources, habitat and life support, security and defence.

The Moon, a European, intersectoral ambition

The race to the Moon is on, positions are being taken, the cards are being dealt. This new lunar momentum, this new stage of exploration, involve a wide variety of actors. The space sector is now made up of established states and newcomers, traditional industries and recent private players ranging from start-ups to multinationals. For Europe, the challenge is to align different but complementary expertise and interests to work on a common roadmap to position Europe at international level. Europe must widely mobilize its leaders, industry and citizens around the lunar project; this committed mobilization is the condition for succeeding in its ambition.

This same ambition transcends borders in technological and scientific sectors with a call to act at intersectoral level. The Moon is not a just a destination to reach, but above all a field of exploration and exploitation with as yet unknown potential. All space and non-space sectors can find an interest and sources of development. Their coordinated mobilization is one of the first key steps of the lunar project.

The race to the Moon as an exploration initiative is also a civilization issue at a time when social and environmental responsibility are paramount. Europe has a contribution to make in this future narrative. Working together on a lunar ambition is a project that goes well beyond science. It questions its fundamentals, it organization, its relation to society and to the future. Questioning settlement on the Moon should therefore involve a resolutely interdisciplinary approach that promotes values.

The watchwords of a viable lunar strategy are therefore cooperation, intersectorality and responsibility ; three terms at the heart of our approach.

The Moon, an intersectoral thinking process

In 2021, ANRT organized thinktank groups to work on the six themes featured in this white paper. Each group was made up of space and non-space experts, reflecting the public/private intersectoral spirit typical of ANRT activities. For each theme, several structuring axes, strategic objectives and mid-term scenarios were put together. Exchanges of views and discussions during sessions led to the establishment of a coordinated strategy.

MANDATES OF THE WORKING GROUPS

Before starting out on six months of work, the groups received the following thematic mandates :

GOUVERNANCE WG (GWG)

MANDATE IN BRIEF : This group's mandate is to study the governance models of the human lunar momentum. It will tackle the question of the best institutional policy and governance for the emergence then long-term establishment of the European lunar ambition. The position of France and the EU in the global space power game could be discussed. In addition, this group will look at the question of law applicable to lunar activities. Although this is not the main object of its mission, it could take a stand on the Artemis Accords. It could also look at the question of relaunching a multilateral negotiation on an international or European scale aimed at defining revised or new principles governing the human lunar momentum.

INDUSTRIAL AND ECONOMIC STRATEGY WG (ISWG)

MANDATE IN BRIEF : The work of this group will be to study, at a macro-economic scale, the industrial and economic policies that could initiate then establish a European lunar momentum. The group could also take inspiration from Zenon Research studies carried out in collaboration with ANRT. It could for instance look at historic examples of major projects requiring unprecedented efforts in terms of infrastructure or innovation.

ETHICS AND SOCIETY WG (ESWG)

MANDATE IN BRIEF : This mandate has a triple objective. First, it will attempt to identify the "motivational whys" behind the human lunar ambition. It will then attempt to pinpoint

the societal impacts and ethical questions at the heart of the European lunar momentum. Lastly, it will define ways to ensure that this same project can be understood and desired by public opinion. Put simply, this group's mandate centres on the pedagogical side of the lunar project.

HABITAT AND LIFE SUPPORT WG (HLSWG)

MANDATE IN BRIEF : This will involve the crucial question of the lunar habitat. It will study the conditions for making life endurable on the Moon for the dozen humans present on site. This definition of "endurable life" will consider more than simple biological questions, and look at the mental health of humans present on the Moon and the inherent human risks.

EXPLOITATION OF RESOURCES WG (ERWG)

MANDATE IN BRIEF : To avoid overlapping, the approach of this WG will be to work by combining catalogues of existing resources with their mapping, in order to mirror them with their potential scientific and/or industrial exploitation.

DEFENCE AND SECURITY WG (DSWG)

MANDATE IN BRIEF : This group will study the protection policy for the scientific and technical potential of France regarding the Moon, the protection of the "Destination Moon" project, along with questions of dual-use research, armament and lunar military cooperation.

governance

MEMBERS OF THE GROUP

Arthur Sauzay : coordinator
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GOVERNANCE

The Moon is back at the centre of space geopolitics, with the major space powers (China, USA and Russia) reaffirming their lunar ambitions, and the emergence of new players, including not just states (India, United Arab Emirates) but private companies. The recent multiplication of lunar projects raises the question of collective governance of these ambitions, both on the Earth and in the lunar environment. The question is all the more important given that projects are aiming at short-term horizons within the next two decades. On this playing field, the USA, with its Artemis Accords and "Moon To Mars"[1] strategy, is building an international network of cooperation for its lunar project. The Chinese-Russian cooperation is defining the shape of its own project. In this situation, France and Europe must take a common stand on governance issues if they intend to drive their own lunar ambition. And this ambition involves a governance issue on two levels : governance of voyages towards the Moon, and governance on the Moon.

The work of the Governance Group has mainly focused on the first question. This is because shifts have taken place in recent months concerning the governance of voyages to the Moon, in other words the way that public and non-public actors interact to define lunar space policy. Once the USA and China-Russia had announced their respective ambitions, they rapidly equipped themselves with mechanisms to formalize these ambitions, with respectively the Artemis Accords and the International Lunar Research Station. In contrast, the European lunar project has not yet been defined, in a situation of highly fragmented dialogue between the different areas of European space

1. Moon projects (Lunar Gateway, Artemis programme) that will serve as stepping stones for an inhabited programme towards Mars in the 2030 decade.

governance (EU institutions, European Space Agency, ministries, parliaments and national agencies, traditional industries and new entrepreneurs, consultancy firms and expert groups, citizens associations, etc.). The internal organization of Europe is a central issue that conditions the continent's capacity to think of itself as a space power and influence the activities, rules and values that will govern lunar activities in the coming years.

Although the group concentrated on European governance of voyages to the Moon, it also underlined the risks of creating a Moon governance that does not feature Europe. The 1979 Treaty set out to create specific rules for the governance and exploitation of the Moon, but it has not been ratified by the main space powers. More recently, the entry of the private sector and commercialization projects for space resources, supported by new legal frameworks (in the United States, Luxembourg, the United Arab Emirates and Japan) could weaken some of the key principles featured in the five main treaties forming the heart of international space law, and therefore the very principle of multilateral management of space activities. Yet to date, the legal framework of a Moon governance seems particularly incomplete. While a new agreement on the Moon currently seems compromised, global-scale ambitions for domination, and the strategic and economic interests they carry, make an exacting text more difficult.

The emergence of the Artemis Accords is symptomatic of the era in which the Moon project is evolving. As the space industry becomes polarized once again, Europe, which has always put itself forward as a major player in international cooperation, must take a stand. The partial

withdrawal of the Russians from the "Lunar Gateway" Moon station, judged as too centred on the USA, is another example. In this fragmented situation, Europe needs to question its own strategy in terms of governance aimed at the Moon.

Lastly, apart from its organizational capacity, Europe's strength in governance on the Moon will also depend on the capacity of its public and private stakeholders to develop a presence on and around the Moon, in other words, its capacity to affirm itself as a fully-fledged participant in the new global race to the Moon.

To help trigger a true European lunar impetus, a strategic objective for the continent, the working group bases its recommendations on a European alliance for the Moon, outlined below.

1

DEBATES AND DEFINING DIRECTIONS

GOVERNANCE AND LEGITIMITY

Unlike other contemporary ambitions (digital, climate, ecological and energy transition, etc.), Moon-related challenges are mostly absent from the current European public debate. Although the space sector has increasingly featured on political and media agendas since the arrival of Thierry Breton at the European Commission and the new director general of the ESA, Josef Aschbacher, the Moon tends to take a back seat. The lunar ambition suffers from a lack of legitimacy that must urgently be addressed. The construction of this legitimacy is also the object of other chapters.

To create the legitimacy of the lunar ambition, three conditions need to be met. The first two concern the politization and mediatization of lunar issues. The entire chain of public and political relations in the sector needs to be rethought and reinforced. Exploration of the Moon needs to be put forward as a subject of debate and a specific objective, both in media targeting the general public and within national and European public institutions. With support from experts in the sector and popularisers, lunar exploration and the different underlying projects must be debated in national and European democratic spaces, primarily parliaments, and also aimed at the public space through assemblies, debates and citizen consultations. The involvement of organized civil society, especially general public media (traditional and new), is vital to build and organize this public space. The strong point of the Space X company is that it presents every one of its innovations – and even its failures – as an interesting item of information.

Including the lunar debate in general public media programmes would undoubtedly move it closer to the political agenda.

To this end, 2022 (with a French presidential election, French presidency of the EU, the ESA-EU Space Summit, the ESA Ministerial Conference, etc.) will be decisive to lead this politization of the lunar ambition. Moreover, the politization of lunar exploration would also ultimately increase and secure the budgets allocated to it : the manifestation of political interest being, as a last resort, budgetary. We know how the ISS has suffered from budgetary uncertainties, perpetuated year after year, even though this type of project needs long-term budget security to attract private investments. The project of a treaty for an international Moon base should be more demanding than article 15 of the IGA (intergovernmental accord for the ISS) and thus guarantee durable financing, both public and private.

On a different note, the third condition that will consolidate the legitimacy of the lunar ambition is its capacity to incarnate European values. In this area, the European conception of lunar governance could be based on three pillars : multilateral, inclusive management of the Moon; resolution of conflicts; and promotion of sustainable management of the Moon, in other words, a project in line with protecting the climate of earthly ecosystems. Places of extra-terrestrial cooperation, like the ISS, have demonstrated their importance in peaceful inter-state relations. The lunar base would be an additional place of international cooperation that would initially be scientific but would also guarantee untroubled diplomatic relations. These large cooperative projects are arenas for building common management of common global projects : a capacity to jointly tackle issues that still needs to be developed to overcome climate and social challenges. Europe will need to put itself forward as a demanding partner to

ensure that the directions taken to explore the Moon are pursued in full awareness of environmental constraints and to overcome these major challenges for humanity now and in the future.

In addition, in order to consolidate the legitimacy of the Moon project, it is vital to involve organized civil society (the media, business, associations) and in particular citizens – voters and taxpayers – in the thinking process. Citizens' priorities and communication codes have changed since the first Apollo missions. Two years of pandemic have weakened the bonds between science and society (cf. chapter on ETHICS AND SOCIETY). The question of investing in space, in particular to settle on the Moon, is not self-evident for the general public. On the one hand, much remains to be done to re-establish connections between major space discoveries and the aspirations of European citizens deeply concerned about earthly problems ; on the other hand, it will be much easier for policies to take on the lunar ambition if it is an important issue for the electorate. Involving civil society and making informative efforts to explain the context, challenges and risks constitutes the only way to avoid an outright rejection of the project, perceived as unimportant, or even incompatible with expectations on sustainable development.

GOVERNANCE AND UNITY

At European scale, the issue is not so much to invent a new space policy as to update the way it is organized. Despite growing cooperation between the ESA and the European Union, the continent's space sector is subject to two types of fragmentation.

The first is a vertical fragmentation between European space governments and a large number of industrial actors and start-ups. In this latter area, Europe has

successfully fostered champions in the sectors of launchers, telecommunications, and Earth observation. Nevertheless, Europe's space sector has not yet succeeded in mobilizing this ecosystem to fuel its own lunar ambition, despite several actors participating in the US Artemis project and the Lunar Gateway. The second form of fragmentation is horizontal. The framework of European space governance is unclear (states/EU, EU/ESA) and the EU has limited margins for manoeuvre in the space sector. Article 189 of the TFEU only grants the EU with a residual jurisdiction without any real levers to lead a lunar strategy supported by the necessary budget. Joint action between the EU and the ESA in clear fields of action with clear cooperation mechanisms could nevertheless drive this same lunar strategy. While the ESA has the capacity to ensure the operational side of missions involving the Moon, on a political level the EU could incarnate a long-term lunar vision.

The lunar ambition can thus reduce this double fragmentation by clarifying the role of the different levels of European space governance, as is already the case for the programmes Galileo (satellite navigation system) and Copernicus (Earth observation), driven by the EU (EUSPA) and the ESA through partnership agreements.

Yet while the lunar ambition needs to foster European unity on a project and values, the aim is not to centralize space governance along the lines of the US and Chinese models. The specific features of European governance should generate more flexible models that are nevertheless sufficiently mobilizing to trigger real momentum at European scale. This is the philosophy of the proposed alliance.

2

SCENARIO

SCENARIO: A EUROPEAN ALLIANCE FOR THE MOON

objectives

The scenario recommended by the governance group is an Alliance for Lunar Europe, which could be called the "Blue Moon Alliance" (BMA). Integrating the blue colour of the EU flag obviously does not point to any kind of appropriation of the Moon, but rather indicates the EU's ambition to be a stakeholder in the lunar momentum and to bring along its values[2].

The BMA aims to give Europe a space for dialogue and for conceiving projects involving stakeholders from different backgrounds gathered round the European lunar ambition (ESA, national space agencies and ministries, EU institutions, members of parliament, traditional companies and entrepreneurs, investment and capital-risk banks, non-governmental organizations and citizens' associations). The aim is to bring together four groups : European space states, European space institutions, space and non-space companies, and the general public. This alliance will improve the flow of European space governance by putting actors round the table who will coordinate their action and then drive a common strategy at their scale. This European principle of subsidiarity has proved effective in other sectors, such as the European "GAIA-X" cloud, the European Green Digital Coalition bringing together states and digital companies to find sustainable solutions[3], and the European Battery Alliance, etc. This confirms that projects that are both technical-scientific and political are possible, but that they require industrialists and public actors to agree on the objectives, more dialogue, and wider use of public-private cofounding mechanisms and partnerships

2. The US company Blue Origin pilots a lander project called "Blue Moon", but this is not an obstacle to using the suggested name, since the scope is clearly much broader.

3. https://digital-strategy.ec.europa.eu/en/policies/european-green-digital-coalition.

between states and industries. These same mechanisms will be central to the development of new economic models combining the space and non-space sectors. The initial engagement of national or European public financing remains indispensable to encourage private actors, already sensitive to potential markets, to invest in these projects in the very long term. Funding of the Alliance will reflect the diversity of the potential economic models and stakeholders.

A crucial point for its acceptability and effectiveness in the current context, the BMA will not act as a kind of "contra-alliance" against the United States' Artemis Accords. In fact, several European states have already ratified the US bilateral accord and others plan to do so. The aim is to create the conditions for lunar project specific to Europe capable of influencing the geopolitics of space and the Moon.

implementation

The BMA would be launched at the initiative of at least two EU states, such as France and Germany, and then involve other states, companies (space and non-space, traditional and NewSpace), organized civil society actors (NGO's, associations, universities), etc. Gathered at a European Lunar Conference in 2022-2023, these parties would launch the Alliance with a joint founding declaration. This initiative would therefore above all be political.

The Alliance would regularly meet in forums to jointly define and develop the European lunar strategy. It would not aim to limit the jurisdiction, sovereignty, or strategic autonomy of its members. Instead, concerning in particular states and space agencies, it would aim to foster internal dialogue before the conclusion of any agreements with non-European actors. For companies and civil society actors, the aim would be to increase the visibility of projects and skills existing on the continent.

The BMA should also make concrete the multilateral perspective put forward by Europe. Initially European, in a second stage it could make partnerships with other non-European states. For example, African states emerging in the space sector could join the Blue Moon Alliance.

benefits

The first benefit of this alliance would be to make the lunar challenge credible in the eyes of actors who do not necessarily believe in it today. Public, collective affirmation that Europe must be and wants to be part of lunar governance will also encourage companies, including those absent or marginally present in the space sector, to develop projects involving the Moon. For civil society and citizens, this new arena would foster information and debate on the issues and their compliance with expectations in terms of socio-economics, sustainable development, and collective security.

The Alliance would create the conditions for a European lunar momentum by positioning the Moon as a key issue for Europe regarding the projection of its values, the future of its civil society, and the dynamism of its innovation and talents.

Lastly, another benefit has already been evoked in the very definition of the principle behind the Alliance : to decompartmentalize the European space sector. By providing a space for dialogue and projects in which European lunar strategies can be debated, it would act to reinforce European space ambitions currently floundering in the face of acceleration by other players, in particular American and Chinese.

3

STRATEGIC OBJECTIVES AND RECOMMENDATIONS

STRATEGIC OBJECTIVES

- **Politicize the lunar ambition.** The space sector needs to get back on political agendas, and politics need to get back into the space sector. Space exploration saw its finest hour when political and scientific agendas centred on a common ambition. As our societies face new challenges, the space sector needs to break down more barriers and demonstrate how it can serve society, though its multi-area applications that are known today and remain to be discovered tomorrow. It must reconnect with politics and dare to move closer to citizens. The space sector is indispensable for all of us who currently use its applications. Making space a societal issue again means putting the lunar ambition back on political agendas.

- **Found European lunar motivations on European values and identity.** A European ambition to return to the Moon should not be about following or imitating others. On the contrary, Europe should set off to the moon armed with its values and its identity. Europe does not need to choose sides, but it can, or should, embody a singular path : multilateralism, pacifism, democracy and sustainability are crucial. Europe must hold up sustainability as the guiding principle of its space policy, starting from the conception of its projects.

- **Involve and extend the space ecosystem to European scale taking an intersectoral approach.** The Alliance should diminish current frontiers. This will involve mobilizing European space companies and opening the door to new actors and companies from outside the space industry that can bring their expertise and projects. This encourages vocations, especially scientific, and generates highly skilled jobs with applications that go far beyond space (health, environment, energy, communications, transport, etc.).

OPERATIONAL RECOMMENDATIONS

- Europe must declare its ambition to be proactive in the exploration and then governance of the Moon. It must reaffirm the values that should structure current and future lunar momentum, in particular a multilateral approach and sustainable development.

- France, Germany and Italy, in particular, should act to initiate European exploration of the Moon and a lunar conference in 2022, a key step in the creation of the Blue Moon Alliance.

- Those involved in initiating the preparation of the BMA could also, in a first stage and to guide its work, launch regular “Eurobarometer” or “focus group”-type studies on lunar issues to sound out the level of interest of European citizens.

- France should support a position favourable to new multilateral negotiations of texts to add to the existing body in order to avoid crystallization of the USA/China-Russia opposition. These texts should take into account changes

in the space sector and diversify their panels (as is already the case in some key international legal organizations)..

- France could support the modification of European regulations (e.g. article 189 of the TFEU) to grant greater margins of manoeuvre to the European Union in implementing space policies.

- Those involved in setting up the BMA could, over time, produce a European Citizen Convention for Space Exploration that could be a long-term source of recommendations.

- Take a prescriptive approach to promote greater funding for R&D programmes on space and the Moon.

- Finance documentary, recreational and artistic programmes on the European exploration of space, based on the US model.

ethics and society

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ETHICS AND SOCIETY

A challenge for civilization,

the exploration of space needs to be analysed in terms of ethics and its relationship to society. This analysis, which is all too often a "cosmetic" part of the thinking process, merits our attention on two counts. First, because lunar exploration, which is primarily a scientific, technical project, will follow on the heels of a pandemic that has marred relations between science and society, further undermining expert opinions and confidence in progress. Second, because this new race to the Moon is taking place in a very different context from that of the first Apollo missions. At the time, during the decades from 1960-1980, progress was centred on technology, and then at the turn of the 21st century began to take on more anthropogenic dimensions related to innovation revolving around usages.

The new race to the Moon faces new challenges related to geopolitics, climate, socio-economics, society and health that require building new international solidarities ; progress and innovation are now mostly centred on climate and the equilibrium of the planet's ecosystem. Recent events in the world have damaged the halo that used to surround science and technology, breaking the promise of human progress.

The lunar project only makes sense globally : in gathering all nations to work on a common project, pursuing knowledge and exploration of the outskirts of Earth towards outer space, it provides an occasion to put international solidarity to tackle tomorrow's challenges, including climate and demographic change. Fitting this lunar project into this context and working for the good of this context is not only a positive externality, it is imperative.

All of the above elements raise a fundamental question concerning what meaning to give to this lunar momentum, which constitutes the core focus of the Ethics and Society working group for the Destination Moon white paper.

1

DEBATES AND DEFINING DIRECTIONS

DARE TO ASK WHY

Space exploration projects, and agencies' agendas in general, are usually dictated by scientific and industrial considerations. While the pragmatism of these considerations is unquestionable, the European lunar approach needs to be centred on identifying less utilitarian motivations and seeking out a true holistic purpose. The announced projects, IRLS and Artemis, serve an industrial, scientific agenda comprising geopolitical and commercial ambitions. In other words, business as usual. In the definition of its lunar motivations, Europe can dare to add more humanist dimensions to the scientific, geopolitical and industrial contingencies. To make the voyage in order to convey an enlightened, rational humanity puts values and acts at the foundation of the European ambition.

To pursue this ambition, Europe will point out, in compliance with the 1967 Treaty, that space, including the Moon and other celestial bodies, are a perquisite for humanity and therefore at the heart of a necessarily global enterprise. The tragedy of the commons brings a warning of what could occur on the Moon in the absence of coordination: overexploitation, pollution and sovereign predation. All the more so given that the benefits of lunar exploration are intended to benefit the whole of humanity: scientific research, lunar innovation for the Earth, integration of a universal principle of interoperability, emergence of a more inclusive, peaceful global governance. The Moon could be the crystallization of common ambitions and collective knowhow. The cooperation would involve discovering new alterities, between states, between sectors

and actors in the socio-economic sphere, and between forms of intelligence, both living and technical. The moon base would therefore be a worthy successor to the ISS or the CERN, incarnating cooperative science working for global diplomacy.

SOFT POWER
A KEY ISSUE

A strategic challenge, the lunar project is at the heart of soft power dynamics. Scrutinized and criticized, the project is subject to cultural and media attention around the world. Europe and France must therefore equip themselves with a capacity for international analysis of space trends and influences. On the operational level, this analysis capacity will take the form of monitoring sources of influence (actors) and forms of influence (amount of media attention, recurrence of approaches, propulsion of actors, portrayal in the media, etc.). The history of the conquest of space justifies this kind of operational tool, which should be handled carefully : the communication tactics of the Reagan administration, for example, led to the weakening of the Soviet defence space project. More recently, SpaceX has shown that innovation also requires a suitable communication process capable of demonstrating power.

As well as analysing these dynamics, it is important to put forward European soft power, for example through a narrative that fosters a sense of belonging, European identity, and international adhesion. The construction of a collective European imagination is central to the production of this narrative : to take Europe and its values to a desirable cislunar space. The financing of series and audio-visual content, both informative and recreational, strategic games and artistic creation, is vital to the construction of these narratives. The American space

power has successfully achieved this the past and continues to do so; now Europe needs to invest in this approach, drawing from its intellectual, cultural and scientific talents. For example, the production of a series of documentaries by the public audio-visual service (Arte) to mark the anniversary of Apollo 11 was well received and illustrated the growing popularity of space programmes.

ADHERENCE
AT THE HEART OF THE DEBATE

The group considers that the term "social acceptability of the lunar project" is not appropriate. It transmits the idea of a passive role played by actors whose acceptation we seek. It is preferable to opt for an active approach, stimulating adherence to the lunar project. Adherence comprises two elements: understanding and desire, and from an operational aspect, the involvement of citizens in the lunar project. In France for example, the private space flights carried out by Richard Branson and Jeff Bezos in the summer of 2021 met with a hostile reaction. Presented as the whim of billionaires looking for thrills, the technological benefits of these two events were lost behind strong but often unfavourable media coverage. This illustrates the disconnection between contemporary social reality and the way that the space sector communicates with it. Greater communication efforts must be made to demonstrate the benefits for society brought by economic space applications and exploration and research programmes.

The lunar project will be all the more in line with its times if it genuinely correlates with planetary challenges and the ambitions of young people. Between our Earth whose resources are now numbered and the infinite possibilities of space, the coexistence of opposites involves

reasoned audacity : while the allocation of resources more than ever looks like a choice, that allocation needs to be doubly optimal, with objectives that both have less impact on the planet and are more useful for humanity.

The lunar project is an opportunity to rework the way our fellow citizens imagine the use of technologies. It is an occasion to better show how technological developments can provide everyday, sustainable benefits for planet Earth, our climate, and humanity. If the lunar project wants to avoid coming across as the latest whim of space agencies, it needs to find adherence from citizens and make sense in the current climate of global tensions. The space sector needs to move away from the reign of foregone conclusions: in questioning its own meaning, it should also kindle new interest through a new dramaturgy, a renewed symbolic halo. The path that space ethics and its communication must follow is a narrow one : space exploration should not be the luxury of states or individuals, but nor it should not succumb to utilitarianism. This path involves a lunar ambition for the common good, a path that could be defended by Europe.

Adherence involves a re-politization of lunar exploration. This dimension involves promoting the lunar project in the political arena, kindling the interest of both citizens and political decision-makers with a narration supporting major European challenges: recovery, power, belonging, and challenges shared globally. The political field is a place for constructing a sense of belonging and adoption by European citizens, which is indispensable to the lunar project's durability in a socio-political reality subject to increasingly rapid upheavals. This is a specific characteristic of the space sector in democratic states : it includes both a long-term agenda featuring space projects and all the realities and promises involved, and a short-term agenda featuring the policy that determines funding and guidelines, with a pre-determined requirement for success.

2

SCÉNARIO

EUROPE, A THIRD WAY AIMED AT SOLVING TOMORROW'S CHALLENGE

The exploration of space is by no means trivial : it conveys the values of the society that undertakes it. In their respective lunar ambitions, the Americans and Chinese have crystallized a desire for civilizational, geopolitical, scientific and industrial conquest. Between a capitalist, liberal space ambition on one side and a rigorously planned, confident space ambition on the other, Europe can open up a third way : one that unyieldingly conveys the values of humanism, excellence, cooperation, peace, audacity, responsibility, sustainability and inclusion. A Europe of influence that, if it stands united, will be followed by numerous other non-European countries to act as a moderating lever in the face of the two established blocs.

Inclusion and sustainability must be the cornerstones of the European lunar project.

Inclusion is broken down into several levels, and goes far beyond simple political inclusion. On the one hand, it involves including citizens in the process of drawing up and deciding on the European lunar project. An idea that the Ethics and Society group shares with the Governance WG and that puts forward the imperative of connecting the project and ambitions to society. On the other hand, inclusion also involves actors from the spheres of economics, education, associations and non-space politics ; the same actors that will act alongside agencies and industrialists to shape an attractive European project that fits in with the times and acts to serve the times. The next level of inclusion is on a different level, that of a pacified relationship between society, science and technology – all in a post-pandemic context that has largely undermined

this relationship. Lastly, inclusion is embodied in the coming together of non-space nations and historic space powers. The European lunar project would thus associate the talents and experiences of new space nations.

Sustainability involves two aspects. Firstly, on the Earth : the allocation of resources is more than ever a choice whose legitimacy, effectiveness and role in global strategy must be questioned. Devoting human, material and natural resources to the lunar ambition involves a necessarily strategic choice that must be made in informed awareness before European citizens. This choice requires comparing the cost of access with the cost of renouncement. Renouncement, undoubtedly convincing on the ecological and even short-term economic levels, would be geopolitically divisive when Europe could position itself as the ambassador of pacific, sustainable, inclusive exploration. The other aspect is on the Moon : the installation of an expanding base camp on the Moon needs to be guided by research and development to benefit the cislunar area, and by ambitious but reasoned exploration that opens the way to outer space and new knowledge.

The Moon is an opportunity to demonstrate the possibility of leading a highly technological human project without sacrificing contemporary imperatives of inclusion and sustainability : to make the Moon a place where new scientific knowledge, technological advances and human progress come together.

3

STRATEGIC OBJECTIVES AND RECOMMENDATIONS

STRATEGIC OBJECTIVES

- **Embody a different way.** As Europe draws the lines of its lunar project, it needs to make it part of its geopolitical, environmental, socio-economic and cultural context.

- **Grasp a geopolitical opportunity.** The race to the Moon is on, and Europe must urgently seize this opportunity to take part with its federating, inclusive spirt, at the risk of dropping out of the race for the long term.

- **Reasoned audacity, a new way of thinking.** The lunar project can be the occasion for a new way of thinking about most of the issues and challenges confronting earthlings, such as habitat, the circular economy and energy. The lunar project must fit into an Earth-Moon momentum able to ensure its sustainability and the reasoned allocation of resources to the project. This is a mobilizing, integrating impetus involving all European vital forces beyond the traditional space community.

- **From desire to adherence.** The European lunar project is based on a component of desire that requires rethinking its narration and communication, similar to the American project. Two elements that should be built from the start and en route. The connections between emotion and reason can be stimulated by the project's historical roots, its symbolic halo, and its legacy for humanity, involving a responsible vision and mobilizing inspiration.

- **Improve the science/society relationship.** Following a pandemic that has further undermined the relationship between science and society, the lunar project needs to be brought closer to citizens' everyday lives though an appropriate communication and media approach.

OPERATIONAL RECOMMENDATIONS

POLITICS

- Contribute to the creation of a French and European scientific advisor based on the Canadian model, working with the highest national authorities to advise them on global scientific issues. This advisor will act as a mediator between the world of science, the political sphere, and citizens.

- Politicize the challenges of space exploration to make it a subject of public debate able to find its place in 2022, a particularly crucial year in terms of politics (French presidential elections, French presidency of the EU, inter-ministerial dialogue on space, etc.).

- Give more visibility to the notion of scientific diplomacy and that of "commons" to preserve in the name of humanity (to avoid the threat of a "tragedy of the commons" in the case of a degradation of the Moon's extra-atmospheric area).

SOCIETY

- Encourage space exploration actors to go out and meet their audience and citizens by creating new narratives while adapting to new codes and communication methods (presence on social media, etc.).

- Encourage space exploration actors to better reflect their society (age pyramid, gender parity, representativity, etc.) and prevalent ideas (sustainability, peace, inclusion, etc.).

- Act to encourage the involvement of civil society actors in the strategy decision-making bodies of space agencies, in particular concerning Moon exploration projects.

- Organize citizen consultation on space and inhabited lunar exploration by 2023, from low orbit to outer space (especially Mars).

EDUCATION

- Include a chapter on space in science and history-geography lessons in high school.

- Inform students about potential jobs in the space exploration sectors, in both science and humanities and social science.

CREATION

- Encourage artist residency projects and workshops devoted to space within space agencies and cultural, scientific and technological institutions ; and reciprocally, researcher residencies in artistic places.

- Take the opportunity for socially and economically attractive cultural creativity to mobilize a cultural industry (an openly European slant vs. what is done in the USA : Metaverse, Far West, reality shows, etc.). This is just the right moment to mobilize our cultural industries on this new structuring challenge.

- Encourage prospective and forecasting research initiatives on technological developments and possible services aimed at and on the Moon.

- Invite the development of a digital twin of the Moon, initiated by Europe. This twin could be used to test out the different potential settlement sites.

habitat and life support

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HABITAT AND LIFE SUPPORT

Since the Horizon project

commissioned by NASA in 1959, then the First Lunar Outpost several years later, up to more recent projects like the Moon Village initiated by the former director general of the ESA, NASA's Artemis roadmap, and the Russian-Chinese ILRS, lunar base camps have sparked imaginations and set a challenge for engineering science that raises societal questions. The means of manufacture – 3D printing, prefabrication, inflatable infrastructure – and the missions allocated to this base are highly varied. Beyond the techniques involved, these future Moon bases, their form and their function, will act to transmit a message, a particular vision of the lunar ambition of the state or states that built them and the private companies that contributed. The conception and implementation of the base are a technical, organizational, and architectural translation of a social system based on cooperation and interoperability. In addition, the living conditions and survival of the astronauts constitute a crucial mission of the Moon base. The geographic location of the base will be important to organize coherent responses in terms of habitat and protection of astronauts vis-à-vis specific risks. European lunar exploration would not be about domestication, but rather aimed at interaction between the Moon, the Earth, the states and partners present. It would be

based on a holistic principle of integrative coexistence between humans, technologies and environments. Cooperation is not so much a choice as a necessity resulting from two systemic constraints: the hostile lunar environment and earthly challenges. This principle of cooperation and lack of conflict takes space habitats away from earthly conflicts, allowing collaboration between astronauts from states with tense relations on Earth, thus making space exploration an effective diplomatic tool.

All of these dimensions have stimulated the work of the habitat and life support group.

1

DEBATES AND DEFINING DIRECTIONS

Futuristic projections of Moon bases feature a complex made up of several modules that can house several dozen humans. In an initial phase, the objective of modules sent to the Moon will be to provide adequate life support to the handful of pioneers carrying out short missions, with a strategy of survival[1]. In a second stage, following the expansion of the community and the development of infrastructures, the Moon base will house a veritable artificial society settled and living on the Moon, raising questions of organization and social interaction.

The group's considerations have centred on three notions corresponding to the main three functions of a Moon base: surviving, living and settling.

SURVIVING

Energy, water and food, air, and the protection of astronauts comprise the four basic components that the Moon base must provide without fail.

ENERGY AND LIGHT

The initial problem of energy can nevertheless be solved by a variety of energy resources. The two biggest sources would probably be solar energy, already partly solved, and the generation of nuclear energy from small units, which still needs improving. NASA has been using nuclear energy in its space missions since the 1960s and still does on its

1. By survival we mean the satisfaction of basic needs (food, oxygen, water, protection from the hostile environment) during the first missions. The establishment of a complex base on the Moon comprising several modules ensuring these conditions for survival would move the focus from survival on the Moon to life on the Moon.

KRUSTY[2] project. In fact, the agency's recent SPD-6 directive dating from 2020, and a presidential memorandum on nuclear energy in space of the same year, point to renewed interest in this resource for missions to the Moon and Mars. The SPD-6 directive anticipates the demonstration of a nuclear fission system on the Moon's surface capable of generating up to 40 kilowatts of electricity. Back in 2017-2018, NASA tested out the prototype of its small KRUSTY reactor that can be transported to the Moon and Mars and produce 1 kilowatt of electric power from enriched uranium.

Energy is a vital component on the Moon base, concerning autonomy on board and around the base, and among other things the charging of rover, robot and drone batteries, and the supply of apparatus on board. Energy is vital for producing light during lunar nights lasting fourteen days, thus influencing the choice of geographic settlement – a few small areas of the Moon enjoy almost constant sunshine – and the development of energy storage facilities. This constitutes a major area of innovation for both the Earth and the Moon.

WATER

The exploitation of local water resources, while technically possible, will depend on the limited quantities available. However, bringing in water from Earth will initially be indispensable, although extremely expensive and so difficult to sustain. Considering the increasing water stress on the Earth, effective, durable management of this water stock will be a priority. Circular, automated management of on-site water stocks could be ensured by water reuse and recycling technologies. The technologies developed for this purpose could also be employed on the Earth.

FOOD

Food will need to be customized and tailored to satisfy individual astronauts' physiological and psychological requirements. Eating is an important part of the day that

2. An acronym of Kilopower Reactor using Stirling Technology, KRUSTY is a NASA project to develop reactors with a power of ten kilowatts for space exploration.

goes beyond its vital function in providing well-being, social connection and an emotional link with the Earth. It is important that astronauts enjoy a varied, appropriate menu. Food will be initially brought from Earth and progressively produced locally, the aim being to create a closed, sustainable ecosystem featuring a variety of life forms[3]. Progress made in this area will be transferrable to earthly challenges regarding food and circularity.

ASTRONAUT SAFETY

Another factor is the psychological strain of long missions on astronauts. Radiation and variations in gravity have a physiological impact on the human body which still requires study. Some of these impacts are reversible depending on the length of stay. Along with creating a more protective habitat for astronauts, the study of prevention and reversibility of physiological impacts could benefit research on human health on Earth. As an example, the study of bone loss phenomena resulting from gravity differences, already observed during flights on orbital stations, has improved knowledge for osteoporosis treatment. Developments made in the Apollo programme (such as higher-resolution images of the Moon) led to improvements in MRI technologies which went on to be adapted for the medical field. Today, remote monitoring of astronauts' health in a hostile environment or in autonomous situations has a number of similarities with new forms of personalized medicine on the ground, and digital health.

3. Such as for example the Lunar Hatch project, or ESA's MELISSA project.

LIVING

Once the immediate needs of surviving on the lunar surface have been resolved, the specific challenges of long-term human presence on the Moon will need to be tackled.

Designing a viable Moon base therefore needs to involve holistic consideration of life, including both human and non-human life, along with the physical, psychological and social aspects of human life.

The moment that humans set foot on the Moon, they bring along a whole host of bacteria arriving on their bodies as clandestine passengers. Moreover, according to recent research, preserving this microbiological balance is the key to maintaining astronauts' mental, physical and social health. As the Moon base starts to take shape, the astronauts could bring with them other forms of plant and animal life. In the long term, the base will become a genuine ecosystem, raising questions regarding the interaction and equilibrium of all of these forms of life on board. And like any equilibrium, hazard will play a part, and the unexpected will have to be taken into account, affecting both vital and technical aspects, an intrinsic part of all exploration.

Human life also depends on the equilibrium between physical, psychological and social lives. The relative solitude that the first astronauts may experience, combined with the stress of high-risk missions, are essential components of pioneer exploration. As the Moon base expands and the number of astronauts increases, other dimensions of social life will emerge. On board, the capacity to temporarily isolate from the rest of the group, the creation of common recreational areas and private relaxation zones are three key requirements to maintain the mental health of the astronauts. This also involves keeping contact with Earth, with a possibility of making calls to loved ones and high-quality Internet access[4], all involving new-generation interactive software. Careful recruitment of the astronauts

4. See ESA's Moonlight project.

that make up the lunar crews is crucial to ensure the social balance of the base and its performance. Astronaut recruitment has moved from teams of military heroes to inclusive teams comprising versatile engineers capable of resolving complex problems under maximum stress. With the increased number of astronauts and the establishment of a new form of society, analytical tools and human and social science concepts will need to be used to put together base teams and study their behaviour. We also need to immediately start thinking about the coexistence of human and artificial intelligence at the base, which requires employing cognitive engineering (focused on the automatic processing of knowledge), neuroscience, robotics and AI.

Taking this kind of approach will make it possible to anticipate psychosocial risks by acting on the parameters of the mission (duration, team composition, work schedule, cultural references, etc.). Encouraging similar missions beforehand (following the example of the Mars 500 mission) is a pertinent way to anticipate these risks.

SETTLING

The lunar habitat must protect astronauts from temperature changes (from -150°C to +150°C), radiation levels (in the absence of an atmosphere and magnetosphere, up to 1,000 greater than on Earth) and a twenty-eight day nychthemeron (nights and days of 14 Earth days). Module design is generally entrusted to engineers and tends to focus on this crucial aspect without considering the organization of an actual living space. The ISS carried out the first long-term non-Earth habitat experiment : the lessons learned are useful, but a more comfortable living space needs to be designed. The interior design of the Crew Dragon capsules also demonstrate the capacity to opt for a minimalist, quality design without sacrificing technological and safety requirements. Nevertheless, a long-term installation suitable for housing astronauts

during extended missions needs to comprise modules designed for living rather than simply surviving. The ergonomics of the module should be studied particularly carefully, creating room for both scientific and survival equipment and living spaces. In fact, the question of ergonomics should be considered from the very first modules sending only a few astronauts on pioneer missions.

The conception of the lunar habitat, and all the more so if Europe drives an international base project, should take into account the interoperability and modularity of base elements, along with the area the base serves and the ease of logistics. Human settlements on the Moon need to be upgradable : as exploration progresses, new needs will emerge and new elements will be sent from the Earth. Since its creation, the international space station has continued to develop thanks to the contributions of the community. A modular design would avoid rapid obsolescence of the first base elements. The interoperability of the elements installed is a critical issue that should be uncompromisingly defended with the establishment of standards on all of the equipment and functionalities of the living base. For example, a difference in pressure between two modules produced by different manufacturers would prevent them from being anchored and joined, a problem that could be overcome by an international standard on pressure levels on board the Moon base. Inevitably, solidarity between crews will be tested in this hostile environment and technical aspects should be designed with that in mind from the outset.

2

SCENARIO

FOR A EUROPEAN LUNAR HABITAT MODEL

The design of a European "lunar village" should reflect the third way proposed by our continent: a global lunar ambition. This imperative can be broken down into different dimensions.

Cooperation: The "lunar village" will reflect the core identity of European space, in other words, cooperation. Which was in fact the spirit of the ESA's Moon Village. Based on the model of an international space station, the lunar village could host astronauts from all nationalities and all agencies or non-institutional bodies, with highly diverse missions. On a technological level, this spirit of cooperation takes the form of interoperability. Interoperability will be the key principle of the elaboration and then construction of the station, guaranteeing the will of cooperating states and their industries to work together. Drawing lessons from the ISS's experience of the IGA (intergovernmental agreement regulating the rights and duties of participating states), operating rules should take into account both public and private interests for sustainable, responsible exploration and exploitation.

Sustainability and circularity: Today's unprecedented challenges related to climate and society create additional constraints regarding the project's social acceptability. Sustainability and circularity therefore take on a new dimension that is both ethical (to ensure that the project fits in with the times) and technological (innovation to meet with new requirements). Everything needs to be done to ensure that the lunar ambition, which is costly in terms of resources, knows how to use them in the most efficient, sustainable way possible in order to keep its environmental footprint to a strict minimum. In addition, R&D efforts made to design a circular lunar habitat will feed into an

earthly habitat with equally optimum management of resources and waste. If Europe can drive a project that champions sustainability and circularity, it will show that it is possible to carry through a highly technological and innovative project that is marked by frugality and transposable to earthly challenges.

Earth-Moon connection : The Moon life base can only be conceived in a spirit of Earth-Moon complementarity ; this duality has two potentials. Firstly, a heuristic potential of awareness-raising, taking further what is commonly called the "overview effect", in other words the astronauts' awareness of the fragility of our planet and the unicity of its ecosystem. Next, this complementarity has a technological potential with the mutual transfer of earthly and lunar innovations. Earth-Moon complementarity should be set up as a cornerstone of the European lunar mission and a stated motivation of the continental lunar ambition. In time, it could be extended to a "Moon to Mars and beyond" approach. The Earth-Moon couple is a first step towards space exploration, to Mars and beyond. This objective will also catalyse current earth transitions, in particular the energy transition, digital hybridization, and inevitable changes in ways of living and working.

Pragmatism, interoperability and progressiveness : humans' return to the Moon now means long-term settlement. A long-term expanding base camp on the Moon implies confident programming for the long term, over several decades. It is therefore crucial to opt to take a pragmatic, interoperable approach that responds to current needs and anticipates future missions. A holistic, interdisciplinary, open way of thinking will facilitate the agility and scalability indispensable to exploring these "New Lands". The discoveries made on the Moon will confront us with potential opportunities as yet unimagined.

3

STRATEGIC OBJECTIVES AND RECOMMENDATIONS

PREPARE

- **Initiate research programmes.** On the one side, list, observe and model interactions and interdependencies between humans and earthly environments, in particular the most hostile ones, to study possible ways of adapting, and to anticipate preventative measures and remedies in a perspective of establishing humans on the Moon ; on the other side, launch technological research and development programmes, for example for new materials and modes of construction.

- **Encourage analogue missions.** Based on the Mars500 mission and Biosphere experiences, encourage missions on lunar analogue sites – Europe possess geological areas suitable for this purpose and excellent infrastructures currently being built, like the Luna experiment. The construction or development of analogue sites would be a pertinent investment in preparing lunar missions. Analogue observation and study sites will also be a place for testing out Earth-Moon complementarity and the necessary inter-disciplinarity and diversity of talents.

- **Foster interdisciplinarity.** Encourage interdisciplinary dialogue on human and non-human life beyond Earth, cutting across exobiology, engineering and sociology. For example, it would be difficult for a lawyer designing the regulatory framework for a Moon base to disregard the technical data and scientific missions involved. In addition, the cohabitation of humans in a closed space requires prior dialogue between physiology and behaviour scientists. This interdisciplinarity will be made concrete by taking a multi-field approach.

DESIGN

- **Sustainability.** Design the Moon base with a twofold approach of a smaller environmental footprint (on both the Moon and the Earth) and operational sustainability. Interoperability is a cornerstone of this sustainability and its resilience ; a cornerstone that Europe should defend.

- **Project management drawing from a broad expert panel.** The conception and construction of lunar modules should involve a panel closely associating numerical analysts, engineers, architects and companies – the only way to resolve technological challenges in an integrative, innovating way.

- **Design an optimal, appropriate nutrition system.** Develop a nutrition and farming system that is appropriate and diverse in order to transport as little food as possible from Earth in the long term. The nutrition question should also involve personalizing astronauts' food to correspond to their physiological, genetic/epigenetic dimensions. Insofar as food is an important part of group cohesion, the nutrition system lies at the junction of individual needs and community stability.

- **Design a special health system.** Establishing a health system that includes prevention, diagnosis, follow-up and treatment is indispensable. This area is both essential for inhabited exploration and its future, and at the heart of our global health issues.

DEVELOP

- **Foster intersectoral innovation for the lunar habitat.** Mobilize in an intersectoral way the space and non-space sectors to come up with common solutions for everyday life on the base (mobility, health communication, energy, etc.). The production of a digital twin of the Moon to tackle

- technological and social issues could result from European expertise, with continental industry in a position to compete. European competencies could also be employed for other innovative interfaces such as metaverses for health or piloting of the base, digital twins of Moon base camps, etc.

- **Learn from earthly errors.** Particular attention should be paid to the balance between exploration and exploitation, in order to learn from our mistakes and failures on Earth.

- **Innovate in water, air and energy production and storage.** Develop automated technological solutions for producing, storing and recycling water, air and energy.

- **Develop technologies to facilitate life and the habitat in a hostile environment** employing connectivity, advanced robotics, AI and the internet of things. These same technologies will also be at the heart of social interactions on the Moon and between the Moon and Earth to facilitate human autonomy.

- **Develop and set up infrastructures for communication** assistance, and communication in the cislunar orbit (see the ESA's Moonlight project).

- **Develop and set up infrastructures and logistics chains** involving sectoral actors (transporters, etc.) to build, access and develop the Moon base and Earth-Moon interactions.

exploitation of resources

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EXPLOITATION OF RESOURCES

Pipe dream for some, promise

dfor the future for others, the exploitation of space and lunar resources generates as much emotion as it does interests and techno-scientific challenges. Yet in situ resource utilization, or ISRU, is a being studied and supported by space agencies, mostly in the United States (with Artemis) and China/Russia (with ILRS), which anticipate long-term installation around and on the Moon by the end of the decade. One way of taking the heat out of the debate is to look at the different levels of lunar resource exploitation. In fact, large-scale economic exploitation of space resources is currently uncertain, both in terms of feasibility and interest, yet the exploitation of resources at a different scale can be envisaged. Establishing an automated base, then a sustainable human base on the Moon will require extensive knowledge of lunar resources, including basic molecules for long-term space transport (oxygen and hydrogen), intermittent energy storage (hydrogen), and life support (oxygen), as well as materials to build the base camp.

ISRU could therefore reduce the quantity of materials and equipment to be transported from Earth and promote more sustainable presence on the Moon: go further, stay longer, fuel space vehicles with propellant and therefore extend their lifespan, thus reducing the total cost of missions and space debris. Since sustainability must be the key value of the European lunar momentum, the exploitation of Moon resources must be looked at from this point of view. IRSU would make it possible to reinvent the way that space missions are put together, with a greater emphasis on reusability to ensure the durability of space services provided to Earth (potentially threatened by the increase in low-orbit debris), the development of a cislunar economy (Earth-Moon continuum), and international collaboration (since all nations will need these resources).

The field of study of this chapter is to analyse the feasibility of exploiting lunar resources and their potential uses.

1

DEBATES AND DEFINING DIRECTIONS

DO NOT FORGET PRESUPPOSITIONS

We should not forget everything that lunar ISRU presupposes, in terms of both knowledge and infrastructure. This exploitation aims at the long term : although the first Moon exploration missions will mostly bring along resources from Earth, in the long term the base will aim towards greater autonomy. Considerable efforts will be required in four areas to make lunar ISRU conceivable, then possible.

The first involves mapping. Although we are already partially aware of the topography of the Moon, precise geological mapping is indispensable. A major step forward was achieved by the United States Geological Survey (USGS), which in April 2020 published the first basic map of the Moon's surface geology. Its subsoil still needs to be documented with much more precision, bearing in mind that it took a century (1912 to 2012) to establish the current geological map of France. Europe can truly hold its own in this geological and geophysical mapping of our natural satellite. In fact, at the end of the last century, Europe refocused its inhabited flight strategy on telecommunications and Earth observation. Close association between the European mining industry and the space sector (public and private) would also be beneficial to successfully carry out this general mapping and estimate the exploitable potential of mineral and lunar water resources. At European scale, this requires an inventory of public and private actors and their technologies capable of carrying out this resource exploration with a view to their future usage. This inventory could lead to setting up public-private thematic consortiums for European ISRU on the Moon.

The second effort involves developing technologies and then installing the necessary infrastructures o to collect, treat, purify, process and enrich resources, all augmented by geolocation and transport to the Moon's surface. A cost-benefit analysis comparing in situ exploitation with bringing items along from the Earth will need to be carried out to determine which option is best. This infrastructure effort will depend on how the necessary resources are exploited. Research and development to identify critical technologies for exploiting resources is unprecedented, but can be largely based on industrial experience on Earth. These new value chains could be rapidly demonstrated on the Earth, then on a small scale in space, taking advantage of numerous discovery missions to the Moon planned over the next decade. The targeted resources could be the following :

- Due to its availability in the lunar substratum (44% of the actual structure of regolith), oxygen would be the first molecule to be exploited for space transport (oxygen represents 80% of the mass of launch vehicle propellants) and life support.
- The lunar substratum and regolith could be employed to create infrastructures (using 3D printing).
- Once water resources have been identified (place and quantity), they could be employed for life support, and to produce oxygen and hydrogen (for space transport, energy storage and production, and for surviving lunar nights and all surface activities).
- At a later date, depending on the mapping, precious metals (e.g. Ni, Pt) or rarer molecules (e.g. helium 3) could also be extracted with specific space usages that remain to be determined.

The third effort is defining an economic model and creating short-term commercial uses, without waiting for installations to be in place on the Moon. As a reminder, because of gravity, it will take 40% less energy to get to low orbit from the Moon than from the Earth, and one-third of the energy to get to geostationary orbit from the Moon than from Earth. For example, a low-orbit depot of cryogenic propellants (O_2/H_2) could be established in the next five

years. Water would be sent as a passenger from Earth in volumes not used by existing launch systems, then stored in orbit, electrolyzed and separated, after which the O_2 and H_2 would be liquified and stored in a cryogenic form, before being transferred in the upper floors of the launchers. This would foster progress on the development of key technological building blocks (electrolysis, liquification, adaptation of upper floors of launchers, transfer of propellants), develop interoperability standards for refuelling launch systems in orbit, and demonstrate and create a short-term commercial usage, thus attracting investment to this new industry. At the same time, the technological building blocks associated with $O_2/H_2O/H_2$ value chains could be developed, leading to potential production of oxygen, then water, and lastly hydrogen, on the Moon's surface, by the 2030s. Water, oxygen and hydrogen could be used on the Moon for survival during lunar nights, for all energy needs, mobility and life support, and/or be transported in the different orbit depots taking advantage of the Moon's low gravity. Lastly, these technological developments could be made in synergy with the green hydrogen transition on Earth, because space innovation will undoubtedly lead to the acceleration of some earthly developments.

The fourth effort concerns governance, to ensure that ISRU promotes international collaboration and avoids confrontation over resources. In fact, due to its strong commitment to the energy transition on Earth and the massive development of the green hydrogen industry, Europe is a legitimate candidate for setting up and controlling $H_2O/O_2/H_2$ value chains in space from space resources. If Europe positions itself now on this exploitation of lunar resources in a reasoned, moderate and sustainable manner, it could drive international collaboration and universal peace at the heart of the Moon project, acting as the facilitator of a sustainable human presence in space.

SUSTAINABILITY

Sustainability calls for the reasoned exploitation of lunar resources. For the general public and critics of the lunar project, the exploitation of space resources has a purely extracting, consuming purpose, the very same that is accused on Earth of having led us to the climate situation we find ourselves in. The sustainability of the Moon should be looked at in terms of a lower impact on earthly and lunar resources. The exploitation of space resources should be understood taking good note of the different parameters of sustainability between the Earth and the Moon. As an example, the production of carbon chains constitutes waste on Earth, but becomes a resource on the Moon. In addition, in the absence of a magnetosphere, the Moon will not retain some of the emissions produced by exploiting resources. Based on our experience of the limits of resource exploitation on Earth, particular attention will need to be paid to lunar resources. Not all resources are equally abundant on the Moon: polar water is only limitedly available and non-renewable, unlike regolith and solar radiation stocks.

This sustainability strategy for ISRU is embodied in the act of refuelling. The limited lifespan of space objects is the Achilles' heel of green space. Refuelling in space is a short-term technical solution. Provided, nevertheless, that the cost of replacing the object is higher than the cost of simply refuelling it.

2

SCENARIO

The acceptability of lunar exploration, by societies currently tackling major challenges on the Earth, should be a central preoccupation. The lunar project will be all the more acceptable if it is sustainable ; in other words, capable of costing as little as possible in terms of earthly resources. The optimization of resources that are both lunar and earthly, which is at the heart of the ISRU strategy, therefore has a twofold imperative : sustainability, and acceptability. The exploitation of lunar resources must therefore be thought out in terms of long-term development, considering different timescales. Following an Earth-Satellites-Moon-Space rationale, this will mean thinking about development that uses resources in a more coherent, efficient and responsible way. Once of the strengths of lunar exploration is that it can constitute an observation laboratory of human impact on a territory considered as previously virgin.

The first stage starts from an observation : the satellite market already in place. The sustainability objective requires looking for technical solutions that can extend the lifespan of satellites in orbit. Among these solutions, the development of refuelling techniques in orbit would work to increase the lifespan of low Earth orbit (LEO) space objects, and even limit orbit saturation. These refuelling techniques could go on to be used for the Moon. .

The second stage would involve sending water into LEO in order to learn to perform its electrolysis in orbit in sufficient quantities. This technological development could be used to refuel operational objects in orbit, and perhaps even launcher stages directly from space. These first two stages would be aimed at a five-year timescale.

The third stage of this value chain of lunar and space resources aims at a **5-10-year horizon**. It involves learning to extract and produce the following :

- O_2 from lunar regolith (44% O_2 in Moon rock). This oxygen could be used as a life support and to refuel for transportation.
- O_2 and H_2 from the water present on the Moon, once it has been identified. O_2/H_2 could be used for long-term space transport, H_2 could be employed to store energy for surviving lunar nights and all future developments on the Moon surface (H_2 can meet energy requirements from a few Watts to several dozen Megawatts).
- Material from lunar regolith (with 3D printing and additive manufacturing techniques) for the construction of basic infrastructures, landing strips, and the road system indispensable to limit dust clogging. Using regolith as a construction material could also protect astronauts from radiation.

The fourth stage situated at a **horizon of 15-20 years**, would involve improving our capacities and knowledge on extraction and production of other basic molecules from lunar resources (metals, He_3, etc.) to manufacture and maintain objects in orbit and on the Moon.

Lastly, at a horizon of 15-20 years, **a final stage** would consist in studying the recovery of carbon emitted by inhabited flights and the Moon Station (space gateway) to use it on the Moon (where carbon is absent), for organic growth (e.g. agriculture) and other applications to be determined. The advantages of bringing carbon (e.g. in solid form) from the Earth to the Moon could also be studied (applications to be determined).

In addition, the reuse of space debris in the Earth's orbit could also be envisaged in terms of secondary materials. Numerous space debris items are particularly interesting, mainly for their electronic components or usable

metals. Repatriating this debris to the Moon along with the means to process and reuse it in situ would have the double advantage of circularity of the lunar model and preservation of the LEO.

All of these stages would illustrate Europe's commitment to a clear vertical axis : that of exploiting the energy of space and lunar resources (refuelling, life support, energy production and storage) for the sustainable, autonomous expansion of a life base on the Moon. The establishment of a strategic European vision in twenty years is needed to federate and encourage the space industry and other industries on the subject (note that the success of this new vertical axis would be based on creating extremely complex value chains requiring the collaboration of numerous complementary actors).

3

STRATEGIC OBJECTIVES AND RECOMMENDATIONS

KNOW

- **Employ European technologies and their knowhow for the purpose of observing the Moon.** Use Europe's high-level technologies for observing the Earth and direct them towards the Moon.
- **Map and make an inventory of the lunar subsoil.** Encourage an international initiative for geological, hydrogeological and geophysical mapping coupled with a detailed inventory of the Moon's subsoil resources.
- **Make an inventory of waste.** Catalogue the waste developing in space in order to prepare a system to capture, transport and recycle.
- **Make an inventory of European companies, knowhow and technologies for ISRU.** List the European companies and technologies that can be involved in ISRU from the prospection and design stages. This inventory could be extended to other countries, and should be intersectoral to foster synergy between space and non-space actors.
- **Adopt a prospective design approach.** List the requirements that lunar resources could satisfy taking a prospective design approach.

CONVINCE

- **Envisage principles for exploiting** lunar resources that correspond to European values and strategic axes.
- **Foster a policy based on complementarity.** Convince politicians of the benefits of massive investment in developing technologies to explore and exploit lunar resources based

on the complementarity of returns on investment for the Earth and the Moon (numerous syner-gies with earthly developments underway for the energy transition). This same complementarity is an indispensable factor of adherence to the lunar project.

- **Demystify the subject of lunar resources.** Clarify the subject by clearly defining several credible, economically viable avenues of sustainable, reasoned exploitation of resources (with short- and mid-term commercial uses, e.g. refuelling in orbit).

ANTICIPATE AND MANAGE

- **Opt for a holistic, sustainable strategy.** Take a systemic, holistic approach to avoid making the exploitation of resources an end in itself, but rather make it a means to develop critical technologies useful for establishing a life base and a means of increasing our fundamental knowledge on space and its exploration.
- **Opt for a Moon-to-Mars rationale.** Take a Moon-to-Mars approach and make the Moon our testing ground to improve the exploitation of non-earthly resources and use it as a springboard towards outer space.
- **Be among the first to reach interesting areas.** Reach areas of interest areas early (deposits, water, bright side, dark side, etc.) to avoid trailing behind in the long term.
- **Encourage international cooperation.** Foster international collaboration by providing unique expertise and cross-cutting services (the appropriate use of resources will be a cornerstone of all sustainable development in space, and necessary for everyone). Europe could thus play a bridge role between nations, for the benefit of peace.

industrial and économic strategies

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INDUSTRIAL AND ECONOMIC STRATEGIES

The ambition to return to the Moon is part of a very different geopolitical strategy than during the Apollo era. The destination is the same, but the objectives and economic situation are totally new. Inhabited missions sent to the Moon surface from July 1969 to December 1972 acted to demonstrate American power. The main aim of that power was to outdo its Soviet rival of the time, with little concern for missions' short duration, since the long-term extension of the project was not necessarily a priority. On an economic level, Apollo featured the USA as a project manager splashing out between 150 and 180 billion dollars and involving a few private actors in the process. The lunar ambition of the time was not about economic benefits, notwithstanding the Keynesian consequences of this unprece-dented public investment. But it did contribute to a very positive return on investment and did much to boost US soft power in the midst of the Cold War and in the aftermath of World War Two.

The new lunar ambition fits in with a history of great explorations and trade routes over sea and land, demonstrations of soft power and dominance. The great global power balances of tomorrow will take place in space and on the Moon.

The new race to the Moon, including Artemis and the Chinese-Russian projects, has totally different perspectives from the first time round. Moon missions will last longer, from a few days to several months, and presence around our natural satellite will be established in the long term. Future economic benefits, the fruits of exploration and exploitation of lunar resources and knowledge developed on an "extra-terrestrial" site, are one of the main motivations behind returning to the Moon. The Moon may feature as-yet unknown potential resources, the discovery of which will bring new motivations.

The economic parameters of space have changed considerably since Apollo 11. The space sector has seen a synchronous wave of privatization and commercialization of its activities. While the state maintains a leading role, project management and risk-taking on innovation have moved towards the private sector. Mainly emerging from digital and data industries, some new players have shifted the sector's technological and economic parameters. These same players also demonstrate an ambition to diversify their financial sources beyond public funding (raising capital, entering the stock market). Public powers, on the other hand, are watching their budgets more carefully. While the Americans remain far ahead in terms of financing, with NASA's budget amounting to over 23.3 billion dollars (2021 budget, estimated at 0.11% of 2020 GDP), the new exploration of the Moon will also include the emergence of new national space industries.

While space exploration used to be mostly based on industrial-military ambitions and geopolitical prestige, the new lunar ambition is characterized by the importance given to economic parameters in space exploration, both for financing and for returns on investment. As pointed out by the report produced by Zenon Research in collaboration with ANRT, *"to go beyond a symbolic, one-off return to the Moon and ensure that new programmes last for the long term"*, *"the European lunar project should make a priority of establishing realistic economic models"*.

If France and Europe want to be active stakeholders in lunar exploration, it is vital that they put together an industrial and economic strategy capable of initiating, supporting and establishing their lunar momentum. This question was central to the work carried out by the industrial and economic strategy working group.

1

DEBATES AND DEFINING DIRECTIONS

RETHINK THE ECONOMIC MODEL OF SPACE EXPLORATION

The Moon base and the Lunar Gateway project can be seen as the relay of an ISS at the end of its life. The ISS has left a considerable heritage and the project has enabled numerous states to work together, despite sometimes tense diplomatic situations on the Earth. Its history has nevertheless been under a permanent sword of Damocles : its long-term financing. The high number of private actors involved cannot disguise the important role played by states in making strategic decisions, ensuring governance, and financing operations and global infrastructure projects. In particular when the exorbitant costs cannot be borne by private power alone, or by states acting solo. The ISS economic model, based on financing from public funds with little private sub-contracting, is at permanent risk of a turnaround in budgetary policy by states. The financial models for lunar exploration therefore need to be rethought to better divide risks and political and financial commitments between public powers and private players, increasingly attracted by the potential profits to be had from space, as shown for example by the rapid development of space tourism and the construction of private orbital stations. Public private partnerships (PPPs) have been at the heart of NASA programmes and enabled it to ensure the autonomous capacity of its inhabited flights. By fostering the association of private financial projects with new lunar missions, this tool is a series avenue for

diversifying funding sources. Space and lunar stations could constitute R&D laboratories, even production labs, offering physical properties (low gravity, radiation, etc.) and experiment possibilities that are unmatchable on Earth. Nevertheless, experience on board the ISS shows that the lunar base should be equipped with a legal framework adapted to in situ innovation – the kind of framework that the ISS lacked.

In in the first stage, massive public investment will be required; but by mobilizing space and non-space industries for sustainable presence on the Moon, the development of viable economic models made possible thanks to the exploration and exploitation of the Moon mean that a true lunar economy closely involving the private sector could be established in the long term.

THE LUNAR MOMENTUM AS AN OPPORTUNITY TO INITIATE A EUROPEAN NEW SPACE

Long-term settlement on the Moon can be an opportunity for France and Europe to accelerate the large-scale development of breakthrough technologies (new means of propulsion, 3D printing in orbit, etc.). This objective is part of the US space ecosystem with its Artemis programme, involving the emergence of new private actors with diverse sources of capital and supporting a large share (larger than in the past) of the risk of their innovations and potential failures. .

The aim is not for Europe to start from scratch with its space economy, equipped with cutting-edge major actors in the sector. Nor does it mean focusing solely on an innovative start-up model, which itself presupposes disrupting

an existing economic model, since such a model does not yet exist for lunar activities. On the contrary, the aim is to create a European-style New Space based on a new model. Its development requires bringing together two agendas that are all too often described as divergent in a new space economy : that of states, powerful funders of the sector looking for strategic autonomy ; and that of private players looking for competitiveness and profitability. If France and Europe want to put themselves forward as a lunar power, they will need to adopt an economic policy that, while adapted to New Space, can satisfy European strategic independence. The continent includes giants at the leading edge of the airspace sectors, as well as energy and pharmaceutics. The European-style New Space must combine its space ecosystem with risk-taking and institute public control as a service (it is worth studying the "anchor customer" model in which the state acts as a client, thus giving credit to private actors' business plans). The diversification of financing sources combined with a true incentive policy for intersectoral space innovation is all the more recommendable because the emergence of new actors is shifting the rules of the game, as seen in the United States. Attracting private actors to Europe as a space territory is a key challenge.

2

SCENARIO

The new economic context of the race to the Moon involves certain strategic choices at French and European scales. A principle of realism must guide industrial and economic strategy. France does not possess the same financial means as the US space power, and so the lunar ambition must unavoidably be elaborated at European scale. The European industrial and economic strategy for the Moon could opt to take one of two options.

(**1**) Choose to follow in the footsteps of other major powers and embark on a global infrastructure project, from launchers and launch pads right up to landers and the Moon base. Although the cost of this project is beyond current means, it would nevertheless ensure Europe a frontine place in the general governance of the Moon and more widely human space expansion.

(**2**) Choose to take on a limited number of challenges on the lunar value chain for which France and Europe would become indispensable (energy at the Moon base, refuelling and manufacturing in orbit, internet on the Moon, lunar cloud, digital twins, on-site resources, etc.) for the lunar projects initiated by other space powers.

This second option may appear easier to reach. It is perhaps by targeting some specific technological sectors with high added value that France and Europe could ensure the influence of their vision in the development of human activities on the Moon. They would however need to make sure that their contributions were invaluable to avoid remaining on the sidelines.

This same option also seems pragmatic, i.e. admitting fewer means to concentrate on selected technological challenges with high potential for which France and Europe have proved their competitiveness : energy, mobility, habitat and life support, treatment of waste, water and mineral resources; or that constitute domains of sovereignty such as data storage and processing, telecommunication networks, etc.

Nevertheless, this option requires constant financing and efforts to maintain a global lead in the technological niches targeted.

This choice could also lead France and Europe to position their Moon-focused technological development taking an Earth-Moon complementarity approach. The responses made by industrialists to lunar issues could be transposed onto earthly problems. Investment in the space sector would therefore be perceived as a double-trigger investment : in the short term with a return on investment on Earth ; and in the long term with a return on investment in a more uncertain lunar context but supported by the former. This Earth-Moon complementarity must be put forward as a programmatic axiom for lunar projects. It does not mean claiming to solve problems on Earth using the Moon, but rather guaranteeing that lunar investments have systematic benefits for Earth.

3

OBJECTIVES AND RECOMMENDATIONS

STRATEGIC OBJECTIVES

- **Develop** sectors particularly strategic for space (AI, data, robotics, security, e-health, Deep Tech, etc.) in a spirit of Earth-Moon complementarity.

- **With this objective, develop a regulatory policy capable of attracting and securing investments in space and innovation initiative.** The examples of the USA and Luxembourg show the importance of unleashing energy through a policy of removing obstacles.

- **Put European strategic independence at the heart of the definition of economic policies on lunar exploration** with the aim of guaranteeing independent access to space and defending our critical technologies.

- **Take advantage of the New Space era centred on the image of the space entrepreneur** and economic returns to put the Moon and exploration at the heart of this mindset.

- **Anchor economic objectives in a contemporary need for sovereignty** with the idea that independent access to the Moon requires independence in terms of infrastructure, transport, logistics, telecommunications and energy production.

- **Mobilize space and non-space sectors** in a common, coordinated effort with a view to developing critical technologies for the lunar project.

OPERATIONAL RECOMMENDATIONS

- **Write this lunar economic strategy into the constitution of the Blue Moon Alliance** (see GOVERNANCE chapter) to correspond to the major political events of 2022. The Blue Moon Alliance could constitute a strong means to position France in the new race to the Moon.

- **Carry out a high-level study** on the economic and industrial strategy for the Moon : identification of investments required and potential returns on European scale.

- **Involve digital actors more closely** in space exploration projects, similar to their involvement in low-orbit space telecommunication projects.

- **Mobilize non-space sectors** with the aim of creating a global ecosystem around the Moon : mining, energy, waste processing, telecommunications, infrastructure, logistics, waste management and agribusiness industries.

- **Raise awareness** among European cultural industries of the creative potential related to this expansion.

- **Increase the share devoted to space** in economic support programmes to finance a renewed space policy and including support for exploration and exploitation technologies, with an objective of Earth-Moon complementarity of returns on investments (ROI).

- **Make public-private partnerships a lever of innovation** and encourage all forms of alliance between economic actors and public actors to work towards the European

lunar ambition. Innovative space projects could be driven by semi-public companies that would go on to be privatized.

- **Encourage** the construction of European lunar demonstrators and analogues to set them up as laboratories of cooperation and innovation.

security and defence

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SECURITY AND DEFENCE

Regarding security and defence, and also the protection of the sovereign space interests of states, space exploration in general and the lunar ambition in particular find themselves in a paradoxical position. While it is undeniable that space applications have historically been developed in a dual context, half way between military and civil, and in a context of high geopolitical tensions, it is also true that the exploration of space constitutes a melting pot of international scientific and technical cooperation, with science sometimes transcending borders. The conquest of space has its roots in this spirit of cooperation dating from the end of the 19th century. It is worth remembering that it was major international scientific unions which, following two international polar years (1882-1883, 1932-1933), organized the international geophysical year (1957-1958). At this event, the two major powers of the time (USSR and USA) announced their ambition to become space powers. Despite the Cold War, a spirit of cooperation has consistently prevailed in international arenas, in particular at the United Nations and the Committee on Space Research (COSPAR).

The protection of the strategic interests of lunar exploration in the 21st century must consequently pay attention to this dual aspect : sovereign interests on one side, and scientific, cultural and economic cooperation on the other.

When it comes to space exploration, the terms security and defence evoke science fiction images straight from Star Wars. Nevertheless, and on a much closer timescale, the main concern is providing security for astronauts and protecting the scientific assets of the nations present, whether cooperative or not. Although this dimension is less spectacular, it is none the less strategic. The protection of astronauts and scientific assets could also be a place for learning, anticipating and apprehending the new conflicts generated by space exploration. The expertise developed in this context by international space forces in general and the air and space force in particular could constitute useful knowledge that will be highly solicited in the future.

With this in mind, the security and defence group opted to take a pragmatic, operational approach, attempting to identify the risks and how to counter them. The aim was to outline a potential future programme that enables lunar projects to remain secure with maximum autonomy and to count on remote support. This programme concerns both installations and robotic or human missions. It covers the preparation of the mission, its operation, and the return phases.

1

DEBATES

SECURING ASSETS

The installation and use of a long-term, expanding human base on the Moon constitute a totally new strategic asset that will need to be made secure. This security will not just concern the base, it will also include transits and lunar orbits. The latter two have the same key strategic dimensions to be considered right from the start of the lunar mission. They are central to the progressive installation of the base from Earth, around the Moon, and then on the Moon. In a second phase, once the base has been set up, it will involve protecting artificial lunar societies already in place. This protection calls for a holistic conception of security. More specifically, the assets to secure are the astronauts, the infrastructure that houses them and allows them to carry out their missions (living and work modules, lunar vehicles), and also (perhaps especially) their scientific experiments, the means to carry them out, and their results. Securing all of these material, organizational and informational assets requires identifying the risks and then managing them in situ.

The protection of assets with economic aims, in particular concerning private initiatives, should be taken into account. Under the legal framework in force, resulting from a corpus of treaties on space, space activities remain under the supervision of the state that authorized them, even when they are purely economic and undertaken by private actors. Which means that that state must also ensure all aspects of protection.

IDENTIFYING THE CONTEXT OF
CONFLICT AND COUNTER-CONFLICT

Studying how to make strategic assets secure does not mean assuming the existence of severe conflict. And ensuring security is by no means incompatible with peaceful, pacified exploration of the Moon. All too often defence is viewed with distrust by the space exploration sphere. The historic reason could be the first discussions between the USA and the USSR at the United Nations during the weeks and months that followed Sputnik's launch into orbit. At the time, the main preoccupations were to de-escalate space conflicts and move away from the weaponization of the space environment. But times have changed, and though the Russians and Americans succeeded in finding several areas of space cooperation, we are currently seeing a polarization between China (teamed up with Russia) and the United States, to the point that star wars once again appears in the collective imagination.

Nothing however prevents Europe from combining an imperative of security with the search for a balance between conflict and counter-conflict, nor from putting forward a lunar ambition imbued with sense and ethical values. Europe is a major lever of international space cooperation – cooperation that is made stronger by the quality of its scientific and industrial institutions. Thanks to this strong identity, Europe can put itself forward as a pacifying power on the Moon, while ensuring the protection of its strategic interests. On their side, Member States can provide assistance in securing artificial lunar societies thanks to their space armies. Beyond Europe, for all nations present on the Moon, avoiding a space war should be a priority ambition given the unknown character of this field of conflict and potential human and technological losses. This peaceful ambition would avoid the risk of repercussions on earthly conflicts.

2

SCENARIO

IDENTIFY THE RISKS, PREPARE A RESPONSE

Ensuring lunar security and protecting strategic assets requires identifying risks before the launch of a mission, during its operation, and once it is over.

Before a lunar mission, the major risks are political. A space exploration policy that is patchy or insufficiently assertive would either lead to delays in the race to the Moon, or to lack of preparation for a mission decided at the last minute. In addition, if Europe were to choose to collaborate with another space power to achieve its lunar ambition, particular attention would need to be paid to a plan to protect strategic assets and to cooperate on securing the mission. The new cooperation frameworks being drawn up should be the object of active monitoring : both the Artemis Accords and agreements between Russia and China for the ILRS, and including the Lunar Gateway and other existing inter-state agreements. These texts draw out a new strategic landscape that needs to be anticipated, kept under surveillance and protected. Similarly, soft power aspects related to space have sparked new interest from the powers in place. Europe should monitor communication and influence campaigns on space in general and the Moon in particular. Reciprocally, equipping the European space industry with an operational capacity for space soft power would be a good idea.

Also before the mission launch, the selection of astronauts is a source of potential risk. Recruiting an insufficiently prepared or badly selected team could jeopardize the mission. The cultural codes and references that need to be integrated to ensure that life runs smoothly in an artificial society are not always obvious and should be a key parameter of recruitment, more than for space stations of the past.

Regarding astronauts, they should preferably undergo a psychosocial assessment and monitoring before, during and after their mission. The security of Moon missions involves providing constant support to Moon and land crew before and during the mission and in preparations for future missions.

During the mission, the risks are mainly operational. Cohabitation between astronauts, robots and their interfaces can be a source of conflict. Social tensions and psychological breakdown should be anticipated. Even the most secure space missions cannot avoid the risk of a physical accident generating a health and operational risk on the base.

Concerning infrastructures more particularly, u a loss of autonomy at the base (energy or telecommunications) is a major risk that could have serious consequences on the durability of installations and astronauts' lives. This loss of autonomy would also be a high source of stress for teams at the base. Cyberattacks on the base from Earth, space or another Moon base are another potential danger. Cohabitation between digital interfaces and humans is at the heart of Moon base operations. The protection of digital assets should be the object of the same level of security as the protection of humans.

In the same vein, the digital identities of the crew members constitute an asset that requires protection. Securing the logistics chain between the Earth and the base is also crucial. The long-term interruption of this chain would in fact be catastrophic for the maintenance of installations and the survival of astronauts. Protecting against threats that could lead to a break in communication, information, organization or equipment between the Earth and the Moon is a central mission of Moon project security.

Contact with unidentified cislunar phenomena and with other forms of intelligent life is another hypothesis to anticipate, given international studies on this subject. Also in the domain of the unexpected, the discovery of a rare, highly sought-after material on the Moon or abundant resources of a known material could generate tensions between the powers present. Mechanisms should be set up in advance to deal with this potential source of conflict.

As soon as the mission ends, a feedback process on lessons learned must be put in place. This should involve all those who actively took part in the mission, the astronauts returned to Earth, the ground crew and the outgoing crew to look at technical aspects with the identification of necessary updates of equipment, decisional processes and interfaces.

This feedback process also has a political and strategic importance in terms of the mission's ambition and its place in national or European programmes. This analysis of the lessons learned and errors committed is a means to consolidate experiences and anticipate the reproduction of any errors. This raises the question of archiving this historical record over time. Ensuring the mission's place in a historical continuity requires constant, effective participation in discussions and international projects centred on the Moon.

3

OBJECTIVES AND RECOMMENDATIONS

STRATEGIC OBJECTIVES

- Encourage at the French and European scale the institutional and industrial promotion of a space doctrine advocating the peaceful, cooperative, sustainable use of space.

- Encourage inter-ministerial reflection on the dual dimension of space activities and long-term human presence on the Moon.

- Adapt the protection policy of the scientific and technical potential of the nation to the specific dimensions of space and the Moon base.

- Develop innovative, secure services for :
    - Space meteorology.
    - Control of lunar and interplanetary telecommunications.
    - Lunar geolocation. NASA is currently working on the possibility of extending the GPS signal to the Moon for the benefit of future missions. It would therefore be interesting to capitalize on the ESA's current initiatives to make a complementary contribution to the US option in space exploration projects.
    - Artificial intelligence and robotics.
    - The metaverse (for remote training and interaction between the Earth and the Moon).
    - Health, e-health.

- Consider emerging space powers (Africa, South America, Gulf States, etc.) as strategic space exploration territories of tomorrow.

- Democratize access to information and European lunar ambitions.

- Respect, when the situation requires, the protection of national security secrets.

OPERATIONAL RECOMMENDATIONS

- **Rapidly establish a Task Force** capable of identifying the risks and reflecting on existing and future industrial innovations, as well as ways to make the lunar base secure from the start and during operations. This Task Force would raise awareness among companies and operators crucial to the security of space innovations to protect strategic interests.

- **Foster the development of technologies** capable, at European scale, of maintaining organizational, communicational and material connection between the Earth and the Moon on a permanent, secure basis. These technologies concern both hardware and software, and robot, logistics and engineering innovations, in association with science, health science, social science and humanities, to ensure optimal management of the Moon base.

- **Encourage, in the recruitment of astronauts,** a range of profiles to match the diverse tasks involved in lunar exploration and compatible with the highest security level of the mission.

AFTERWORD

by CLAUDIE HAIGNERÉ
FORMER CNES / ESA ASTRONAUT, FORMER MINISTER

I propose to conclude this work of collective intelligence in a very personal way, humbly yet enthusiastically.

Born at the time of Sputnik, fascinated and inspired by the Apollo 11 Moon landing, selected as an astronaut candidate by the CNES in 1985 at the heart of the European ambition of inhabited exploration, with the ambitious Hermes space shuttle programmes, the scientific modules Columbus and MTFF, and the polar platform, I have had the honour and the privilege of taking part in two space missions. I have flown to the space stations MIR and ISS, and experienced the exciting human, scientific and technological adventure of the opening of inhabited space exploration to international cooperation, with the multilateral construction of the international space station in low orbit. I have had the responsibility of leading French space policy at the ministry of research, and of working on initiating the sharing of jurisdictions between the European Space Agency, ESA, and the European Union at the ministry of European affairs. At ESA I then intensely used and promoted a wide range of space activities, both for their everyday usefulness and for their economic, international and geostrategic value. But I have also spoken publicly about space research and its capacity to explore a universe full of mysteries, to help us understand and desire scientific and technological progress, in particular to the diverse audiences of Universcience, ranging from the youngest minds to curious visitors at science centres and museums.

Throughout my life, I have floated in the space dimension with inalienable conviction and as-yet unsatiated passion. For me it is clear that space is an avenue of exploration for the future. But this conviction, this perception of the potential it represents for today and tomorrow, is not as clear in the eyes of our national and European citizens. The domain remains largely unknown beyond a handful of highly mediatized events, such as the landing of Philae on comet 67P thanks to the European Rosetta mission, and the inhabited missions on board the ISS including Thomas Pesquet and our ESA astronaut colleagues, not to mention awareness of the threats of space debris or natural catastrophes observable from space. Apart from these headline stories, only our space community involving institutional agencies, space policy experts, space industrialists, and scientists interested in the unique character of microgravity research – only this very restricted circle is aware of all of the challenges and undeniable importance of space activities.

At a time when the major space powers are thinking about establishing bases on the Moon and even on Mars, one question remains unanswered on this subject I care so much about : How does Europe intend to position itself in this new phase of inhabited space exploration ? It is a question with far-reaching consequences, for which a general understanding of the issues and a shared analysis capable of triggering desire are central to both the decision to commit and the level of ambition. This question was the driving force behind the ANRT working group that I was proud to co-chair with CNES representatives, under the expert direction of Clarisse Angelier assisted by the organizational skills of Alban Guyomarc'h during the last two years. Mobilizing and engaging a large scientific and industrial community from outside the space sector on this issue of European presence on the surface of the Moon proved to be highly enriching, involving some audacious forward-looking and imagination without losing hold of reality, raising questions and desires among an assiduous, dedicated group.

Taking an open but coordinated approach, the resulting document carries a unanimous opinion : Europe must grasp the opportunities opened by returning and settling humans on the Moon. The reasons are numerous and the means are varied. Some of them are familiar to us in the space sector, others testify to a complementary, external vision capable of building a narrative that appeals to a wide audience. Without doubt, a European momentum towards the Moon and exploration, expressing its voice and proposing its way, is an investment for the future for France and Europe. Following some intense discussions, it is with conviction and enthusiasm that all of us agreed that Europe could and should bring its own ambitious response, and that the cost of not doing so would be too heavy to bear and justify.

Reading through this white paper, I put together the pieces of a complex puzzle that reveals a holistic, coherent, federating and attractive approach. This work provides the material to think and act, to tell and make heard this new narrative, and to launch into action, mobilizing all traditional energy and new initiatives. If this white paper can act as a hotbed for germinating lush leaves and plump fruit on solid roots for a rich harvest, then this approach and the hours of reflection will have achieved their goal. What is lacking is obviously the views and words of European states and European citizens in all of their diversity, and this paper can act as a breeding ground for all fertile seeds.

In the expansion of humanity to explore Terrae Novae, Europe can and must contribute now, with talent and ambition, to promote its values and expertise, and to create a new impetus to tackle tomorrow and elsewhere in confidence.

It is up to all of us to share this desire and this narrative to act together and succeed. Because, as Oscar Wilde put it : "*Shoot for the Moon. Even if you miss, you'll land among the stars*". There is no question of failure. *Ad astra.*

Created in 2019, the ANRT's Destination Moon group brings together actors from inside and outside the space sector to put together a vision, innovation and communication on the project of a long-term, expanding life base on the Moon. The transformation of the space industry thanks to new technologies opens up new possibilities and gives new meaning to inhabited exploration of the Moon.

ASSOCIATION NATIONALE
RECHERCHE TECHNOLOGIE