Return to the Moon: how to define the lunar business ecosystem?

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Summary:

50 years after Apollo's events, while space industry has good perspectives of evolution, return to the Moon is a major undertaking with many purposes. This paper provides an analysis on what could be an optimum model of development for the Moon economy, taking into consideration wide range of objectives. Our study relies on the concept of business ecosystem by James Moore, its structure and challenges. Finding its source from an ecological meaning, it highlights nature of interactions and allows a deep analysis of features to build a viable framework. Through authors and reviews, demonstration points out the importance of collaboration and innovation, both in business ecosystem theory and space industry. We establish then a concrete model based on three hypothesis. The first one defines creation process for lunar ecosystem, and second one establishes basics of collaboration within the ecosystem. Finally, we use fundamentals of entrepreneurship ecosystem, variation from original Moore's concept, to set our model structure. Critical analysis highlights limits and missings of our development, while looking for alternative reflections on what could be the framework of the Moon economy.

Keywords: Business ecosystem - actors - relationship - innovation - lunar economy - industry - company – collaboration - competition - resources - environment - entrepreneurship - space - interactions – opportunity

Résumé:

50 ans après les missions Apollo, alors que l'industrie spatiale a de bonnes perspectives d'évolution, le retour sur la Lune est un enjeu majeur avec de nombreuses finalités. Ce rapport fournit une analyse de ce que pourrait être un modèle optimal de développement pour l'économie lunaire, prenant en considération un large éventail d'objectifs. Notre étude s'appuie sur le concept d'écosystème d'affaires de James Moore, sa structure et ses challenges. Prenant source d'une métaphore écologique, il révèle la nature des intéractions et permet une analyse approfondie des caractéristiques nécessaires à l'élaboration d'un cadre viable. Au travers des auteurs et revues, notre démonstration souligne l'importance de la collaboration et de l'innovation, à la fois dans le concept d'écosystème d'affaires mais aussi dans l'industrie du spatial. Nous établissons ensuite un modèle concret basé sur trois hypothèses. La première définit les processus de création de l'écosystème lunaire et la seconde établit les bases de collaboration au sein de ce dernier. Pour finir, nous utilisons les fondamentaux de l'écosystème entrepreneurial, dérive du concept original de Moore, pour préciser la structure de notre modèle. L'analyse critique révèle les limites et manquants de notre développement, en recherchant des réflexions alternatives de ce que pourrait être l'organisation de l'économie lunaire.

Mots-clés: Ecosystème d'affaires - acteurs - relations - innovation - économie lunaire - industrie - entreprise - collaboration - compétition - ressources - environnement - entrepreneuriat - spatial – intéractions – opportunité

Summary

Abbreviations list

COST	Commercial Orbital Transportation Services
CNES (in French)	Centre National d'Etudes Spatiales (National Center of Space Studies)
CNSA	China National Space Administration
CSA	Canadian Space Agency
ESA	European Space Agency
EU	European Union
ISECG	International Space Exploration Coordination Group
JAXA	Japan Aerospace Exploration Agency
NASA	National Aeronautics and Space Administration

Introduction

In 1969, Buzz Aldrin and Neil Armstrong walked on the Moon for the first time in history, accomplishing Apollo's mission from NASA. After consequent slowdown of its dynamic, space industry seems to shine again with a wide range of new programs and innovation. In our fast-moving world, return to the Moon is no longer a fantasy and the aim of space exploration is very important. For space agencies and private stakeholders, Moon is a gateway for the next step: Mars and beyond. This variety of actors, missions and purposes brings to several conflicts: there are no rules in space, no framework, but a lack of managerial implications in many scientific missions. However, the Moon economy development has major stakes for a big part of the population: sciences, societal issues, environment, exploration, space tourism and so on. This ambitious project, led by NASA with Artemis program, definitely needs a viable framework. Moreover, space industry suffers sometimes from a lack of credibility with public opinion. For a lot of people, the Moon is no longer a dream to achieve, and going to Mars and beyond is even more unrealistic. If a solid and sustainable structure works for the Moon initiative, it will drive to many other incredible adventures. The aim of this research thesis is to answer the following question: how to define the lunar business ecosystem?

There are not many reviews on the Moon economy topic. The only official agreement ratified by the most important countries in space race is the Outer Space Treaty (1967) which enunciates principles of non-militarization and non-property of celestial bodies. Actually, our main tool to discuss about space industries frameworks would be history. Thanks to ISS program, we have a successful project based on a completely new framework of collaboration cross-countries.

To talk about this topic, we decided to adopt a novel vision, considering the Moon as it is: a different place from Earth, our satellite. If the Moon becomes a place for new businesses and innovation, how to consider its ecosystem? How to build a commercial framework in a completely different world from ours? Do we apply same rules as on Earth? In this Research thesis, we will try to understand what characterize a *business ecosystem*, and how to define the lunar one.

The first step will be to go deeper in management analysis and publications to apprehend the notion of *business ecosystem*. The first term, *ecosystem*, has been introduced by Arthur TansleyIn, a biologist, in the 1930s. 60 years later, James Moore revisited it in an Harvard Business Review article to apply it to business and described all the economic network and interactions between various stakeholders. We will bring notion of evolution of ecosystem and variation from business to entrepreneurship ecosystem. Following that, we will make an overview on space industry evolution through history, economy and innovation. The last stage of our research will be to make the bridge between business theories and space practices to give recommendations. We will deliver a new model based on three hypotheses. We will also study alternative models and their limits. Today, space industry is at a crossroad: from a technology-push industry we moved to a user-pull market. Management principles are keys to a better understanding and governance of space missions such as lunar programs.

1. Academic framework: birth of an ecosystem

1.1. The business ecosystem theory, an ecological metaphor

The concept of business ecosystem is at the heart of the global economic war (Christophe Assens and Joëlle Ensminger, 2015). The framework of a business ecosystem is very wide and subject to discussion, it is important to input the base. At first, the name ecosystem is per definition related to the natural environment and all the organisms within it. So at first the definition is just for a natural purpose, later in the time, it was adapted for a business purpose.

Defined by Moore a business ecosystem is : “An economic community supported by a foundation of interacting organizations and individuals—the organisms of the business world” (James Moore, 1993). In other word the system has a center and one periphery where lot of organisms are gravitating. It involves a mix of a certain number of companies or associations, which grow and develop together in a deep relation (Gérard Koenig, 2012).

According to Moore, the relationship between the actors of an ecosystem is its main characteristic.(Gérard Koenig, 2012) A structure with companies and other actors not interacting is not really an ecosystem anymore, it is more many small ecosystem at the same time. We consider that a company is part of a business ecosystem and not just from one industry. At the same time, an ecosystem can cover several industries. If we take the example of Apple, the ecosystem of its computer is covering the following industries : personal computers but also consumer electronics, informations and communications.

To stay on the natural lexical field, the ecosystem has a life. It is going through four main stage in its evolution (James Moore, 1993).

The first one is its birth. Like every other live beings, the “ecosystem” born in a moment “T” and at a place well defined as well. The place can be more or less precise especially since our world is digitalised. Due to digitalisation, the place can be something intangible.

The second stage that a ecosystem face is the expansion. Beginning from nothing, it will grow more and more to reach its leadership phase. The leadership phase is always limited with a long or short time. The ecosystem is working in a really efficiency way, all the actors are fully using their potential and relations between them are optimised.

At the end the ecosystem enter in the death phase which is the last one of the cycle. It can be due to an external or internal factor. Then the ecosystem can renew or not.

The business ecosystem shares the same phases as the natural and authentic one. At the beginning, there is a movement from a casual group of component to a more organized economy. Then the differents stakeholders collaborate together and adapt themselves around an innovation. Since the emergence of the digitalisation, it changed

the collaboration which can be just an online relation through a digital ecosystem (Satish Nambisan et al., 2019). The innovation can be a product, a service, a new process of sales or something else. The third stage is when the ecosystem arrive to a mature stage, the process, the relations are already optimised. The stakeholders are fully operational and are using all their potential. This period can last more or less long until an alteration. A new market can emerge and eat the ecosystem or make it evolves. This is the end or a re-new of the ecosystem.

This being said, an ecosystem is never alone. It is often directly related to another ecosystem. And this fact can have a lot of importance. The biologist Stephen noted during his natural experiences that the health of an ecosystem can be impacted by the evenement of its environment that it is in. If the environment faces a huge disaster, the related ecosystem will be impacted as well. In term of business, we can take the example of the financial crisis of 2008 which impacted each of the related sectors. The environment collapsed taking with it all the related domains. Everything can have an environment and be the environment of something else (James Moore, 1993).

What about the movement in a ecosystem? In business we can enter in an environment already existing or create its own. Apple and IBM are some examples of companies that created their own environment. They participate as a chief of an ecosystem in leading the suppliers, the partners and other stakeholders which finds an interest in joining the environment. In the case of Apple, the informatic companies belonging in the ecosystem propose by themselves some new features like the apps available in the “appstore”. The New-York based company even develop further in making partnership and working with some media, other branded shops and institutions. The statement of Apple was really proactive at the beginning (James Moore, 1993).

It is not exaggerating to say that the concept of the business ecosystem has been subject of discussion and difference of point of view according to the period of time and to authors. The concept of business ecosystem was first introduced by Moore in the middle of the 90s. He inspired himself from ecologic ecosystem defined by Tansley in 1935 (James Moore, 1993).

It evolves through different state upon the time. We can see the origin of the business ecosystem in 1890 as an industrial district. This organisation was about a very specialised production realised by several little companies in the same district. This organisation was used in Germany for example with the metallurgy district. Ten years later, we talked more about business networks or business cluster. A cluster is per definition a gathering of organisation engaged in relations in a well defined place. A company can take advantage from the cluster to gain knowledge in the shared learning made by all the companies thanks to social or technological relations. We also can find other denominations like company constellation, extended business. It was a vast and still unordered taxonomic profusion to talk about a system not definitely structured and still flexible. Now if business ecosystem is the trend, we can observe other word trending like innovative ecosystem or datasystem of innovation (Gwenaelle Oruezabala, 2017).

The definition of an ecosystem is also something that can have discordance or some several fluctuation. Upon the time, it can be also the subject to a more precise concept. The definition gave by Moore had a lot of success due to its natural metaphor.

It was then easy to understand, to assimilate and communicate. If some scientists agree with the fact that the organisms in an ecosystem share a normal relation, Gregory Bateson for example divided the protagonist in two parts : the predators and their preys. In 2012, Koenig prefers to analyse the ecosystem like a flexible system with evolving relation and places (Gérard Koenig, 2012). According to Iansiti and Levien in 2004, the ecosystem is managing some assets that nobody is really possessing (Marco Iansiti and Roy Levien, 2004). It is due to the phenomenon of interdependence and control of resources. It is to show that the perception of an ecosystem can differ according to the author. Nobody is fully wrong or fully right. It is just a question of point of view. We can consider that the truth to adopt is what is shared by the majority of the author.

What is sure is that the environments are constantly evolving. Koenig realised every ecosystem are not well designed to fit innovation change. Sometimes, it is better for the ecosystem to be adapted to it. It implies that innovation has a huge place as the stakeholders have to adapt to a competition changing every time. Innovation becomes the main focus of every actors. The challenge is now to develop an ecosystem which can cover this key point. The fast moving economy impose a lot of challenge to resolve quickly, a good communication between actors is key to succeed this.

1.2. Business ecosystem mapping : relationships and its consequences

We talked previously about the importance of the relations between the stakeholders. The importance of this relationship is a common point that we can observe in every ecosystem.

1.2.1. Actors

There are many actors in this challenge to build an efficient relationship. Public and private ones, internal or external ones.

Relationships have then to be facilitated. It is the main goal of the leading administrations which will gain indirectly from the success of a local ecosystem .The country has a big role in the creation of ecosystem. Their goal is to take advantage of the characteristics of a given place in order to highlight a competitive advantage which can lead to an added value (Christophe Assens and Joëlle Ensminger, 2015). They are putting in place facilities in term of transport connexion (roads, rails, bus system…). The public administrations and private organisations have to work in deep relation in order to create the most efficient ecosystem, accordingly to their competencies. Both parties, public and private are in a win-win relationship where they will gain from positive connexion (Gwenaelle Oruezabala, 2017).

1.2.2. Characteristic of relationship

The goal of this relationship is to have an ecosystem which is efficient and can adapt to its environment quickly by finding a good answer to every challenge. The business has to go grab by itself the resources that it needs to be competitive in

prospecting relationship with the right partners (Christophe Assens and Joëlle Ensminger, 2015).

Usually, relations between all interplayers are “competitive” and “cooperative” (Gérard Koenig, 2012). They can in one hand be partner in a project, and in other hand be in competition on another market or subject. However, we can highlight two other types of relations in an ecosystem. There is the competencies network where stakeholders exchange together beside competencies. There is also addiction network where in this case the stakeholders are dependant between themselves (Sylvie Mira-Bonnardel et al., 2012).

Sometimes, the lead has to be taken from an actor of ecosystem. He will then be the orchestrator of it (Micharl G. Jacobides, 2019) .

1.2.3. Places

Policies made by public administrations have lead to a gathering of companies to make industrial districts or clusters. It implied that sometimes, different companies in the same market have to share the same location. The thing is that companies share the same point of view on key thing like infrastructures, they all can benefit from implementation by the Government. Then, companies have sometimes interest in cooperation between competitors (which can be in their area) in order to have the best tools and features and then be efficient. Even in competition, they should talk as one voice to the public administration. Like this, they are more credible and more influential to public administrations.

It is what makes the difference between a business ecosystem and a companies network. Whereas business ecosystem and companies network can be similar in the leading system of the organisation (Gwenaelle Oruezabala, 2017). The ecosystem is not just a physical network. It is a system which can have different realities.

1.2.4. Process

Relations can take several aspects. It can be a sharing of resources, of knowledges, of goods, of accomodations. More the system is integrated, more the actors will have benefit from living in the environment.

Common sense is to think that what makes actors enter in relationship is mainly due to geographic proximity. It is something which can be less and less verified since we entered in the world of the “clic”. It is possible to communicate in less than one second to someone at the opposite of the planet. The different “clouds” dematerialised informations. Resources are at the same time everywhere and nowhere (Gwenaelle Oruezabala, 2017).

1.3. From business ecosystem to entrepreneurship ecosystem

Environment can be both the cause or the consequence of innovation. We highlighted an original structure which can be a model to lead innovation, based on the six key domains for entrepreneurship stated by Daniel Isenberg*

1.3.1. Six domains are key criteria

First in term of finance. Financing is often one of the main problems for start-up. This is why they have to play with several other actors who are often present in an entrepreneurship ecosystem. The 3F : family, friends and fools are key for innovators in giving the first investment and also giving energy. Obviously, banks have a big role in this domain, as well as the angel investors who gravitate around this ecosystem. We can find also a financing by venture capital, public market or debt for companies with a more important power.

A second important domain and entrepreneurship domain is shared mindset. Success stories must be key, everybody should share positive vibes. Being in an environment like this helps leading to success. It becomes then a virtuous circle as the success help other to reach success which will help others and so on. These successes will lead to a solid national or international reputation. This mindset doesn't mean that everything is positive. The thing is to transform negativity in positivity. A failure becomes a lesson. There is place for risk taken. How many unicorn has been made by someone which has tried several companies before without success ? We find a large amount of positive word in the lexical field of an entrepreneurship ecosystem as innovation, creativity, experimentation. We can observe that every of these words shares the meaning of an action, of doing or beginning something. An entrepreneurship ecosystem is an environment moving, which does not stay on its achievements.

Start-ups are heavily impacted about something which are not really on their control: infrastructures. A company can decide where to go according to its infrastructure but is not directly responsible about these transformations - except in the case when the whole group raise their voice to the public administrations like we saw previously. This support is in term of logistic, or energy. As well as in term of telecommunication: a company loses all interest to be in an ecosystem if it lost all its ways of communication. A support of knowledge is also part of the game. Start-ups are often not well equipped to face legal or accounting problem. It highlights then the role that has all the organisms gravitating around an ecosystem which can be at first exterior to it.

Human capital is the fourth domain important in an entrepreneurship ecosystem. The innovation has to be from people creative and educated in a way to be so. Sometimes it is just a mindset transmit by family. The knowledge and skills are rare assets that an innovative company has to consider precious. Some special entrepreneurship trainings are existing, however it is not a magical product. It will not deeply change character and nature of somebody.

To succeed in a market, a company has to know well about its characteristics. This rule is also true for the innovative company. The market, fifth domain important for an innovative ecosystem, has to be fitted for innovation. Presence of early customers might

help as they will launch the beginning of a project. The network can help as well depending on the needs: it can be an entrepreneurs network, diaspora network or multinational network. In some areas like the aerospace one, the three networks have their importance.

Last but not least, regulation is a characteristic which can affect and impact dramatically a project. To talk about space industry, policy regulation is decisive for example when a company wants to make business using space ressources. What are the rules and who makes the rules ? It is a considerable subject which has to be taken into account to know if these limits can affect the efficiency of innovation in an ecosystem (Daniel Isenberg, 2011).

These six domains are composing environment in which innovation can start from. Considering that every of these six domains can have variations, it makes every ecosystem more or less unique. They all share the same main purpose to impulse and support the process of innovation.

1.3.2. Adapt to fast-moving economy

Facing the fast-moving economy is a key challenge for an entrepreneurship ecosystem. Even with an ecosystem totally controlled, it is possible to lose control of it. We have the example of IBM who created its own ecosystem around personal computers and then lost the lead in the market due to competitors more able to innovate (James Moore, 1993). However, an innovative ecosystem is supposed to be self-sustaining (Daniel Isenberg, 2011). The key to face innovation is in always reaching progress, always searching innovation, never stay on something acquired. Making good decisions in choosing right relations, to be surrounded by efficient actors.

2. Empirical framework: the Moon, an emerging business

2.1. Lunar economy: from fantasy to reality

July 1969: the entire world is watching Buzz Aldrin and Neil Armstrong walking on the Moon for the first time in history. United States achieved with Apollo mission a “giant leap for mankind” as quoted by Armstrong. The origin of this historical event comes from the appeal of President Kennedy in 1961 in the middle of a Congress session : “I believe this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to Earth.” (Kennedy, 1961). Back to this time, United States and Soviet Union were in a race for space developments and achievements, so Kennedy’s proposal was well received by citizens and administrations. In 1966, thanks to an international team of scientists and engineers, the first unmanned mission was launched by NASA. After several failures and loss, Apollo 11 finally took off on July 16, 1969 from Kennedy Space Center, with Saturn 5 rocket. They achieved their purpose to “land men on the lunar surface and to return them safely to Earth” (History,

2019). This program costed 24 billion of dollars (equivalent to 100 billion of current dollars) and involved 400 000 engineers for many years, mainly for political reasons (History, 2019). However, it had a significant effect on generations, on innovation and space industry. Even if he were born two years after Moon landing, Elon Musk, SpaceX's creator, has been deeply inspired and sees Apollo 11 mission as an icon of space exploration. Many other young people at this time felt a new era of innovation and sciences was coming (Jeffrey Kluger, 2019).

Yet, space exploration did not become very popular immediately after 1969's events. On the contrary, after Cold War ended and Soviets were beaten, American citizens did not see the point to continue Apollo program and highlighted the various consequences of it : casualties, waste of money and waste of time… The last manned mission on the Moon came back to Earth in 1972, after what space industry suffered from a lack of investments for years. Some political initiatives such as the Space Exploration Initiative institute by Georges W. Bush tried to revive space economy, without success (Solidarité & Progrès, 2014). The main issue we could notice is finance. World's history knew many economic crisis, leaving no money for space exploration, and public opinion impacted a lot its importance for society.

After World War II and a consequent slowdown of its dynamic, space industry seems to know its best years with many branches of activity: communication satellites, exploration, Earth observation, navigation, and so on. For the first time in history, the ESA got 14.4 billions euros of fundings from 2020 to 2024 (ESA website, 2019). The global space industry could worth more than 1 trillion of dollars by 2040, against $350 billion in 2019 (Morgan Stanley, 2019). Space industry is emerging as one of the most lucrative industry. Impact is huge: scientific space technologies are used in our daily life for many applications in medicine, transportation, safety, energy, consumer goods but also environment. We are clearly facing a new era for space industry development, due to liberalization of the market with new actors from private companies and emerging countries. From a technology push, we went to a user pull market. This renewed dynamic is called New Space: new actors, new goals, new means and cost-driven strategies, new market structure without monopoly. From an international perspective, things are moving fast. China and India launched complex and ambitious programs. The CNSA accelerated its space programs since 2003, with multiple crewed missions, robotic lunar missions (Chang'e-4) and even its own space station (Jeffrey Kluger, 2019).

As a major event of the beginning of this new era, we celebrated last year Apollo 11's 50th anniversary. This was the opportunity for space community to address Moon topic and future lunar missions. On this occasion, NASA announced the creation of Artemis program, to go back on lunar land by 2024, involving many international actors in this project and focusing on Moon's south pole (Picture 1, Appendix 1). ESA also communicated its priorities to focus on polar water ice, geophysics, resources and samples, radio astronomy and biology (ESA report, 2019). Returning on the Moon has several aims that we can classified per segment and under segment.

2.1.1. Political

Back in 1969, Apollo was about a political war between United States capitalist system and Soviet Union socialist system. What about today ? For Mike Pence, Vice president of United States, it is again about politics but differently. Among his arguments, competition with China, a recent space actor but really fast. “Made in China 2025”, the ambitious program built by Prime minister Li Kequiang, suggested that Chinese companies will lead several technology areas, including aerospace equipment (Oliver Morton, 2019). In 2003, China became the third country ever to launch a human into space. They are currently building deep space crew capsule, and their own space station. In the meantime, they achieved with Chang’e 4 a step further going to hidden face of the Moon. After a year of activity, they successfully diffused some pictures a few days ago, in January 2020. Therefore, stakes are high for Occidental countries and NASA with Artemis program.

2.1.2. Sciences

Even if other strategic goals arrived with the concept of New Space, Sciences are still very important for space exploration. Several domains are concerned by lunar missions:

2.1.2.1. Geology

Geology is a scientific domain dealing with study of physical structure and substance, history and processes acting on them. Moon, as Earth’s satellite, is closely linked to our planet. Because of its fast cooling, Moon has been marked by events affecting our Solar system, meaning that scientists could know more about our own history by studying Moon’s, and about history of Universe (Solidarité & Progrès, 2014).

2.1.2.2. Biology

Going to the Moon and staying there will allow scientists to make great progress on study of Human physiology and survivability of our specie in space. It will also allow them to experiment artificial ecosystems development (Solidarité & Progrès, 2014).

2.1.2.3. Physics

Lunar environment has many advantages for physics study: almost perfect vacuum, no magnetic field, intense cold, and reduced force of gravity. For example, it could be a great place for particle accelerator (ESA report, 2019).

2.1.2.4. Astronomy

Many projects and patents have already been developed on lunar astronomy: using resources from the Moon to build optical mirrors, install an optical industry, build huge telescopes…

Scientists have many reasons to come to the Moon that have been classified by scientific community into three categories: Science of the Moon, on the Moon and from the Moon (Table 1, Appendix 2).

2.1.3. Economics

Global warming and industrial challenges are also part of “the reasons why”. Actually, they are the main difference between space industry in the 70’s and today. Public opinion is different because global situation on Earth and stakes are different. Going to the Moon and implement a viable lunar economy is about sustainability (Mark Holmes, 2019). For humanity to find another place to live, to compensate the lack of resources, to boost development of new technologies and innovation, impacts on our society could be enormous.

We are going to the Moon to stay and even go further in deep space. Several options are considered: exploitation of lunar ressources, install a moonbase for scientific exploration, and use the Moon as a gateway to go to Mars, on a long-term strategy. Objectives are numerous, but how to reach them with so many constraints?

2.2. Collaboration in a challenging environment

Reaching such progress can only happen with a common effort. However, as we said before, space industry knew a lot of changes on the last decade, and has even be renamed “the New Space”, involving new types of actors. So how to build a viable lunar economy and support Moon initiatives ? Who are the main stakeholders and how are they collaborating ? Space industry is full of different types of actors evolving in a very challenging environment. We can split them, observe their different role in Moon business and how they collaborate.

2.2.1. Institutions

In space, the main issue countries are facing is the lack of regulations and clear framework. There is no international institution to set rules, but some international agreements have been signed. In 1967, 109 countries have ratified the Outer Space Treaty which is a “treaty on principles governing the activities of States in the exploration and use of outer space including the Moon and other celestial bodies” (United Nations Office of Outer Space Affairs, 1966). It lays down rules about non-militarization of space activities, freedom of exploration for everyone, and States liability. For example, a private company needs all authorizations from its Government before launching any space activities. About the Moon, it is specified that it should be used only for peaceful purposes. Another agreement has been introduced in 1979 to govern activities on the Moon and all celestial bodies. However, most of the countries refused to ratify, and none of the main actors did it (United States, Russia, China, European countries). In Europe, the European Union is fully involved in space policy, acting as an international representative of

European countries (Ministère de l'Enseignement supérieur, de la Recherche et de l'Innovation, 2011).

2.2.2. Agencies

Many countries are leading their activities via space agencies. The most known are America's (NASA), China's (CNSA), Europe's (ESA), Japan's (JAXA). Every agency is financed by national budget, coordinating space activities, conducting initiatives in their countries (in France, CNES). European Union created a supranational agency, group of 18 EU States members, including France. ESA has a global budget fixed by a Member States Council. We can already note a high collaboration between countries on space policy. On a more high level, space agencies collaborate together: through project, or even through dedicated groups. For example the ISECG gathers 14 space agencies to discuss the Global Exploration Strategy and coordinate their actions (ISECG, 2019). The ISS is a great instance of international collaboration. Launched in 1988, the ISS is used and financed by 5 agencies and their countries: United States (NASA), Russia (Roscosmos), Europe (ESA and agencies of Member States), Japan (JAXA) and Canada (CSA). Operations and management are shared around the Globe (Picture 2, Appendix 3). There is no doubt that this has been a success, with discoveries, daily life impacts, thousands of journal publications (Ruttley et al., 2017). The strength of the ISS is the international collaboration, and impact of the benefits nearly doubled when agencies worked together (Table 2, Appendix 4). For Artemis project to return to the Moon, NASA is willing to collaborate with international agencies, such as Japan and Europe, and get their support.

2.2.3. Private companies

Among this network of space actors, private companies are disrupting the market for a few years now. SpaceX, Blue Origin, Virgin Galactic are ones of them, created by private investors who have seen the opportunity to develop a new segment : the commercial space. Most of them are located in United States and directly compete with governmental organisations. However, their market entry enabled reduction of costs, stimulated innovation and risk-taking, and convinced investors of the sustainability of such investments. They opened a new area for space economy (Monica Grady, 2017). Moreover, it is not just about competition with public agencies and Governments, they also collaborate and bring new ideas to them. To return to the Moon with its Artemis program, NASA has solicited numerous external companies. They created the Commercial Lunar Payload Services (CLPS) initiative, and have already selected 14 companies (including SpaceX and Blue Origin) eligible to bid on proposals (Oliver Morton, 2019). Collaboration between private and public becomes increasingly popular and essential in space industry.

Governments, space agencies, private companies, they all need to work together and collaborate in order to achieve successful missions in a very challenging and technical environment. However, other stakeholders need to be included in this network, and also have a high impact on future Lunar economy: customers and public opinion.

Project to return to the Moon and stay is an ambitious one, requiring many resources: financial, technical, human resources, hardware resources and so on. Collaboration is key, and each actor could find its role: federate and finance, lead and develop, manufacture and innovate, support and consume.

2.3. A single conjecture directed by innovation

Since the first human in space, technological spin-offs from space exploration allowed a great number of progress in society in many domains: medical, public safety, automotive and so on (Picture 3, Appendix 5). Innovation is a driver for space exploration and sciences. Is innovation driving the Moon initiative ? Is it a key parameter to build a sustainable lunar economy ?

Return to the Moon in 5 years is an ambitious deadline, technically speaking. The aim is not only to land on the Moon, but to create new ecosystems and work in a lunar economy. All of these challenges will need the right capabilities and enough Research and Development, while managing risk. Safety, costs, risk reduction and propulsion systems are major challenges. NASA plans on using the heritage we got from decades of experience, with our today's innovative ideas. However, challenges are quite unprecedented: landing humans additionally to large masses on lunar surface could be a game-changer for space exploration. Andy Crocker, director of space strategy and lunar program manager at Dynetics, a NASA supplier, highlights that we need to accept the risk, not looking for zero risk but learning to manage it (Mark Holmes, 2019).

That is where private companies come in. Elon Musk, creator of SpaceX, totally disrupted space industry, bringing new philosophy of risk-taking and new ideas, especially with reusability of rockets. This is the kind of mindset space market needs for ambitious program such as Artemis. Another example is Aerojet Rocketdyne, which delivers propulsion systems at an affordable price thanks to innovation (use of 3D printing, Solar Electric Propulsion…). However, Frank Slazer, Aerojet Rocketdyne vice president of strategy and business development for space, thinks that great technologies will not be enough to go to the Moon: we need a complete moral and financial support from Governments (Mark Holmes, 2019).

For Artemis program, Blue Origin has proposed the biggest lunar lander since Apollo lunar module called Blue Moon. Payload can carry 4,500 kilograms and will, according to Jeff Bezos, fly in a few years (Oliver Morton, 2019). To evaluate viability of such innovation, Peter Bregman and Antonio Nieto-Rodriguez published in Harvard Business Review a 6-question methods, that can be applied in a larger vision to the Return to the Moon initiative. It allows to have a clearer vision on rationality of Moon's projects (Bregman et Nieto-Rodriguez, 2019). The first element to question is the goal (the why): are there rational and fixed objectives ? It needs either to solve a problem or to capture an opportunity. Second question is the who: to success, a project needs to have charismatic sponsor. Third element is the what, the scope, and the fourth question focuses on the means (financial for example, the how). The two last elements are the when and the where, which in Artemis case, are clearly defined.

Innovations are a driving force of potential return to the Moon and lunar economy. But innovations are not only technical, they also could be business models innovations or legal innovations.

3. Reflections on lunar economy model

Business ecosystem concept derived from anthropology, as described by James Moore and reviewed by many authors later, could be used to implement lunar economy. We need first to validate our model matches the Moon industry conditions.

3.1. Business ecosystem concept applied to Moon development

As defined on first part of our report, business ecosystem is an economic community, with a center interacting with peripheral actors. At first, it was a metaphor from Tansley biological definition of natural ecosystem. Here, the parallel is easy because the Moon, besides being a potential new economic system, is also a new natural ecosystem, different from Earth. We deal with an easy representation of reality and ecological metaphor is particularly adapted.

Business ecosystem could be extended to several industries through many actors. In space industry, it is exactly the same. For example, suppliers come from many different business domains: electronics, propulsion, manufacturing, raw materials and so on. If we focus on space exploration and lunar economy development, there are as much areas of expertise as objectives to return to the Moon. For scientists, goals are related to geology, biology, astronomy, whereas private investors think about business opportunity, and space agencies (NASA for example) about Mars exploration and beyond. Here again, Moore's model is suitable to our lunar model.

Another distinctive characteristic of business ecosystem is a close link to another ecosystem. When disaster occurs in one, the other is impacted. Our potential lunar ecosystem will be, at least at first, related to Earth's ones in terms of: financing, knowledge, workforce, logistics, energy… Even if the ultimate goal is to be completely autonomous.

In the same way, business ecosystem concept is commensurate with the Moon future market evolution, with identifiable steps. The birth of the ecosystem is already a fixed date thanks to Artemis program of NASA which plans return of humankind to the Moon for 2024. Location is also easily identifiable: the Moon, with a first landing on South pole. Expansion phase in Moore's theory is characterized by a leadership phase, which could be assimilate to strong leadership by NASA on Artemis mission. Finally, the death phase due to external or internal factors is useful for identification of potential issues: legal fight on owning of resources (internal), politics conflicts between countries (internal), slowdown of technological progress due to lack of workforce and competencies (internal), financial and energy dependance combining to economic crisis on Earth (external),

environmental case of force majeure (external). Once again, we could consider business ecosystem theory as a valid framework for lunar economy.

Through authors and reviews, we found several remits for ecosystem definition. For example, Bateson's model is focused on predators and preys interactions, which does not corresponds to our potential ecosystem, because it could drive to military conflicts or inefficient collaboration between private and public. However, Koenig's model about a flexible system with evolving relations and places is suitable with the Moon's one. Indeed, the unpredictability of Moon's environment causes need for flexibility, stakeholders entering in the ecosystem will be progressive (not all at the beginning), and locations will evolve (first from South pole to remained lands, further on Mars and beyond). Moreover, Iansiti & Levien's model (managing asset which do not belong to stakeholders) may match because of extra terrestrial resources not belonging to anyone (or belonging to everyone).

Our analysis demonstrates the viability of applying business ecosystem theory to the future Moon model through several elements: definition, scope and extended framework, evolution phases and reviewed model. From now on, we will expose hypothesis of operating processes and recommendations for a sustainable structure.

3.2. Proposed model and discussion

The aim of this trial is to emphasize three hypothesis based on our recommendations and analysis, to understand better how to build a viable lunar ecosystem thanks to Moore's concept.

3.2.1. Hypothesis n°1: Creating from scratch

Ecosystems can emerge in two ways. First, companies can join an already existing ecosystem or the ecosystem can be externalised from an existing one, as an evolution. However, in our situation, return to the Moon will require numerous new technologies, inventions and companies will face unprecedented issues. For these reasons, we need to create an environment from scratch. As IBM and Apple, space industry will focus on new objectives to develop Moon's initiative.

To do so, James Moore exposed in his work the necessity to have proactive leaders guiding the movement. As we have seen, many charismatic sponsors have led space industry to its best years. Nowadays, private stakeholders such as Jeff Bezos (Blue Origin) or Elon Musk (SpaceX) are galvanizing initiatives. For Artemis project, NASA is an unquestionable leader, but support and participation of numerous space agencies and countries around the world extends even more the number of proactive actors.

Having sponsors and leaders to create a new business ecosystem is fundamental. In the meantime, building from scratch also means creating a new framework with new rules. In Moore's concept, one of the key elements is government agencies and regulatory bodies. In space, there are no proper regulations adopted internationally, only a few

agreements like the Outer Space Treaty on non-militarization of space and non-property of extra terrestrial resources. This will be a first necessity while creating lunar ecosystem, especially because of the internationalization of the project.

As it cannot be an extension from an existing business ecosystem, the Moon ecosystem will need a solid legal framework, with international government organizations to instaure new rules. They will be able to lean on proactive and charismatic stakeholders such as agencies and private investors.

3.2.2. Hypothesis n°2: A collaborative ecosystem

Business ecosystem by nature is about interactions: relationships are keys to determine the operating mode. We need to define how actors will interact and on which model.

What we have noticed from our previous work is the role of administrations to facilitate these interactions. In space industry, as once again there is no proper regulations, governments and their space agencies are very important. To find compromises and have a win-win situation, private and public actors need to have a common voice. It would be eased by the current situation of the market: close relationship between private and public. Conflicts of interest should be avoid and collaboration is fundamental. One strong advantage is the richness of our history. Indeed, as ISS project (cross-countries) and many recent space missions (private and public working together), humanity proved more than once that collaboration is a road to success. We need to learn lessons from our past to build this new environment.

In a business ecosystem, stakeholders can share different things: resources, knowledge, goods, accomodations. Gwenaelle Oruezabala learnt us that sharing these elements brings benefits to all actors. We also know that the Outer Space Treaty states the Moon does not belong to anyone, we are in a common space. Therefore, sharing resources is already a basic rule. Sharing goods and accommodations is also an important feature. In terms of logistics and implementation of new infrastructures, each stakeholder needs the other. In terms of sharing of knowledge, as one of the main goals is scientific, discoveries need to be shared in order to boost innovation and for society evolution. However, politics aspects could slow collaboration between countries. For example, China is reluctant to share information about their space advances, but on the Moon they will have to make concessions to move forward.

Despite the collaboration, Koenig explained how nature of relations in business ecosystems could lead to different kind of network. Interactions between actors can appear through competition and cooperation, which could be compared to the current situation of space market: coopetition between private and public. Nevertheless, on a land where resources and infrastructures are shared, competition is not very appropriate, or at least not at the beginning. Strong competition could lead to property conflicts and risk-taking. Other types of relation exist according to Sylvie Mira-Bonnardel et al. Sometimes, addiction networks grow because of too many dependencies. In our case, stakeholders and especially regulatory bodies need to be cautious: first with relation of independence to Earth, then with dependencies from one company or organization to another directly

on the Moon. Finally, competencies network is a good way of sharing knowledge and especially for scientific fields, but actors could be faced with comprehension issues as a wide range of business domains will cohabit.

To reach a consensus, our second hypothesis is development of lunar business ecosystem through collaboration. An effective collaboration between private and public, between countries and groups of decision-makers could bring the initiative to success. In spite of sharing resources and knowledge, infrastructures and accommodations have to be common, instauring a co-living international space, as a center of excellence on the Moon.

3.2.3. Hypothesis n°3: Moon as an entrepreneurship ecosystem

As we have already seen in the second part of this research thesis, innovation is a driving force of space industry progress. To build a sustainable ecosystem on the Moon, it would be fair to consider entrepreneurship ecosystem.

First reason to use the entrepreneurship ecosystem model is a quick adaptation to fast-moving economy, focusing on innovation and right relations. It completely matches with space requirements for lunar economy development. Indeed, innovation in space exploration is everywhere: our daily life benefits from it in many domains. We need to take advantage of it and create our environment around innovation. It also works for relations: NASA already selected 14 companies to bid and work on innovative systems to help them with Artemis program. However, if entrepreneurship ecosystem seems to be an efficient model for our specific case, we need to draw a reliable framework according to Isenberg's six conditions.

3.2.3.1. Finance

Financing entrepreneurship ecosystems can be a difficult question. To develop lunar economy, the ecosystem will need a huge amount of provision. Programs can count on two kind of investments: public and private. Governments are financing space agencies for this kind of purpose. However, we cannot count only on this kind of assets because of risk-dependency. As the ecosystem will be closely related to Earth's ones, economic crisis and changes of governments could affect very quickly lunar environment. Solution is to find many private investors to support projects.

3.2.3.2. Culture

Another distinctive feature of entrepreneurship is a specific mindset, shared by stakeholders, around creativity, enthusiasm, experimentation and so on. Fortunately, the entrepreneurial spirit, very important for innovation is currently promoted in most countries present in the space game. Ambition for innovation is well driven for now and it has to stay in this way. Space is a resilient industry, especially since people such as Elon Musk brang the "failure becomes lesson" culture, even if risk needs to be well managed for Moon economic development. Moreover, space exploration is full of passionate people, with positive mindset and strong commitment Sky's conquest. The only critical point is

public opinion, which already badly impacted space progresses after Apollo missions, and could have negative effect on public subventions. About return to the Moon, many people are still doubtful about goals and reluctant to pay for it. Stakeholders need to have strong marketing actions and highlight every successful step of this journey.

3.2.3.3. Support

Support is really important to build an ecosystem, and can be expressed through several domains: financial support (see 3.2.3.1.), moral support (see 3.2.3.2.), but also material support. In terms of infrastructures and logistics, stakeholders will have to share responsibility for building them from scratch and instaure processes, but also be helped by public organizations. Another aspect, which is really important in Moon environment, is energy. Even if objective is to be fully autonomous, lunar ecosystem will need support from Earth to start, same as logistics operations. The main risk to anticipate is to become too dependent.

3.2.3.4. Human capital

Creativity, knowledge and passion are valuable assets for the Moon business. Particularity of our ecosystem is the need for many different competencies through the variety of objectives (scientific, commercial, societal…). Lunar entrepreneurship ecosystem will gather engineers, technical people, support functions for business or legal, architects, medical staffs, almost as a sample of our society. However, some key competencies will be needed especially for sciences (for example, in physics or astronomy) because of the unique environment. Despite specific knowledge, particular mindset is also required: commitment to the mission, risk-taking, passion. Entrepreneurship ecosystem needs proactive and dynamic people to take part in such adventures.

3.2.3.5. Market

To sustain, entrepreneurship ecosystem has to know very well the market and find early customers. In space industry, governmental organizations are the main customers. However, as we have seen in the financing part, a return to the Moon will require private investors who will require themselves private customers and business opportunity. With introduction of the New Space, new commercial outlooks appeared: space tourism, commercialization of extra terrestrial resources… As of today, visibility is not clear enough on this kind of topic, because it only concerns very rich people, but we could imagine a growth of commercial activities within lunar ecosystem in the next 30 years.

3.2.3.6. Policy

Entrepreneurial ecosystem could collapse because of legal issues. In space, it is even more sensitive as we leave our comfort zone. No regulations, or almost none, have been set about space exploration. This is a no-man land that nobody can own. However, this is absolutely fundamental to anticipate regulations before setting framework of an

entrepreneurship ecosystem. An external public organism needs to take the lead on these issues.

Our three hypotheses are not discordant from one to another. We broach with our recommendations three main topics: the birth of lunar ecosystem, nature of interactions and importance of collaboration, development of the Moon economy through innovation following the entrepreneurship ecosystem model.

3.3. Questioning our concept

In order to fully analyze all features of the ecosystem model applied to Moon economy development, we need to understand limits of our model and potential alternative concepts to answer our problematic.

3.3.1. Critical analysis of our model

There are a few limits to notice on our previous hypotheses and recommendations. First, the notion of policy and regulatory bodies is complicate to match with the Moon economy because of the lack of regulations and clear framework. Then, sharing of knowledge could be a tricky question when it comes to countries collaboration. We have seen the example of China, which declines to share many progresses of its space industry. Moreover, our analysis demonstrated the dependence of our future ecosystem on some topics: dependence on Earth with logistics, material, energy, and dependence on public opinion and governments for trust, finance, global direction of the project.

One explanation is that business ecosystem may rely on too many stakeholders for such a new initiative. As it is a complete different environment, we could inspire from business ecosystem concept and take all of the features we recommended, collaboration, innovation, in order to develop a new theory.

We can note the lack of vertical integration. As the ecosystem model is mainly focus on interactions and nature of relations, horizontally, we miss program management part and a governance model. It could have influence policy issues, but it also highlight the lack of a very important notion for space industry: risk-management.

3.3.2. Review of other theories

As our model has limits, we could ask ourselves: is there any other concept surrounding the return to the Moon economy ? Do we miss some features to be implemented ? We will see in this part other authors' vision on lunar potential economy.

First model to observe is the COTS-like acquisition model (Allison F. Zuniga et al., 2019). Willing of this model is to establish partnership agreements between NASA and industrial private actors to enable cost-sharing and risk-sharing. It is based on acquisition

method used by NASA for its Artemis program. Objectives are numerous: cost reduction and affordability of lunar technologies, encouraging creation of infrastructure services on the Moon to support space agency missions, motivate space commercial activities. Development plan takes into account risk-assessment and important milestones. Benefits for NASA are lunar commercial products and a boost in space exploration capacity. For other stakeholders, it is an opportunity to enter lunar market at lower costs and raise private capital to build new business plans. This concept is really interesting because it plans every step of development, taking into account risk and technical features. However, it is a model limited to NASA and its partners on Artemis program, not including regulations, international collaboration and potential evolution of the ecosystem.

Some authors have also proposed public-private models for lunar economic development (Eligar Sadeh et al., 2019). These models rely on government and politics support to finance initiatives. Authors highlight the importance of attractive activities on the Moon to involve more private investors in the market. A sustainable lunar economy could be then implemented, as soon as the return on investment is higher than level of risk. These models are founded on government implications to reduce risk for potential private stakeholders. In 2004, George W. Bush Commission emphasized role of federal governments to stimulate private space industry, stating that major challenge for space industry vision is to survive to different president administrations and Congress (President's commission on implementation of United States exploration policy, 2004). These concepts acknowledge NASA's authority and necessity for government implications. Nevertheless, they focus on collaboration between private and public without considering international collaboration, or framework for the Moon business development. Once again, these models are restricted to United States, which is not compliant with a global vision of lunar economy.

Conclusion

In this research, business ecosystem concept is reviewed through several authors. Using a term coming from anthropology, James Moore was the first economist to implement the ecosystem as a way of frame business (Moore, 1993). He explained ecosystems evolution through time and places, from birth to death. Many authors used this framework to define and study nature of interactions, such as cooperation or competition or relations of interdependencies (Koenig, 2012). Later on, as innovation started to be a key element of ecosystems, reviews evolved from business ecosystem concept to entrepreneurship ecosystem. A new framework of conditions, actors and characteristics was born (Isenberg, 2014).

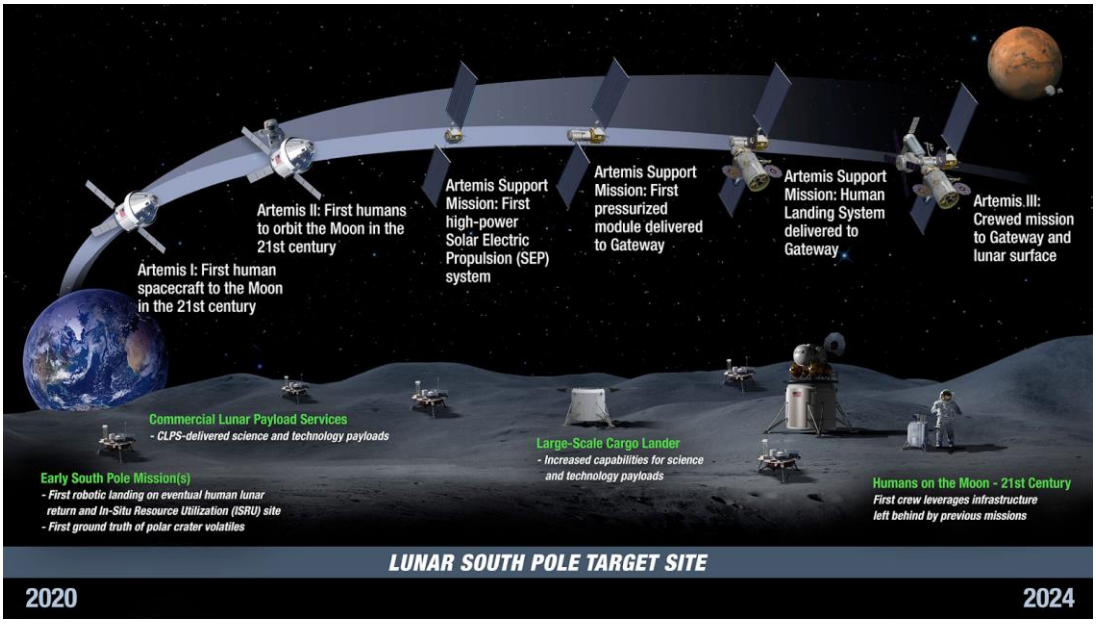
This research thesis also went through the evolution of space industry, and especially of space exploration and Moon missions. We highlighted many purposes for return to the Moon, concerning a wide range of business domains, from sciences to economics. We also noticed how collaboration is key for space industry, with the entry of private stakeholders on the market. Nowadays, private and public actors working together makes great achievements for society. Moreover, we noted the efficiency of cross-cultural and international collaboration as our world is more and more global, especially with demonstration of ISS success. Finally, we have seen in the last part of the empirical analysis the importance of innovation to guide and emphasize advancements. Technical challenges are ambitious to return to the Moon in 5 years, as programmed by Artemis (NASA mission).

Making the bridge between managerial reviews on business ecosystems, and characteristics and needs of space industry allowed us to demonstrate the capability of this concept to build a viable model for the Moon. We pointed out three hypotheses on creation of the lunar ecosystem and a regulatory body to set rules, which has to be from scratch; nature of the interactions with a strong collaboration from all stakeholders; and evolution of the Moon ecosystem into an entrepreneurship ecosystem, centered on sharing of knowledge and innovation.

However, we noticed the limits of our model. As we studied alternative models, we found out that risk-management and technical aspects was not enough takes into account. Further researches need to assess risk and introduce notion of management of technical issues.

Appendices

Appendix 1



Picture 1 - Artemis Phase 1: To the Lunar surface by 2024 (NASA, 2019)

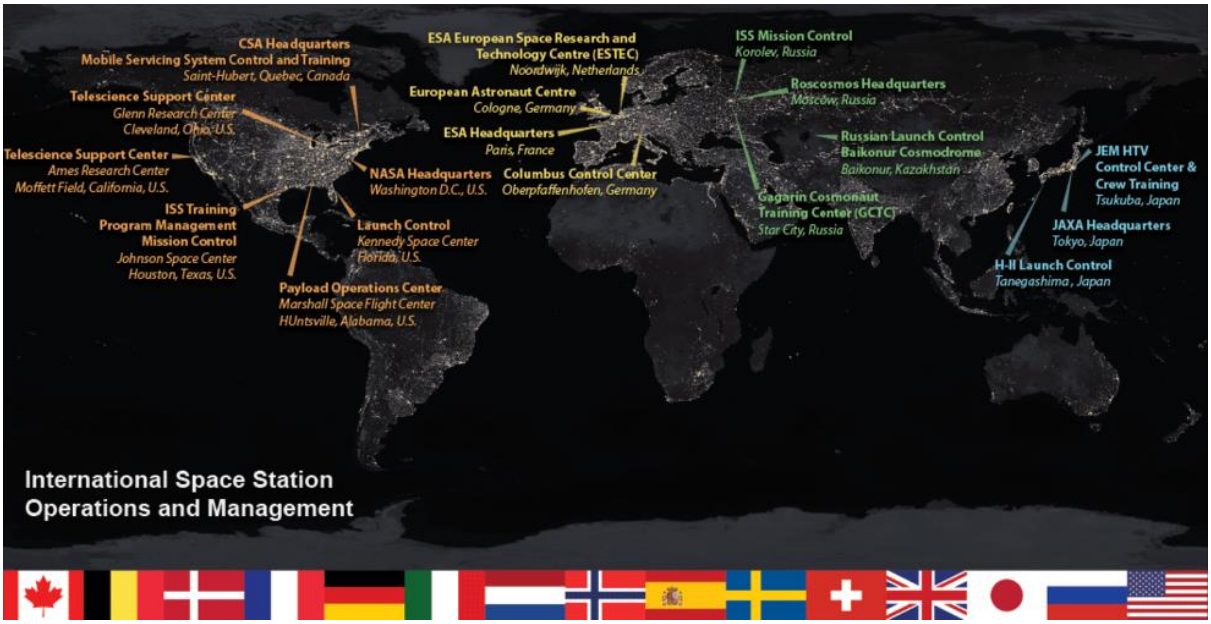
Appendix 2

ESA UNCLASSIFIED - Releasable to the Public

Of the Moon	On the Moon	From the Moon
Bombardment	Habitability of the Earth through time	Radio astronomy
Structure from core to crust	Life in the Universe	Optical and infrared astronomy
Rock diversity and distribution	Survivability in space	Cosmic ray astronomy
Polar volatiles (e.g. ice)	Physiology and medicine	
Volcanism	Fundamental physics	
Impact processes	Space physics	
Regolith	History of the Sun and Solar System	
Atmosphere, plasma and dust	Impact rate	
Tectonics	Earth-Moon formation	

Table 1: Science of the Moon, on the Moon, from the Moon as identified by the global scientific community (ESA, 2019)

Appendix 3



Picture 2: Facilities around the world support the operation and management of the International Space Station (NASA, 1998)

Appendix 4

	Agency Only	Collaboration (Hosting)	Investigations Implemented	Collaboration (Participating)	Total Agency Impact
CSA	21	8	29	24	53
ESA	217	72	289	219	508
JAXA	376	164	540	82	622
NASA*	553	155	708	83	791
Roscosmos	356	138	494	191	685
			2060		

*NASA utilization includes investigations by the Italian Space Agency (ASI), an ISS Participant Agency

Table 2: ISS benefits increased through international collaboration (Ruttley et al., 2017)

Appendix 5

Picture 3: 14 Out of this World Innovations from Space (Florida Tech Marketing and Communications, 2018)

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