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The Space Building Blocs Analogy: Technology and Cooperation in the International Society of Outer Space

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Abstract

This thesis examines how agencies or companies become, and develop as, actors in outer space. It identifies two factors--technological development and cooperation--as key in this process, and assesses the role of each in the progress of a space agency or company. To this end, it applies a process tracing method to eight case studies. It is argued that technology and cooperation operate under a system analogous to building blocs: the space building blocs analogy.

This research finds that technological development or acquisition has a positive impact on actor development and is a necessary and sufficient condition for the progress of a space agency or company, whereas cooperation mostly has a positive impact but remains a complementary condition for progress since it only achieves explanatory sufficiency.

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I really hope it is worth it.

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Introduction

The importance of space is clearly dependent on how it is framed by the international community. One can only imagine the impact it might have, or perhaps rely on works of fiction that attempt to describe it, in order to get a sense of its importance in the coming years. Before this future, however, we can be certain that it is not an easy road for the international community to tread. It is a daunting task for any actor in it. If so, in the present, what factors can positively influence such a bold enterprise? In other words, what factors can facilitate space exploration for an actor in the international community?

Space is, nonetheless, nothing new. Leaving aside the fact that it has existed much longer than we have, it is worth remembering that it has been a key player in major conflicts since the middle of the twentieth century. As a matter of fact, since the 1957 launching of satellite Sputnik I, we have become a part of the *Space Age*, not all-encompassing as it might sound, but tied to every other major historical and political event. That also means space is not a player itself, but rather it is what researchers have come to know as a new dimension integrated into the international community. That notion of space as a playing field, just like any sport, requires players, rules and a specific game. In this thesis we evaluate both the players and their game in space, or in social science language, the *actors* and their interactions involving *stakes* in the *International Society of Outer Space*. More specifically, we evaluate how conditions, such as technological progress and cooperation, play a role in the development and rise of these actors.

This thesis is divided into six sections. The first section begins with a literature review, in which six categories of contributions are identified. The second section focuses on the challenges of traditional Westphalian theory of State sovereignty, the role of international space law in regulating space cooperation, the effects of international economic growth on space development and exploration, and outer space as a specific field of interactions in the international community. The latter is used as the theoretical framework for this study, as it explains the existence of a field-specific conglomerate of interactions, or *society*, that is closely tied to space activities. In this thesis, this will be called the *International Society of Outer Space* or *ISOS*.

Section three, our theoretical section, introduces the internal mechanisms of space technology development, distribution, and cooperation inside the *International Society of Outer Space* by proposing two hypotheses. In order to facilitate the understanding of these mechanisms, *the space building blocs analogy* is developed and explained. The fourth section justifies the use of case analysis and process tracing as the methodology for this thesis.

The fifth section provides historical context to ease the understanding of the analysis of the actors inside the *ISOS*. Next, in the sixth section, the analysis turns to the actors that have been chosen for the case studies: the United States (National Aeronautics and Space Administration or NASA), the Soviet Union/Russia (Roscosmos), Japan (Japanese Aerospace Exploration Agency or JAXA), China (Chinese National Space Administration or CNSA), Brazil (Agência Espacial Brasileira or AEB), India (Indian Space Research Organization or ISRO), Canada (Canadian Space Agency or CSA), The European Space Agency and SpaceX. In the seventh section, using a process-tracing technique in each case study, and applying smoking-gun and hoop tests, the research shows that technological progress is a necessary and sufficient condition to develop as an actor in the *ISOS*, whereas cooperation only provides explanatory sufficiency to actor development.

In the end, we deliver some concluding remarks, propose future studies, and encourage more research to be done regarding space politics.

Literature Review

From the void of outer space and its celestial bodies to the role of humanity through the State, defining the relationship between the international community and the cosmos comprises a broad, yet familiar, range of works on the matter. The literature on space exploration from an international perspective can be divided into the following six groups:

1. The militarization of space (Webb, 2009; Bormann, 2009; Sheehan, 2009).
2. The role of the State in space (Dolman, 2002; Meijer, 2009; Havercroft & Duvall, 2009).
3. Outer space as a specific field of interactions inside the international community (Musgrave & Nexon, 2018).
4. Challenges of the traditional Westphalian theory of State sovereignty in space (Stuart, 2009).
5. The role of international space law in regulating space cooperation (Salter & Leeson, 2014; Eymork, 2012).
6. The effects of international economic growth on space development and exploration (Devezas et al., 2012).

For this thesis we employ the last four research themes. These bear more importance as they deal with space as a specific field of inquiry, the challenges of space interactions, and the factors that influence them. Subsequently, we review them in broad terms to explain the different mechanisms stated by the authors, for they will provide valuable insight into the evolution of actors in outer space.

Musgrave and Nexon's (2018) work on the field of space interactions comes from a constructivist perspective, with a focus beyond military interests, but still centered on the State in space. The authors were intrigued by what makes governments invest in an expensive project, which will not necessarily provide any palpable military or economic benefits, as was the case of the Apollo Project and the numerous trips to the Moon. They use a field-theoretic approach combined with hegemonic order theory to prove the existence of field-specific international communities of interaction, known as societies, comprised of field-specific hierarchies and stakes. Agents, or actors, inside these hierarchies, aim to acquire these stakes, which are resources from a specific field, to climb up a corresponding field-specific hierarchy

(Musgrave & Nelson, 2018, p. 519). This study not only provides an explanation for the interest in lunar exploration, which appears unjustifiable from a realist perspective, but also a theoretical foundation from which to analyze the interactions involving outer space. In any case, their analysis is still limited to what the role of the State in space exploration was fifty years ago. It remains a possibility that new factors or conditions may have altered the hierarchy of space exploration in the years that followed.

Secondly, on the topic of the State's space interactions, *Unbundling Sovereignty, Territory and State* by Stuart (2009) questions the prevailing individualistic and state-centric perspective in outer-spatial relations. She uses the International Space Station (ISS) as an example of the difficulties encountered when extrapolating the Westphalian concept of sovereignty. In its place, she tests other theories, such as cosmopolitanism and regime theory, in order to determine how fitting they are in conditions of sovereignty unbounded from the territory. Stuart (2009, pp. 20-22) determined that concepts such as sovereignty precede the significance of space politics, and therefore, are destined to change as a result of exogenous events and technological advancements. It is not only the inquiry on the role of the State but also the structures accompanying that concept, which renders this analysis one of the best in the discipline. It concludes that States can achieve cooperation beyond their Westphalian limits due in part to a common interest. However, it fails to include an analysis of the impact private actors can have while interacting with state actors as peers in space, nor any other probable effects beyond matching interests and cooperation.

Other authors, such as Salter and Leeson (2014), broaden the analysis on space interaction and put the government supervision in doubt through a more economical perspective. In their research, they made use of game theory and continuous dealings to prove that celestial anarchy, or the lack of a ruling Leviathan that safeguards private property, would not appear to be a problem for private actors. As a matter of fact, they were wary of possible misinterpretations of the limitations of property imposed by the OST since they are not actually a country (Salter & Leeson, 2014, p. 593). Their contribution provides something beyond a critique on international space law: it also announces the existence, and possible political independence, of private actors in outer space. However, as the authors mention, this work does not explain which conditions favor the rise of private actors in the first place.

Finally, Eymork's (2013) conclusions on the role of international space law and its impact on cooperation also contribute to the literature in an important way. Her doctoral dissertation investigated the benefits of extracting fuels from the Moon, and the difficulties faced by cooperation around this. Taking satellite communications as an example, she considered that treaties and conventions are in charge of ruling over the functioning of outer space. Taking that into account she states that, due to the increasing interest in space market and its equally growing accessibility, we depend on legislation to consolidate future effective coordination (Eymork, 2013, p. 31). In contrast to Dolman and Salter & Leeson (2014), Eymork puts international space law as the groundwork for international space cooperation, while also noting the increasing ease of access to the space market compared to previous years. Even though it might seem intuitive, her work considers technology as an important tool that States, and other actors, depend on to interact in space. However, it is worth adding a distinction between technology meant for earth orbits, like satellites, and technology that actually provides access to and through space (i.e. rockets, probes and rovers).

The influence of technology can also be seen in Devezas et al.' work (2012) on the impact of economic growth on space exploration development. They analyzed waves of global growth, or K-waves, and found that the Space Race matched the wave of growth experienced around the 1950s. In turn, they concluded, as another growth wave seems to be approaching, that a new space race is bound to happen soon (Devezas et al., 2012, p. 978). Considering a space race is a complex phenomenon, however, such a phenomenon cannot be solely confirmed by K-waves. As a result, we limit to taking into account the impact of technology development, which could actually impact growth and effectively increase the number of actors in space.

These articles provide a broad look into the studies of actors in outer space, from questioning the role of the State to redefining the traditional conceptions of interaction in international relations. Nevertheless, focusing mostly on what is to be in regards of the State and its role in outer space left out most of the historical processes that have transpired since the Space Race, and the insight that can be acquired from them.

In this thesis, we will explore aspects not yet considered by the literature, such as technological progress and actor cooperation, while building on what was previously studied.

An integral historical evaluation will allow us to test these factors' explanatory capacity in the development and rise of new actors in outer space.

Theoretical Framework

In order to analyze the emergence of actors in outer space, and subsequently the impact of technology and cooperation, it is necessary to theoretically determine this plane of interactions and conditions. For this, the theoretical groundwork previously set by Musgrave and Nexon (2018) in their analysis of specific fields of interactions will be used.

The field-theoretic approach proposes that many global policies actually take place inside clusters of interactions under an internal hierarchy called "societies" which positions *actors*, also called agents, differently throughout it. Actors' positions on these hierarchies are not determined solely by their economic or military capabilities, but also by their possession of socially valued assets. Field-theory also considers actors as actors that act strategically to obtain these hierarchy-specific assets, also known as *stakes* (Musgrave & Nexon, 2018, p. 597). Extrapolating this to outer space, we would find actors whose goals are to acquire stakes such as aerospace technology and knowledge.

In addition, hegemonic-order theory enriches the inner structure of these multiple types of hierarchies in global politics (Musgrave & Nexon, 2018, p. 595). It establishes that relations inside these fields are determined by two related characteristics. Firstly, a pattern of interactions among actors, or hierarchy, defined as the power that some participants possess in relation to others. Secondly, a series of rules set up by the actors and applied when they so desire (Nexon & Neumann, 2017, p. 7). In a similar fashion to the field-theoretic approach, it highlights that certain specific types of capital or assets acquire a certain level of ideological or sociological meaning that makes them valuable (Nexon & Neumann, 2017, p. 8). Other traditional resources of value found in international relations, such as economic and military power, also influence an actor's position on the hierarchy along with these stakes. As the authors themselves mention, this allows for the rise of specific fields of international interactions for topics such as nuclear development and space exploration (Nexon & Neumann, 2017, p. 10).

As a result, these contributions allow us to demarcate field, or ***society***, of international interactions closely tied to outer space. In summary, this field is comprised by agents or ***actors***--as we will call them to avoid confusion with agency--, which can be either government agencies, companies, or joint ventures between both, that have goals related to space exploration. Their success in space exploration varies their position in a hierarchy inside this field. To be improve their position they need to obtain field-specific ***stakes*** or assets, which in this case is space technology. In order to simplify the analysis, we will call this field of interactions the *International Society of Outer Space* or *ISOS*, which will refer to the cluster of actors in the international community that interact and have goals tied to outer space and earth orbits.

We should also note that the study carried out by Musgrave and Nexon (2018) only focused on the *Space Race*, therefore, we believe this might have limited the explanatory capacity of the theory as a result. Considering the current conditions of the *ISOS* are different from those fifty years ago, as we will explore soon, we would like to offer a broader analysis on the impact of stakes and the functioning of the hierarchy.

For instance, the hierarchy lacks a constant condition, such as an amount of space technology to accumulate or a fixed goal, that allows us to determine which is the best actor among all. This lack of real winners challenges competition as the motivation behind stake accumulation, at least as a general rule. However, it does not mean scientists, governments and companies do not wish to better themselves and their achievements. Therefore, victory, which translates as a higher position in the *ISOS*'s hierarchy, is not a condition or a state in itself but rather a continuous process, an advantage that has to be maintained. This also infers that the need to maintain an advantage, against others or an oneself, is what drives progress in space exploration. Instead of having a competition-based hierarchy, we suggest progress stems from an actor's own need for improvement. In other words, space exploration progress would be positive every time an actor progresses by going a step further in the scale and scope of their projects. However, when an actor decides to pause its space exploration projects or narrow the scope of them, it would have a negative impact in progress.

Bearing in mind these considerations on the *International Society of Outer Space*, we can now ask: What are the mechanisms that allow actors in the *ISOS* to move through the hierarchy? In other words, What influences an actor's development and rise inside the *ISOS*?

In this thesis we establish the *space building blocs analogy* as the assumption from which the rest of our analysis builds upon.

The analogy states that stakes, or space technology, in the *ISOS* function as blocs of technology that are accumulated by an actor, either through acquisition or self-produced development, in order to serve their own space goals and sustain their progress in the society. Furthermore, the space building blocs analogy, or more specifically, the way technology can be obtained, proves that technological progress among actors in the *ISOS* is not necessarily a path of individual development, but one that can and does benefit from cooperative technology building.

In other words, stakes in the *ISOS* are tradeable blocs of technology that can be shared between actors. These cooperative interactions can provide the missing piece/s required to achieve the desired technological goal necessary to fulfill this need for improvements in space exploration.

We also emphasize the nonlinearity of paths of technological progress because actors can provide each other with the necessary space technology to jump start their space exploration agenda and indigenous technology development. This can also help explain any examples of cooperative projects in space exploration, as they would consist of a set of individual pieces of space technology coming together to become something greater.

Considering the *space building blocs analogy*, we suggest the following hypotheses might explain an actor's development and rise in the *ISOS*:

H1: Technological progress help actors maintain space exploration progress.

H2: Cooperative actions, such as acquiring blocs of space technology from other actors or sharing projects of space exploration, help actors maintain space exploration progress.

Space exploration progress is established as a permanent condition because of the notion of constant improvement set by the hierarchy.

To further the focus of our analysis in the aforementioned hypotheses, we establish certain dimensions of analysis and variables that will better the understanding of this study on the history of the *ISOS*.

Blocs (H1): related to *stakes*, also known as technological assets. This will be measured through space technology breakthroughs on a case-by-case basis.

Actors (H2): related to the following variables: *actor type*, that determines if they are governmental or private; and *actor interest*, that determines if their focus is either scientific/ civilian, military or economic.

Dimensions	*Variables*	*Category Systems*
Blocs *(H1)*	*Space technology or stakes*	• Develops technology • Acquires technology
Actors *(H2)*	*Actor type*	• Government agency • Public/Private venture • Company
	Actor interest/goals	• Scientific • Military • Economic

In order to streamline the selection of space agencies analyzed through time, we should differentiate them according to their roles and scope. Even though space is one thing on its own, there exist two approaches to the way it is used. On the one side, we have what we will call *Inwards Space*, which is the use of space for earthbound purposes. This refers mainly to satellite communications and projects of information gathering about weather, geography, the oceans, and all that comes from earth observation. For instance, projects like UNOOSA's UN-SPIDER are quite a feat in international cooperation, but their scope is still earthbound. The main focus of our study, however, is *Outwards Space*, which we define as the actual use of outer space, mainly encompassing deep space exploration. This is the side of outer space we believe will come to have a role in the future of international, or not so national, relations.

That differentiation will limit our cases to those agencies and companies that, at the very least, have had successful projects involving Outwards Space. This, along with sound rocket capabilities, or easy access to them, will be what we consider as Minimum Requirements. As a result, this is the list of space agencies and companies that at least have an interest in exploring the deep reaches of outer space.

AGENCY	TYPE	MINIMUM REQUIREMENTS	INTERPLANETARY AND/OR INTERSTELAR PROBES	ASTRONAUTS	INTERNATIONAL SPACE STATION	SUCCESSFUL HUMAN SPACE PROGRAM
NASA *(USA)*	Civilian	Yes	Yes	Yes	Yes	Yes (until 1972)
ROSCOSMOS *(USSR/Russia)*	Civilian/Military/ Economic	Yes	Yes	Yes	Yes	No
ESA *(Europe)*	Civilian	Yes	Yes	Yes	Yes	No
CSA *(Canada)*	Civilian	Yes	Yes	Yes	Yes	No
JAXA *(Japan)*	Civilian	Yes	Yes	Yes	Yes	No
CNSA *(China)*	Civilian/Military	Yes	Yes	Yes	No	No
ISRO *(India)*	Civilian	Yes	Yes	No	No	No
SpaceX *(USA)*	Economic	Yes	No	No	No	No
AEB *(Brazil)*	Civilian	Yes	No	Yes (2006)	Yes (2006)	No

Methods

This dissertation will employ a qualitative methodology to develop a historical analysis with the objective of evaluating the explanatory abilities of the aforementioned hypotheses. This study will focus solely on the interactions among actors and accumulation of stakes in the *International Society of Outer Space*, specifically limited to Outwards Space, throughout the launch of the *Sputnik I* satellite in 1957 to the 2010s.

We will test the influence of our hypotheses on the *ISOS* using case studies and process tracing. This analytical tool is defined as the systematic evaluation of selected evidence through the light of hypotheses and questions proposed by the author. Process tracing allows us to infer causal chains and describe evidence that is a part of a temporal sequence of events (Collier, 2011, pp. 823-824). In other words, it allows us to distinguish moments of trajectory formation and reinforcement.

Van Evera, in his work on process tracing, notes that theories set numerous differing causal chains, and that this analytical tool can be adapted to fit those patterns and provide evidence on all the links in the chain (Van Evera, 2002, p. 74). The two hypotheses stated before act as two separate, yet related, chains. Throughout our analysis we will determine which of them provide effective explanations.

To reconstruct these timeline of events, we will gather information from primary sources, for example: information available in web pages, and reports from agencies and companies. This will be complemented with secondary sources, such as scientific studies and articles, all from the 1950s onwards. This way we will collect enough information to analyze and pin point trajectory changing events throughout the history of humans, the State and space.

Regarding our analysis, the hypotheses will be tested to see if they fall into one of the three categories of conditions Mahoney (2015, pp. 203-204) suggests in his analysis of process tracing and historical explanation. The first one, a necessary condition, is one that if removed from the causal chain will yield a different result. The second one, a contributing condition, is a factor that increases the probability of a certain outcome but not necessarily causes it. And the third one, an INUS condition, which is one unnecessary for the outcome.

The testing process will consist of two processes. Firstly, a smoking-gun test, which states that if piece of given evidence that supports the hypothesis is found in a case, it supports the hypothesis as true. In other words, if the test is passed, it provides explanatory sufficiency for a certain hypothesis (Mahoney, 2015, pp. 210-211). Secondly, a hoop test, which states that a given piece of evidence must be present in a case for the hypothesis to be true. This test, if passed, posits a certain hypothesis as a necessary condition (Mahoney, 2015, pp. 207-208)

Historical Context

In this short chapter we will explore the chronological evolution of the *ISOS,* and the four phases of the Space Age, mainly focused on the evolution of interests and relations among actors. This overview will provide context over major events and facilitate the understanding of our analysis.

It is safe to say that the first phase in the *ISOS*, The Space Race, brought the first two *ISOS*'s actors, and the society itself, into existence. It is also, as we will see, a very distinctive period in the history of space exploration. Everything changed in October of 1957 with the launch of the first Soviet satellite, *Sputnik I*, that shocked the world and forced the United States into creating NASA with only one primary focus: going to the Moon (Ferguson, 2013, pp. 10-11).

As we mentioned before, this made the Moon the truly valid milestone, and root of all space exploration then. This notion was consolidated with John F. Kennedy's speech of May 25th, 1961, and the subsequent raise in NASA's funding (Whalen, 2002, p. 4). Framing the natural satellite as a benchmark of power successfully installed the notion of hierarchy introduced in the *ISOS*, and basically this society itself. It was ultimately State funding that transformed these goals into actual achievements, and obtaining that funding was the result of eloquent political justification (Devezas et al., 2012, p. 982), since there is no actual realist rationale that backs blasting humans to a rock in space. NASA became important in hindsight due to being the one, and still only, agency to land people on the Moon. As a result, history deemed the United States victorious in the Space Race; which also further solidified the notion that the Moon was the ultimate goal, since none of the contenders intended to go further.

But they ultimately did, just not as most expected. Even though humans have not flown beyond the orbit since then, it would not be fair for the last 40 years of space exploration to ignore the impact of probes and satellites in deep space exploration. It is, in fact, the knowledge gained in these decades that might facilitate future settlements on the Moon or Mars. Part of this shift came as a result of changes in political perspective and economic availability. This, in turn, leads to the second period of this Space Age: The First Space Crisis.

Three factors changed the game during this period, the first two of which mostly affected NASA. Perhaps defining this period as a crisis might come across as too NASA-centric, but considering they were the only ones actually landing men on the Moon until 1972, they ought to be considered a central actor. Firstly, it was a shift in political interests that made US Congress trim NASA's budget after the Cold War battlefield had switched away from the Moon to Vietnam (Starbuck & Stephenson, 2005, p. 4). Secondly, it was the energy crisis of the 1970s that raised awareness and forced NASA into taking a more energy efficient outlook after the cancellation of the costly Apollo program (Ferguson, 2013, p. 12). This meant less money against the fixed pressure of maintaining a presence in space. As a result, NASA had to improve rocket technology if it intended to continue on the path of space exploration. As a side effect, this change of plans also lowered the bar for space exploration. The early dreams of colonies on the Moon, frequent space travel and trips to Mars was cut short for the generation that grew up with space as a "place you could go to" (Devezas et al., 2012, p. 982).

However, the *ISOS* was, and is, more than NASA. It was during this crisis when the society witnessed the rise of new actors: the first countries, beyond the USSR and the USA, that dared to face space as well. In the race to secure a position in space, and most importantly, access to it, countries fared very differently. Japan and China started their path depending on technology provided by the USA and USSR respectively. Similarly, India did not begin from scratch, but focused on a way of achieving independent access to space. In other cases, some that lacked sound rocket capabilities could at least acquire access to them with ease, as was the Canadian case.

This had varying effects which we will later explore as we analyze the impact of technology accumulation and cooperation, but it changed the landscape and hierarchy into one with multiple actors. This transformation proceeded to seem more fit as the 1990s came to be, and along with it, the third period of the Space Age: The Space Market.

Private and public demand for launch vehicles became a driving force at the end of the century. What had been reserved for scientific, national, military, or even astropolitical matters, was now broadened due to a demanding economic sector. This was mainly a result of the rise of satellite communications (Yao, Hu & Yang, 2017, p. 18). In order to put said satellites in orbit, a constant supply of launch vehicles is required. Even though this almost exclusively concerned those countries that already had sound rocket capabilities, one key factor in this period was that actors in the position to produce and sell such vehicles intended to benefit from this increasing interest.

Unexpectedly however, by 2003 the total number of active launch systems had increased by a third since 1991, yet the total number of launches had decreased. This was due to a combination of factors during the Space Market decade: the opening of the Soviet Union, or what was left of it, to the space market and the commercialization of their rockets remaining from the Cold War; a growing rocket supply market inspired by satellite demand; the globalization of the launch business; and the burst of this satellite-demand boom at the end of the 1990s (Isakowitz et al., 2004, p. ix). In other words, rocket manufacturers took a leap of faith that ultimately did not pay off.

This leads to our fourth, and current, period of the Space Age: The Second Space Crisis. Once again, this refers to a shift in what was expected to happen in previous decades. The notion of multiple competing actors was challenged by the fact that in 2004 a quarter of the launch vehicle families performed two-thirds of all launches and carried 80% of all cargo (Isakowitz et al., 2004, p. xvii).

The burst of the satellite-demand bubble that tarnished economic interest in rockets was accompanied by some grim catastrophes in different agencies (NASA, CNSA, AEB) that forced a shift in focus during the first decade of the century. However, a new notion of space exploration developed during the early 2000s when the International Space Station became a symbol of space cooperation. As nations pushed for a cooperative exploration of the closest boundary to space, one particular company found itself rising successfully through the failure many other companies experienced the previous decade. SpaceX, the company founded by Elon Musk, found its place in the center of the space exploration industry by the 2010s. The decade that would also experience the rebirth of deep space exploration as agencies, and SpaceX as well, began to set in motion plans to take humans not only back to the Moon, but also Mars.

It is in this context of a renewed--yet completely different--Space Race that the issue of the conditions that allow for an actor to improve its position in the hierarchy becomes central. This, in turn, will better our understanding of how factors such as cooperation and technology may have a role in the future of the *International Society of Outer Space*.

Case Analysis

To summarize what was previously stated, the *ISOS* went through four distinct periods that: firstly, installed competition and set the ground for the development of a hierarchy; secondly, lowered the bar and allowed for new actors to participate; thirdly, grew overambitiously and collapsed, reaffirming the difficulties and costs of space; and lastly, reframed itself and installed new objectives for the future of space exploration. In summary, space exploration has proven to be a strenuous path that is insisted on nonetheless.

In the following section, we will begin analyzing the different cases selected for our study. After that, we will test the explanatory capabilities of both hypotheses stated beforehand.

The First Two: The United States and the Soviet Union

We will start with the two most important figures in space exploration from the previous century, the United States and the Soviet Union/Russia, which provide an interesting first approach to the analysis of space technology accumulation. We will then proceed with other governments that subsequently joined the International Society of Outer Space, add the only private enterprise inside its ranks, and finish with closing remarks on each actor.

Focusing solely on the first period, The Space Race, their role as founding actors of the *ISOS* clearly demonstrates they achieved what they did through the accumulation of technology alone. If a country is to be credited for starting the age of space exploration, the Soviet Union deserves it. Aside from their first satellite which started it all, their classified military program was also responsible for other “firsts” in space exploration: first animal in orbit (Laika), first human in space and orbit (Yuri Gagarin), first lunar (Luna 2) and interplanetary probe (Mars 3), and so on ("CHRONICLE OF SOVIET-RUSSIAN SPACE PROGRAM", n.d.)--all successes that ultimately seemed to pale in comparison to NASA’s success landing humans on the Moon six times.

We should note that for some it would be correct to conclude that this ultimately culminated in a victory by NASA, mostly due to the fact that the agency managed to acquire the necessary amount of technological development to achieve, between 1969 to 1972, the goal they set out to accomplish. This victory can prove to be an example of indigenous technological development having positive results. However, we should also bear in mind that the condition of "victorious" in the *ISOS* is a variable concept that has to be kept stable throughout time, and the Space Race was the only period where that condition was stable. Putting aside other arguments, such as NASA never returning to the Moon in almost fifty years, if we move forward in time we do not seem to find a common goal throughout.

This, in turn, puts the Space Race as an exceptional time in the history of space exploration, as it was driven by a common goal and the competition of two actors. If we picture the Space Race as what it is, a race, we can illustrate the technological development of both actors as threads, individual and continuous efforts towards one point, the Moon. Two threads drawn from different pencils that share the same canvas or goal. Compared to it, the present appears strangely unfamiliar. For instance, the USA and Russia abandoned competition and moved into making the International Space Station a reality, which would have been unexpected if it had been forethought then (Sebesta, 2000, p. 647). Therefore, for its exceptionality, the Space Race should not be the starting point of explanatory theory. To put it in simpler terms, there is no commonly shared objective that determines victory in the *International Society of Outer Space*. As a result, measuring technological development similarly across cases is hard as every actos follows their own path.

If there is no race then, we cannot consider that every path of technological development has the same goal. Instead, as mentioned earlier, the need for constant progress transforms development into an individual race. But then, how does technology development work?

To get some perspective on the future of technological accumulation, we should first consider this idea of "linear trail". More specifically, we should start considering how the paths of technology acquisition of these first actors were notably different, because those, as we will see, have affected the landscape of the ISOS in different ways.

For instance, most of the advancements in Soviet space technology came from The Khrunichev Space Center and the S.P. Korolev RSC Energia ("1960-1993 Development of Rocket Technology", n.d.). While Khrunichev and Energia maintained their original structure of in-house manufacturing as they made –and still make– their world-famous Proton, Angara, and Soyuz rockets, NASA was a completely revamped agency born from the shell of its aeronautic predecessor NACA (Ferguson, 2013, pp. 60-61). NASA was molded into the desired structure to best suit its purpose, which consisted of a politically weak and civilian-managed agency. Its research and development process were also overhauled, managing large-scale projects without the traditional committee structure, relying instead on contracting (Ferguson, 2013, p. 57 and pp. 60-61). This meant the political pressure put on NASA and its goals were redirected to the companies hired to realize those goals. For instance, the rocket that served all the manned Apollo missions to the Moon, the Saturn V, was a joint venture between three different companies: Boeing, McDonnell Douglas and North American aviation ("Historical Snapshot: Saturn V Moon Rocket", n.d.). Both cases serve to illustrate the difference between developing and acquiring technology, through in-house manufacturing and subcontracting respectively. However, the most insightful consequence is how they complicate the individuality of accumulating stakes in the International Society of Outer Space.

As far as we know, technology seemed to work in a fairly linear way, like we mentioned previously, as if it were a line drawing that progress constantly if so desired, twirling and twisting in different directions with varying results. However, it remains constantly dependent on the individuality of a single pencil, or, in other words, the individuality of an actor’s space exploration prospect and capabilities. That is the way it is inferred when Musgrave and Nexon describe the role of stakes and their impact on the actor. They refer to the roles of these stakes mostly as a means of achieving the upper hand in the hierarchy (Musgrave & Nexon, 2018, p. 597). Nevertheless, technology and cooperation complicate the simplicity of this theory; and as the *ISOS* constantly welcomes new actors with different perspectives and objectives, this supposition of individual and linear technological development throughout the field faces difficulties.

Therefore, the expansion of the *ISOS* throughout the other periods of the Space Age can also help us expand over our question through the impact of stakes over other actors as well.

Since both had admirable space exploration capabilities and achieved remarkable goals, it did not take long for other countries to appear interested in space as well. Soon Canada, Japan, China, India, Brazil and the European Union found their way into the *ISOS*. Most of them, in fact, started their venture into space far earlier, and far more eagerly, than what one would suspect.

Selective Cooperation: Japan and China

Japan represents a curious case, as it evolved from a very rampant conglomerate of agencies that slowly burnt and matured into a centralized agency.

Hideo Itokawa pioneered space investigation in the University of Tokyo in 1955 when he assembled a team to produce a rocket to acquire information about the atmosphere. However, it was not until the USA broadcast satellite images of the 1964 Tokyo Olympics that the Japanese government began to take notice of Itokawa's work. His project finally came to fruition in 1969 under the three new Japanese space agencies: The National Space Development Agency of Japan (NASDA), which focused on communications and satellite observation; the Institute for Space and Astronautical Science (ISAS), centered on space research and astronomical satellites; and the Space Activities Commission (SAC), which reported to the prime minister and focused on establishing and coordination of space policy. Regardless of how eager in its domestic institutions, Japan's first actual breakthrough was the agreement with the United States government for the transfer of Delta's launch vehicle technology and development assistance for the N-vehicle. This agreement came with restrictions for any commercial application or offering of the vehicle, and for convenience reasons, the parts were mostly purchased from the USA (Isakowitz et al., 2004, p. 185).

This case illustrates the impact of technology as an asset. The limitations imposed on the Japanese space industry in its first steps not only show that a country can also take a less excruciating and more comfortable way of accessing space, but also that said comfort may require sacrifices in the form of independence. As this demonstrates, an actor can acquire technology and not necessarily develop it from scratch. In fact, this was not the only example of an assisted beginning.

A similar development can be seen in the Chinese case. Even though they had invented the rocket, or a rudimentary version of it, back in 970, almost a thousand years had to pass for an actual Chinese space program to establish itself. It was realized in 1956 when the Central Committee of the Communist Party established the Fifth Research Academy of the Ministry of National Defense.

At first, considering they did not have any sort of rocket capacities, the Chinese government decided to ask the Soviet Union for help, and their communist partner provided

R-2 rockets, documentation, and about a hundred specialists. Soon enough, by 1960, China had replicated and domestically built their “version” of the R-2. Ten years later, China demonstrated their indigenous rocket capacity when the LM-1 (Long March) managed to carry the Dong Fang Hong satellite into Low-Earth Orbit (Isakowitz et al., 2004, p. 261).

The main difference between the Japanese and Chinese cases were the conditions for technological transference. Whereas the Soviet Union was absolutely open, and arguably naive, the USA took precautions in every step of the way; from manufacturing to supplying, to even use. But both were, nonetheless, stories of reliable, tested, and almost shared access to space. Something the competition-driven Space Race clearly did not allow.

Still, that does not imply that technological cooperation was free from complications n along the way. During the Market Race, as demand began to push for more launch services and the Cold War drew to a close, most actors encountered difficulties.

Japan had acquired independent launch capabilities by the 1990s. However, achieving this through the United States ended up limiting their market potential, saving their rockets almost exclusively to government payloads due to market pressures. This case illustrates that the benefits from cooperation can vary. It can be useful for acquiring technology instead of producing it autonomously from scratch, but it is not costless. At the start of the Second Space Crisis, Japan saw its space industries and agencies collapse. Even though the Japanese tried cutting down production price for a new H-IIA model, a series of consecutive launch failures deeply affected the Japanese space industry. This, along with other setbacks, made the Ministry of Education and Science of Japan draw a line and force the three space agencies (NADSA, ISAS and SAC) to merge into JAXA in 2003 (Isakowitz et al., 2004, p. 186).

China, on the other hand, also had a difficult experience throughout the 1990s. Development progressed and subsequent improvements were made to the Long March (LM) launch vehicles. In 1989, the LM won commercial contracts to launch three satellites. However, the streak did not last long, and in 1996 a run of failures and disasters took a toll in the credibility and reliability of the Chinese commercial launch program. This also sparked controversy as the U.S. government accused companies that used LM launch vehicles of illegally transferring technology to the Chinese. The crackdown of satellite export to China ended up sidelining the Long March in the commercial launch market by 1999 (Isakowitz et al., 2004, p. 262). Soon after, China announced its Kaitouzhe indigenous rocket system publicly in 2000, and the development of the launch vehicle progressed rapidly due to prior knowledge in Intercontinental Ballistic Missiles. The first launch attempt allegedly happened in 2002 but resulted in failure (Isakowitz et al., 2004, p. 207). China, then CNSA, began working on its most significant activity in the space program yet with the development of a human space program and, after four unmanned flights, it became the third nation with the indigenous capacity to launch people into space by 2003 (Isakowitz et al., 2004, p. 262). Subsequent remarkable achievements in space exploration include the first Chinese astronaut spacewalk in 2008, and their two proto-space stations: Tiangong-1 in 2011 and Tiangong-2 in 2016. These last two would later serve as the foundation for their own Chinese Space Station due to launch sometime in the near future (China Power Team, 2019).

Bold Individuality: Brazil and India

As evidenced by the two previous cases, cooperation tends to offer a jump start in technological development whilst serving as a means to fulfil an actor's desires in space exploration. We can find similar cases in the development of independent capabilities in the Indian Space Research Organization (ISRO) and the Brazilian Space Agency (AEB).

India did not deem investing in space exploration and national satellite technology a priority until the early 1960s, when Vikram Sarabhi convinced the Prime Minister that such developments were necessary for a country to flourish. That framing of space exploration focused on improving the lives of its citizens rather than any other political endeavor. It was argued that satellite communications would provide India with improved communications, weather forecasting, mapping and resource monitoring. This vision pushed for the development of an indigenous launch system capable of deploying the satellites that would serve this purpose (Isakowitz et al., 2004, p. 345). Throughout most of its history, India depended on Russian, European and U.S. launch vehicles for their INSAT/GSATs, while also delving into developing launch systems domestically (Isakowitz et al., 2004, p. 345). This was mostly due to the weight of their payloads, which were too heavy for their own rockets to carry to orbit. However, recent developments in the last decades, such as the new Polar Launch Service Vehicle (PLSV), managed to launch lunar (Chandrayaan 1) and interplanetary (Mars Orbiter Mission) probes in 2008 and 2013 respectively ("ISRO's Timeline from 1960s to Today - ISRO", n.d.).

Nevertheless, as we have seen in the Japanese case, sometimes attempts to acquire technology can be made more difficult or can be obstructed by external parties. For instance, the technology required for the GSLV rocket was requested from the Russians in 1991 but pushed back to 1998 after complaints from the U.S. government arguing it would violate the Missile Technology Control Regime (Isakowitz et al., 2004, p. 346).

Similarly, Brazil had a complicated relationship with cooperation and technological development. The AEB, aside from changing names multiple times since its inception, began experimenting with rockets in the early 1960s. After more than a decade cooperating with the French Space Agency (CNES), Brazil opted out for a domestic program mainly due to how costly it was. In 1979, the Brazilian Complete Space Mission was created, and the VLS-1 project was approved. As expected, due to developing launch capabilities indigenously, the launch of the VLS rocket would not take place until 1997 and 1999, with both attempts resulting in failure; the third attempt in 2003, ended up in a catastrophic accident (Isakowitz et al., 2004, p. 537). Even though the first Brazilian domestic attempts were tragic, their apogee in space exploration came in 2006 when they became the first Latin American country to send an astronaut thanks to their cooperation with the International Space Station project. In this last decade, however, the AEB space project has been mostly limited to satellite deployment ("Linha do Tempo - Agência Espacial Brasileira", 2018).

As evidenced in both cases, technological development can occur domestically, reinforcing this previous idea of individual development seen in the Space Race. While true that India and Brazil pushed themselves to innovate through stake accumulation as much as possible, some of their most remarkable advancements came through cooperation. This also demonstrates the difficulties of isolating actors and their interests from other actors as well. The International Society of Outer Space does not appear to be a conjunction of closed systems of technological development inside a closed system, but a permeable macro-system (*ISOS*) consisting of permeable micro-systems (*actors*).

We will now examine, through the Canadian and European case, how this actor-to-actor permeability can shape technological development.

The Outliers: Canada and Europe

Canada, represented by the Canadian Space Agency (CSA), is perhaps the most interesting actor out of all those selected from the *ISOS*'s Outward Space branch. Unlike any of its counterparts, it has never had an indigenous launch system, something which is frowned upon to this day (Morillaro, 2018) yet it remains valuable to our analysis. This is because they question the "stacking" principle of accumulating stakes. If Canada has no solid indigenous access to outer space, a basic requirement, why is it considered in the first place? This is because the CSA is famous for its contributions rather than for its individual capabilities.

Canada began launching satellites in the early 1960s through the United States and NASA. However, in 1974, NASA subcontracted Canada to develop a robotic arm, known as Canadarm, that would be attached to the Space Shuttle and serve as an assisting tool. They also provided telemetry instruments for the Voyager 2 solar system probe. Later in the decade, in 1979, they would become a cooperative member of the European Space Agency. All this contribution to space exploration would soon be rewarded when NASA extended an invitation to fly a Canadian astronaut in 1982, commencing the Canadian Human Space program. Soon enough, Canada would become one of the countries to sign the International Space Station (ISS) program agreement in 1986, becoming a permanent member of a cooperative conglomerate comprised of the United States, Canada, Japan and the European Space Agency. Consequent contributions were the Mobile Servicing System module with Canadarm2 and the Dextre robot, that became part of the early ISS in 1999 and 2008, respectively ("Canadian Space Milestones", 2018)

As it becomes clear, the International Space Station represents a significant milestone for human space exploration, space cooperation, and as we will see, for the *ISOS'*s theoretical framework as a whole. Before expanding on it, however, we should first delve into on our last pending member of the ISS, and probably the most different case of all: the European Space Agency (ESA). In its conception, the ESA consisted of Belgium, Denmark, France, the Federal Republic of Germany, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom. Later additions include: Ireland, Austria, Norway, Finland, Portugal, Greece, Luxemburg, the Czech Republic, Romania, Poland, Estonia and Hungary; with several other European countries signing a Cooperation Agreement with the agency ("ELDO/ESRO/ESA: Key dates 1960-2018", 2018)

A European commission for space research had already been set up in 1960, but thirteen years later, in 1973, a conference of European countries finally decided on the creation of a European Space Agency and several projects under its watch. It hosted the new French Ariane launch system project under the ESA ideals of peaceful use of outer space and cooperation among the European countries (Isakowitz et al., 2004, p. 44).

Negotiations were not simple, but they believed that cost efficiency was indispensable, which could be achieved redistributing resources between activities and partners' priorities (Krige, 2000, p. 1). This was the foundation for the first multi-state space agency. Not an outstanding surprise, as the European Union was well on its way to becoming what it is today, but one in contrast to the other actors we have seen so far.

As pointed out by Kigre et al. (2000, pp. 37-38), one of the more noteworthy moments in the trajectory of the ESA was the re-orientation of activities from satellite applications to space transportation systems. This change of focus for the agency halfway through the 1980s set the groundwork, at least initially, for the consolidation of the Ariane launch system family, that would later provide indigenous access to space.

Common allocation of resources –or redistribution of cost– allowed for a distributed benefit from both the Ariane program and Vega program, managed by France (CNES) and Italy (ASI), respectively. Both of these launch systems managed to stay active mostly thanks to cooperation, as competition against the Russian and USA rockets was hard to endure in the 1990s, even more so with the lack of demand at the beginning of the century. As a matter of fact, the Ariane project is dependent on over fifty European companies scattered across different countries, and all contribute in proportion to their use of it. Nowadays even part of the industry started to also share a fraction of the cost of manufacture (Isakowitz et al., 2004, p. 19) (Isakowitz et al., 2004, p. 37). As popular and expensive as it came to be, the Ariane rocket family stayed afloat during the Second Space Crisis thanks to cooperation. In other words, it was ultimately a French project, yet European aid was what allowed it to flourish.

A noteworthy consequence of the adoption of the Ariane project was how it challenged US hegemony in launch systems and levelled the western playing field. In other words, it improved ESA's position in the hierarchy, which would set the stage for more balanced cooperation down the line (Krige et al., 2000, p. 55). In addition, this newfound interest from the European Space Agency in investing in outwards space exploration paved the way for it to become a founding member of the International Space Station, the most ambitious cooperative project in space history (Krige et al., 2000, p. 69), and the next case in our analysis.

The Apex of Cooperation: The International Space Station and SpaceX

The International Space Station is not just a step-up for the European Space Agency, NASA, the various Japanese agencies, and the CSA; it was the boldest enterprise in international space cooperation yet. It was also the most scrutinized project in recent times, mainly due to its low cost-technological return ratio (Sebesta, 2000, p. 607). The strain of carrying out such a complex and expensive project shows actors' cooperative nature and how sometimes they tend to opt for similar paths of development. In fact, it highlights the impact of cooperation, as Salter and Leeson (2014) suggested, even when such a massive project is not supposed to yield the expected amount of scientific progress in return. The project and the modular additions made by each countries were pushed back a decade to 1998. This delay allowed the Russians to join the project, a previously unthinkable situation made possible by previous instances of space cooperation and their own experience with the MIR Space Station (Sebesta, 2000, pp. 610-611).

This conglomerate of actors clearly shows not only a disposition to cooperation as expected, but a continuing demand for exploration and progress. The International Space Station was a project comprising many actors proficient in their field, albeit in different parts of it, but proficient enough to manage such a large-scale cooperative project work. This, in the end, has served to consolidate the importance of experience and progress previously gathered by these actors.

Technological and cooperative interests were put to the test throughout the 2000s as NASA, JAXA (Japan), ROSCOSMOS (Russia), the ESA and the CSA managed to steadily build a laboratory floating in orbit. Constructed in its majority from 1998 to 2011, it took forty assembly missions, mostly carried out by NASA's Space Shuttle system, to mostly complete to today's standards ("Building the International Space Station", n.d.). It is hard to determine if the cancellation of the Shuttle program after the 1986 and 2003 disasters is what slowed the ISS's expansion to a crawl. However, two key players stepped up to provide continuous access to the Station: ROSCOSMOS, the Russian conglomerate agency of the space and rocket industry, and the nowadays famous private space enterprise: SpaceX (G.F., 2018)

For most of this decade, the Russians assisted with their decades-old and expensive, yet reliable and incredibly popular, Soyuz rocket launch systems to supply the ISS after the Shuttle (Isakowitz et al., 2004, p. 430). On the other side however, SpaceX appeared as a unique actor in this *ISOS* that provided a cost-efficient approach to rocket technology.

In 2002, Elon Musk founded a start-up company named Space Exploration Technologies, or commonly known as SpaceX. Its first developed vehicle was the Falcon I, fully funded by private investment, which launched in early 2004 (Isakowitz et al., 2004, pp. 160-161). The company was envisaged when Musk instructed a team of professionals experienced in the space launch industry to study the economic feasibility of developing a low-cost launch vehicle in a highly expensive labor market. After the study's positive results, he established the company and hired experienced engineers to build the Falcon vehicle (Isakowitz et al., 2004, p. 168).

The impact of SpaceX's technological proficiency was quickly evident if put in contrast to its competitor, Kistler Aerospace. It was founded in 1993 with the idea to privately design and build a completely reusable launch vehicle using technologies that would create a low-cost and reliable system. The original idea behind this revolutionary vehicle involved the concept of space tourism. However, after a great start, funding was cut short mainly as a result of the shrinking of the Low-Earth Orbit (LEO) commercial market of communications in the 1990s. This forced Kistler to shelter under a NASA Space Launch Initiative program contract in order to keep their K-1 vehicle project afloat (Isakowitz et al., 2004, p. 202). This, unfortunately, did not turn out well as SpaceX soon insisted that their Falcon project was a much more advanced and reliable one in comparison, and one that had proven so in just a couple of years since its inception. As a result, NASA was cornered into dropping Kistler K-1 for not delivering the expected progress, and SpaceX took its place ("Who Killed Kistler Aerospace?", 2005). In hindsight, this comes as no surprise, since NASA was in desperate need for reliability after the Shuttle disaster and Bush's demand for a future trip to the Moon and Mars starting 2020 (Ferguson, 2013, p. 203).

SpaceX made a convincing offer, and one that would pay off in the future, as they achieved the ability to send and return humans from LEO by 2010; and by 2012 they had already docked to the ISS ("Company | SpaceX", n.d.). Besides some setbacks, such as the explosion of SpaceX's Dragon –a human transport capsule– headed for the ISS in 2015 (Al-Rodhan, 2015), the company eventually achieved outstanding achievements such as orbital rocket re-flight by 2017, and later managed to dock the Dragon capsule to the ISS in March of 2019 ("Dragon | SpaceX", n.d.). Most importantly, NASA announced in their Commercial Crew Program that SpaceX would provide the consistent launch presence needed since the termination of the Shuttle program in 2011 ("NASA Astronauts Flying Aboard Crew Dragon", 2018). This made SpaceX the first distinct company to openly cooperate with NASA. We use the term distinct as the company is technically "racing" NASA since they announced their own multiplanetary trips for the next decade to the Moon and Mars ("Mars | SpaceX", n.d.).

Testing

We have seen a wide variety of actors, their cases, and how cooperation and technological development influenced them. In this section, we will test the hypotheses through smoking-gun and hoop tests to determine what kind of explanatory condition they are, and their role in the causal mechanism of space exploration progress.

First Hypothesis: Technological Progress

In order to determine if the first hypothesis is valid, and which type of condition best fits the influence of technological progress on maintaining space exploration progress, we employ smoking-gun and hoop tests.

Smoking-gun tests require a given piece of evidence to be found in a case in order to support the hypothesis that refers to it (Mahoney, 2015, pp. 210-211). In the case of technological progress, we need to see if it is found in any of the cases or moments of space exploration progress for us to determine its explanatory sufficiency.

In all of them, as seen throughout our case analysis, technological progress appears. Either through acquisition or development, blocs of space technology are a permanent part of the process. Sufficiency, or its presence in cases of space exploration progress, is evident. However, is technological progress necessary?

Hoop tests demand a given piece of evidence to be present for the hypothesis to be true (Mahoney, 2015, pp. 207-208). In this test we need to determine, not only that technological progress is present in every case for it to be necessary, but also the causal mechanism to verify it influences space exploration progress.

There are almost no cases were constant technological progress is missing. We can evidence this in the Space Race, in the desire to improve rocket cost and technology later in the 1980s, in the modern International Space Station, and in the new missions to the Moon and Mars. The only exception to constant technological progress among the cases selected is the Brazilian case, which practically faded away after their short involvement with the ISS in the 2000s. There were no other Brazilian astronauts in the ISS or any other large scale plans since then. It is clear the Latin American country lacked the resources to make itself valuable or make valuable progress in the last decade as we found no evidence of later efforts to prove the contrary.

Therefore, since technological progress influences progress space exploration progress directly, it is a necessary condition for it. As a result, the first hypothesis is valid.

if only Technological Progress **(**TP**)** $\Rightarrow$ ***Space Exploration Progress*** (SEP)

Second Hypothesis: Cooperation

Progress through cooperation seems rather unlikely at first when compared to the independent development of technology. However, as we proved previously, technology can be either developed independently or acquired. If developed, it can be transferred to other actors.

Similarly, in order to determine if the second hypothesis is valid, and which type of condition best fits the influence of cooperation on maintaining space exploration progress, we employ smoking-gun and hoop tests.

Smoking-gun tests require a given piece of evidence to be found in a case in order to support the hypothesis that refers to it (Mahoney, 2015, pp. 210-211). In the case of cooperation, we need to see if it is found in any of the cases or moments of space exploration progress for us to determine its explanatory sufficiency.

Sufficiency in this case is easily proved thanks to the presence of cooperation in some of the most important moments of space exploration progress. Cases such as Japan, China, India, Canada, the ESA, the ISS and SpaceX demonstrate how cooperation is present in space exploration progress. However, is cooperation found across all cases? Or in other words, is it necessary?

Some cases complicate the condition of necessity of cooperation. The United States and USSR practically built all by themselves, while some instances in the Brazilian and Indian cases suggest cooperation may not be opted for every time. As these actors managed to maintain space exploration progress by themselves in certain instances, cooperation does not fulfill the requirements stated in the hoop test. Failing it proves that cooperation is not a necessary condition to maintain space exploration progress. However, we are yet to determine what kind of condition cooperation is, and its impact on space exploration progress.

The impact of cooperation can be seen as positive in the Soviet and US's aid to China and Japan respectively. However, differences arise. China, for instance, had a very loose "contract" with the Soviets whilst Japan practically lost any opportunity to join the market as a rocket-provider, even for their own Japanese companies. In similar cases, such as the Brazilian one, it can prove too costly to manage, and an actor might even opt for a more indigenous approach to developing technology. Perhaps the Brazilians could have continued their Outwards Space focus on space exploration through the 2010s had they continued to cooperate. This is something that cannot be proved, however. In contrast, China single-handedly operated two proto-space station satellites as a test for their upcoming Chinese Space Station, which demonstrates cooperation is not a necessary condition for success.

In spite of that, the flexibility of exchange of space technology we state in the *space building blocs analogy* suggests cooperation is a beneficial option for those actors who opt for it. As most of our cases show, excluding the USA and the USSR, the first approach to space technology usually comes through cooperation as it provides a jump start in such an arduous enterprise. Benefit-wise, cooperation in space exploration progress is practically the ideal choice in any case where there is an actual opportunity to cooperate in any sort of way. The Canadian case and the introduction of the Russians to the ISS clearly show Salter & Leeson (2014) were on the right about the impact of positive cooperation. If the relationship of technological exchange or cooperation is noticeably beneficial, it will tend to occur. This is because actors will desire to cut costs most of the time, and cooperation is one certain way to achieve this. Therefore, in order for space technology cooperation to work in such large-scale projects such as the ISS, it is necessary to weave certain flexibility into stakes.

To add even more clarity to the relationship between the space building blocs analogy and cooperation we can extrapolate the unbounded notion of sovereignty provided by Stuart (2009). If we already consider the ISS as a conglomerate of pieces made and owned by different countries, which means no actor owns the ISS, it becomes evident the same can be applied to technology. Each actor provided an actual bloc of the entire project, which became one conjunction of blocs that operate together. This piece-by-piece set-up is the most convincing argument in favor of the applicability of the *space building blocs analogy* and the positive impact of cooperation.

Nevertheless, since cooperation remains something that is not present in every case of space exploration progress--as the US, USSR, China, and India prove--it is not a necessary condition for an actor’s progress. It still provides explanatory sufficiency, as it is present in the ESA, Canada, the ISS and SpaceX’s dependence on NASA.

We conclude then that cooperation is what Mahoney (2015, pp. 203-204) would define as a complementary condition, since it increases the probability of maintaining space exploration progress when present in conjunction with technological development. As a result, the causal mechanism of cooperation would be the following:

if only Cooperation (C) ⇏ **SEP**

Impossible since **C** ***depends on*** **TP**

when **SPE** ***exists*** ⇒ **C** ***might exist*** (sufficiency)

if **TP** ⇒ ***then*** **C** ⇒ **SEP**

Closing Remarks

In conclusion, the International Society of Outer Space is society that encompasses multiple *actors* that require *blocs* of technology in order to maintain their space exploration projects and progress. These projects can be carried out either individually or by multiple actors through technological cooperation, allowed by the flexibility of technological progress demonstrated in the *space building blocs analogy*.

As stated before, the results indicate that actors who intend to become a part of the bold enterprise that is space must pursue deep technological progress in space technology, and should definitely resort to cooperation if the option is available. Outwards Space is, in the end, a system that functions as the common enemy for those who seek to explore it. The cost of doing so is exceptionally high. Therefore, softening the impact always benefits the plausibility of space programs. This could, in turn, ease justification for space policy, or in other cases, provide a wider margin of profit. It is not an entirely rewarding option, as the Japanese or Brazilian case might prove, yet it remains more convenient due to the overall benefit of mutual trust, just as Salter and Leeson (2014) predicted. Beyond it, as the years go by and exploration and actors' presence intensify, we might continue to evidence the evolution of traditional Westphalian theory and the many ways technology and cooperation change the way international interactions work, as both this and Stuart's (2009) studies prove.

In the end, the space building blocs analogy reunites all the previous propositions made by Stuart (2009), Musgrave and Nexon (2018), and Salter and Leeson (2014), and demonstrates that the means space technology can be obtained and distributed facilitate cooperation. This indicates cooperation is a key element in space exploration, one that is not completely necessary, but one recommended nonetheless. It is the optimal choice when facing the deep void of outer space, as it increases the probability of space exploration progress.

If we consider that Earth, our ship that roams the universe, might one day fail to properly sustain the human species, we should prepare for the possibility of continuing somewhere else. If such day does come, cooperation might not only make it bearable, but also possible. As a result, the arduous path of space exploration is one that, preferably, invites us all as one.

To conclude, we propose future studies could delve into international space law and its nature, as the interactions in this study seem to be, in a sense, rather lawless. It could also push for more updated legislation, which is necessary, since practically most ruling depend on the governments that actually decide to launch a rocket. Furthermore, a broader number and types of studies of international relations or political science regarding space could also bring the subject to more mainstream audiences. This could help to cultivate interest in the political studies of space exploration.

Some subjects almost never get attention until they finally occur. Astropolitics, or broadly known as space politics, is a complex and unique subject we would benefit preparing for, and studying about, as it progressively evolves.

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