Evaluating Geopolitical Dynamics through Social Media and Space Missions: A Quantitative Perspective on Soft Power

Andrea Russo* [1,2] and Davide Coco [3]

[1] *Sorbonne University, ISCD, Paris, France*
[2] *University College Dublin, Ireland*
[3] *University of Rome, Sapienza University, Italy*
* `Andrea.russophd@gmail.com` , *Corresponding author*

Abstract

We present a quantitative method to quantify the geopolitical impact of a space mission, based on data logs of previous mission, and evidencing how even if some missions succeed, they can also bring negative effect to the sponsored country. The objective of this research is to study how the success or failure of a space mission can bring geopolitical benefit or loss to a country. By retrieving various data, including sentiment from #hashtags related to the considered space missions, national budgets for space exploration, and the reliability of space launch systems, from social networks, public institutions, and online repositories, we propose an equation to evaluate the geopolitical soft power importance of a space mission for a particular country or space agency. The goal of this paper focus on estimate the potential impact of a space mission on the public opinion and international relationships, which can be either positive or negative, as even successful missions may negatively affect the international relationships and negotiation with some countries and their partners.

Keywords: Geopolitical dynamics, Soft Power, Space Mission, Political dynamics, Twitter

1 Introduction

Since the end of World War II, the proposal of ambitious space programs by governments and national space agencies has always been a means not only to push forward space exploration and research but also to alter the prestige and geopolitical influence in the international context. For instance, the social policy action by the 35$^{\text{th}}$ United States president John Fitzgerald Kennedy to invest $25 billion (1961 US dollar value) in the Apollo mission [1] was not only a social investment to the increase public work with high qualification skills, but also a geopolitical plan action against the URSS space expansionism.
Geopolitical value appears since the first space missions, for instance, after Russian first space satellite "Sputnik 1" successfully orbited the Earth. The Space Race that characterized the 20$^{\text{th}}$ century, was actually a geopolitical and propaganda race to determine which country would have finally had access (and conquered) the "new and endless world above us". This geopolitical space race has been sustained by a huge effort from a social policy prospective. The $25 billion USD for the Apollo mission on 12th September 1962 (same day of the "Address at Rice University on the Nation's Space Effort" speech by United States President John F. Kennedy to further inform the public about his plan to land a man on the Moon before 1970), are the equivalent of $231 billion USD on 7th February 2022 [Appendix A].
Nowadays, superpowers like the United States, China, or the Russian federation, have increased the frequency of space missions to show their presence and value in a geopolitical and international perspective. The surge of space missions' proposals in the last decades was due also to the cost of access to space, which significantly decreased thanks to the development of reusable launch systems, performing hardware, and IT and IoT improvement.

Space missions have attracted huge money investments by public and private actors, with a social and business impact, due to the their potential economic return and their socioeconomic impact, as the design of a space mission encourages public high quality work and many public services originate from space activity (GPS, global mapping, high speed connection, global communication, and many others) [2].

Aside the aforementioned result, thus the spin-offs of space services to the population, can we also define space missions (both research and security missions) as soft power, given the geopolitical effects obtained from science development/result and IT infrastructure-related services?

A prime example of defense investment by the US from the “Pentagon” is the X37-B, a small shuttle designed to protect key satellite infrastructure from Russian and Chinese physical and cyber threats [3]. Originally developed as a prototype for national defense, this technology is now evolving into a tool of soft power, as states antagonistic to the US are struggling to develop comparable capabilities. These satellites are crucial not only for military operations but also for projecting US influence globally, intertwining security strategies with the exercise of soft power—both for the US and its allies.

In fact, designing a space mission is an extremely difficult task, with a high probability of failure due to the complexity of aerospace systems and the harsh conditions under which they are supposed to operate. The launch system plays an essential role in a space mission, as rockets must be “perfect” systems that respond seamlessly to all the perturbations that they experience during the atmospheric ascent up to the release of the payload into space [4, 5]. Every phase of the ascent trajectory must be carefully studied and planned before flight, as the margin of error is extremely small, even for the apparently simple scenarios.

The technical-scientific difficulty of space missions varies greatly depending on the objective, e.g. the range of possible scenarios increases enormously when it comes to orbital flights from one planet (or celestial body) to another. While for a flyby, the short passage of a high-speed probe near a celestial body, is seen as an extremely critical moment compared to the simple time spent cruising. On the other hand, the orbit insertion of a probe around a celestial body is a more critical moment than the flyby because it requires several active maneuvers that involve multiple simultaneously operating systems on which the entire mission depends. In a similar way, landing on a planet or asteroid is even a more critical accomplishment, as it involves much more complex operations.
But give to the great inherent complexity of aerospace projects, international cooperation allows for mitigating the risks and costs (both financial and time-related) of space missions. There are several examples that show that the cooperation among national space agencies or research institutes has brought benefits to all the parties involved, not only relative to the economic return of scientific discoveries and patented technologies, but also to a positive outcome in terms of reputation and geopolitical prestige associated with these missions. In fact, besides the technical aspects, the organization and management of a space mission are also quite challenging because every political interaction or action during the mission has a series of *emerging behaviors* in international affairs, and nonlinear interactions affect also reactions on political, economical, and security layers, which go beyond the space system [6, 7, 1, 8, 9].

Therefore, space missions involve varying levels of difficulty, where even minor mistakes or marginal defects can result in the loss of an entire mission. For this reason, space exploration often becomes a show-off of technological prowess and technical ’savoir-faire’, which can serve as a tool of soft power when specific goals are achieved.

Improving the success rate of space missions implies, from a geopolitical standpoint, an improvement of the international status. However, on the other hand, a failure can damage the relationship among international partners. The success of the Apollo 11 mission by NASA made the United States the winner of the space race and raised its geopolitical value even though many milestones were reached earlier by the URSS (first orbiting satellite and first human in space, to name a couple). Recently, numerous space missions were successfully launched and fulfilled their planned goals or even performed beyond expectations, receiving positive reception from the public opinion and altering (or consolidating) the international status of the involved countries. But even when a mission succeeds, there may be criticism from the society or even consequences and repercussions from others international actors, affecting the geopolitical status and international relationships of the sponsoring country.

But these social and governmental dynamics can be observed in online platforms, where people discuss and institutions update citizens. During recent years, social science has acquired methods and skills to collect data and use it like hard science to highlight and identify social patterns or social dynamics [10, 11]. Therefore, online social media platforms provide a powerful tool for collecting data and evaluating social interactions across a wide range of fields, such as security [12], disaster response [13], and social influence in different networks. For instance, the analysis of social media content has been used to understand who exerts significant influence in security debates, demonstrating how these platforms can be leveraged to monitor and assess discussions in sensitive areas like national security [14]. Additionally, Twitter has proven to be a critical tool in analyzing societal responses to crises, with research examining messages generated during humanitarian crises and natural disasters, highlighting the value of social media as a real-time data source in emergency contexts [15]. Beyond crisis response, social networks also offer the opportunity to quantify influence in everyday communications. A framework has been developed to assess social influence specifically within mobile social networks, with implications for understanding how information spreads [16] evidencing also possible predictable information cascades [17]. Also, the use of semantic and sentiment analysis algorithms applied to Twitter content has shown how such techniques can offer valuable insights into political movements and public opinion, providing promising perspectives for future studies on political and social activities on social media [18]. These studies highlight the importance of online social media platforms in gathering and analyzing social interaction data across various domains, from security to disaster response and political movements.

In this work, more precisely, we acquired data from social networks like Twitter (currently known as X), to evaluate the sentiment of space missions, which highlight the social reaction about the related space event. The sentiment analysis has been used by many others scientist over different research areas, and, if combined with a high quality computational method, it could highlight important patterns related to social events.

This paper therefore builds on works studying geopolitical dynamics, but there are few papers in the contemporary literature studying how space dynamics can bring an advantage or disadvantage in the case of failure or success of space missions in the geopolitical sphere. This paper serves to fill this gap.

2 Methodology

In recent years, various space missions have had a great communication impact, be it for reasons related to the war in Ukraine, the tension between the US and China or the successes of scientific space missions.

We searched which kind of recent (i.e., after social networks existence) space missions had had repercussions in the geopolitical and security domains, and we collected data for the missions reported in Table 1. The list includes only missions sponsored by countries that develop launch vehicles, as launch success and failure data are used as a way to estimate the country's experience in space missions (see Section Methodology or Table 4).

Table 1: Space mission data collected

Mission	**Country**	**Result**
Tianwen-1	China	Succeeded
Tianhe	China	Succeeded
ASAT	Russia	Succeeded
Mars 2020	US	Succeeded
James Webb	US/EU	Succeeded
Rosetta	EU	Semi-Succeeded

The Tianwen-1 is a Chinese interplanetary mission to send a robotic spacecraft on Mars. It was launched July 23, 2020 [19], and it landed on Mars on May 14, 2021 [20]. The mission consisted of an orbiter, a lander, and a rover called "Zhurong". The mission succeeded, and NASA's associate administrator Thomas Zurbuchen and the director general of Roscosmos Dmitry Rogozin congratulated the China National Space Administration (CNSA).

China has also lunched the Tianhe core module, which is the first module of the Tiangong space station, on April 29, 2021 atop a Long March 5B rocket [21]. The core stage of the LM-5B crashed back to Earth on Saturday, May 8, 2021, after 10 controversial days that captured the world's attention and started a wider conversation about orbital debris and the responsibility for the return of spent stages.

On November 15, 2021, Russia conducted a direct-ascent anti-satellite test (ASAT), destroying one of its own space objects, a defunct satellite, in low-earth orbit [22]. The test captured international attention and was quickly and widely condemned as threatening and irresponsible action, not least for the cloud of uncontrollable debris it created, which will endanger both space assets and human spaceflight for years to come. Other countries in the past have already organised ASAT missions, like the Mission Shakti (India), the ASM-135 ASAT (US) and the 2007 Chinese anti-satellite missile test (China). Others to object in the wake of the test included Australia, the European Union, Japan, NATO, and South Korea. China and India – the two countries other than Russia and the US that have previously conducted destructive ASAT tests —- are yet to comment publicly. Also, following the Russian ASAT mission, the International Space Station started emergency procedures due to the debris, closing its security hatches while the crew sheltered.

Mars 2020 is a Mars rover mission [23] that includes the rover Perseverance and a small helicopter called Ingenuity. It was launched from Earth on July 30, 2020 and landed in Martian crater Jezero on the 18th of February of the following year. The Mars 2020 mission is forming part of NASA's Mars Exploration Program, which will continue with a sample return from Mars. Ingenuity is a robotic helicopter that demonstrated the technology for rotor-craft flight in the extremely thin atmosphere of Mars, becoming the first controlled helicopter on another planet. The budget for the Perseverance rover was US$2.8 billion in 2020 and was cheaper than its predecessor, the Curiosity rover, which costed $3.2 billion. [24]

The James Webb Space Telescope [25] is a space telescope designed primarily to conduct infrared astronomy. NASA led the development of the telescope in collaboration with ESA and CSA (Canadian Space Agency). The mission duration is expected to be about 20 years and, the time planning for all the missions was 20 years (10 for planning and 10 for realization). It was Launched on December 25, 2021 by the contractor Arianespace from the Centre Spatial Guyanais, with an Ariane 5 rocket. The James Webb space telescope had a total budget of USD $\sim$ 9.70 billion (2002 to 2021) and has several scientific goals, including the search for light coming from the first stars and galaxies that formed in the universe after the Big Bang, the study of the galaxy, star, and planet formation and evolution, and studying planetary systems and the origins of life.

The Rosetta mission [26] was a space probe built by the ESA (European Space Agency) launched on March 2, 2004. The mission's goal was to perform a detailed and comprehensive study of comet 67P/Churyumov–Gerasimenko (67P). On August 2014, the spacecraft reached the comet and performed a series of manoeuvers to eventually orbit the comet at distances of 30 to 10 kilometres. The probe also housed a lander called Philae, which unfortunately was unable to last long on the comet's surface after a less-than-perfect landing. This was, indeed, the first mission landing on a comet. Yet, despite the problems, the probe's instruments obtained the first images from a comet's surface, and several instruments made the first direct analysis of a comet, sending back data that would be analysed to determine the composition of the surface. The mission cost was about $\sim$ 1.3 billion € (US $\sim$ \$ 1.8 billion).

It is worth noting that even when the mission succeeds, it may happen that the mission goal has external or side effects that provoke a social or political reaction. Such reactions is spread, when there is something that does not belong to the common day-order, or that may provoke instability in some country-system. We collect data from Twitter to see the social reaction to the space missions in Table 1. In all those cases, the missions succeeded, but, in some cases, the mission can cause a social reaction due to side effects.

For these reason, we have obtained the sentiment analysis score of each tweets for the relative # Hashtag and for each space mission. Sentiment can be considered related to *soft power* because it shapes public perception, influences emotions, and guides behavior without the use of force or coercion. By cultivating positive sentiment, organizations or nations can build trust, attract allies, and sway opinions, ultimately gaining influence in cultural, economic, or political spheres. This power stems from the ability to affect minds and hearts, creating a lasting impact on how entities are perceived globally.

We have collected social reactions from Twitter, for every mission in Table 1 and compared them with the difficulty and quality of the national space organization and the country that launched the space mission to quantify the "Authority and the status of power" status in geopolitical interaction dynamics. To simplify this operation, we create an equation called GSS, to quantify how space mission can influence the geopolitical feelings during international affairs dynamics.

The geopolitical space score (GSS) index is the geopolitical score value from each country, depending on the result of the spaceflight mission, related to statistical and social events [Equation (1)].

$$GSS = \frac{S}{G * B} * (F + Q) \tag{1}$$

S is the Sentiment value from the Twitter event; B is the amount of money invested (budget); G is a difficulty rate associated with the country that launched the space mission, "not because they are easy, but because they are hard" that imply Geopolitical effects; F is related to the success or Failure of the mission; and Q stands for the statistical Quality and difficulty of the country in spaceflight launch organization.

The S and Q parameters are evaluated by data scientists through statistical methods. The G score is the only parameter that needs a subjective value because it depends on personal evaluation and hypotheses to evaluate the difficulty rate of reaching that goal.

2.1 S Factor

To collect data for the selected topic, we use the public API by Twitter and Tweepy. Both services use permission from Twitter to obtain and gather data. We collected a total of $\sim$ 7000 tweets, but any downloaded topic needs revisions and a cleaning process to increase the quality of the research. This has significantly reduced the volume of the tweets. We used the same methodology for each topic to obtain standard and quality data. In addition, to obtain the correct amount of tweets

for each day we use getdaytrends.com, a specific site where it is possible to monitor every topic in real time as well as aged topics.

To calculate the sentiment for the selected topic, we used the VADER sentiment analysis tools provided by MIT. The VADER sentiment quantifies each selected post or sentence's negative, neutral, or positive sentiment, giving in the end of the analysis, a compound score, i.e. the average between all sentence.

However, to evaluate the sentiment for every mission, it is necessary that each mission be very important to the general public or, at least, sufficiently *viral* among the space community.

2.2 G Factor

As mentioned above, the *G* factor is the only parameter without computational or statistical data. This parameter evaluates the country that launches the space mission, corresponding to a difficulty rate implying geopolitical effects. For example, if a small state succeeds in a mission with the same budget and other factors in comparison to a big state such as the US etc., the small state will get a bigger bonus. Unfortunately, there is no universal value factor that gives a score to quantify the difficulty of space missions.

Soft Power is a social evaluation, therefore deriving from the perceptual fluctuations of people. Since people make up a complex system, they cannot give a univocal value to the G factor, because it always depends on the value of the individual and on the oscillations (provoked by news, newspapers, friends, etc.) that modify the perception and evaluation of individuals and society on certain topics.

Due to this problem, we decided to self-evaluate the difficulty of a space mission, even if it is hard to make an assessment that takes into account everything. There are many pros and cons, and, in each case, we know that people cannot evaluate sufficiently well the difficulty of a space mission.

Yet, we believe that people can understand whether it is a surprise if a very small country alone (like Ireland or Pakistan) can accomplish, for example, to build a Martian base, and the US could not do it. We estimate a self-score from 0.1 to 1, where 0.1 is the maximum and 1 is the minimum possible score. For example, a sub-orbital lunch mission could have a 1 score, an orbital mission could be a 0.8 score. The Tianwen-1 could be evaluated as 0.3, like the Martian Ingenuity helicopter on Mars. A full Moon base could be evaluated as 0.2 (or 0.1 if it is on Mars). All other space missions beyond the state-of-the-art technology level cannot be evaluated, because, we do not have sufficient information to be able to carry out the mission successfully, like a human base on the surface of Mercury, Titan or Europa, for example.

2.3 B Factor

In the equation, we thought it was important to evaluate, then quantify, the level of resources invested versus the expected outcome (successful or failed mission). We thought this based on the logic "why should a mission cost a lot of money, while it is possible doing the same things while spending fewer resources?". To evaluate and quantify this factor, we collected data from the most important space agencies of each country. Since the experience gained in the design and management of past missions can be exploited in newer missions, we chose not to use a specific budget for each mission in the equation, but, rather, the annual funds dedicated to space missions. In this logic, it is hard to quantify how much money the oldest mission have helped (with knowledge, moneys, competence, technology) the newest space mission. Also, huge space missions like the JWST, or the Rosetta mission's budget, grows up during years. The budget for the mission is spread over years, and we cannot only take a single space mission budget, because there are also many other funded missions different from the JWST in the same year. Therefore, we thought that the Budget factor, imply also public opinion logic. Public opinion is usually skeptic about spending money for space mission, because they did not (unfortunately) see the huge policy investment on research, security and works employments, "Rockets don't run on cash". And nowadays, is still difficult to quantify the investment return (knowledge, moneys, competence, technology) form the policy investment from space mission. In addition, the budget factor imply also a economic strength from the country that invest on space mission, For example, in the equation, if a small country achieve a successful space mission with a low budget, the GSS score will be higher than a the same country (or a bigger country) will achieve the same mission with a higher budget.

However, to give an insight into space investment, in 2020, the policy plan for the major government in space mission amount of a \$73.98 billion, and it is the ∼ 0,927 % as a share of gross domestic product (GDP), with a medium of ∼0,115875 % for each country. The Organisation for Economic Co-operation and Development (OECD) as show the total value of space budgets from the G20 country [Table 2], and we add in comparison, the years military budget for each country.

Table 2: G20 government space and military budgets (2020)

Country	2020 Space Budget in Billions	∼ National Space Budget %	∼ National Military Budget %
US	22.62	0.480%	3.74%
Russia	3.58	0.210%	4.26%
France	4.04	0.122%	2.07%
Japan	3.32	0.076%	1%
Saudi Arabia	2.1	0.076%	8.45%
China	8.85	0.075%	1.75%
Italy	2.0	0.069%	1.56%
Germany	2.40	0.049%	1.4%

% in billion U.S. dollars [Appendix B]

2.4 F Factor

The factor F, was needed to the equation to weigh/ponder the space mission, and it shows if the mission succeeded or failed. The F factor is equal to 1 if the mission succeeded, or 0 if it failed.

2.5 Q Factor

The factor Q, evidence the statistical risk factor and the reliability for each Country about spaceflight missions. Usually, every space mission have a risk factor, like the Apollo mission had the 95% of failure [27], but this information (if they still made it) is not available to the public. Therefore, since we cannot obtain data for every single mission, we hypothesize a different evaluation method, so we rely as a risk factor on collecting data on the success/failure of each country's space launch. Those data give a specific statistical risk and reliability factor to each country, since year 2010. [Appendix C]

It can happen that some space mission fail. In this scenario, we had imagined a failure factor that influence as a feature on GSS equation.

The failures factor arises when you make mistakes over and over again, and in this case you always lose trust from others. The "Success/Authority improvement" comes from maintaining your own (high) standard for as long as possible. We chose to not put the Failures Factor in the equation, because factor Q evidence all the space mission (satellite mission, supplying mission, scientific mission etc.), and not only the scientific space mission, like those we have chosen as subject of this paper (Table 1).

A well know example for a Failures Factor, could be the Tianhe mission from China, that had unfortunately an uncontrolled stage reentry, and the vector crashed back to Earth without having the possibility to calculate the final crash site, due the amount of variables on the descent stage. Sadly, this inconvenience will arise often by the China, any time when they decide to add a core module on his space station, because the Long March 5B (Y2) cannot claim to get the core module in orbit (hooked to the Tianhe core stage), without losing control of the rocket on re-entry. [28]

The Long March 5B re-entry had provoke concern about the security for some city, because the rocket had an orbital inclination of 41.5 degrees, means the rocket body passes a little farther north than New York, Madrid and Beijing and as far south as southern Chile and Wellington, New Zealand, and could make it is reentry at any point within this area. With obvious concerns for those country.

3 Data & Result

According to our equation, the most important and determinant score are the sentiment score, which refers as the reaction and evaluation about the space mission's result. The resulting online activity give us a social input valuable to quantify and qualify the international social reaction about space mission. Through the analysis of online activity topics, we identified the sentiment that describing the dynamic between space activity mission and geopolitical dynamics. In table 3 we show the sentiment results (S) from the most recently and most know space mission of the last decade.

Mission	**Hashtag**	**Average Sentiment**	**Result**
Tianwen-1	Tianwen-1	0,46447	Succeeded
Tianhe*	ChineseRocket*	-0,05151	Succeeded (Sides effects)
ASAT	ASAT	-0,16607	Succeeded (Sides effects)
Mars 2020*	Perseverance*	0,428263	Succeeded
Mars 2020	Mars2020*	0,487525	Succeeded
James Webb	JWST*	0,480994	Succeeded
Rosetta	Rosetta	0,429542	Semi-Succeeded

Table 3: S factor - Sentiment analysis

* Actually, some hashtags are derived not from the mission itself, but from the effect achieved (losing control of the Chinese rocket on re-entry) or the main subject of the mission (perseverance).

The results clearly evidence that an increase of side effect during mission, increases the negative score sentiments from the space mission community.

Regarding the economical resources invested (B) we collect data from different source, and arranged it on USD Billions dollars. Table 4 was the difficult one to make, because it is hard to obtain data from not-direct-democratic state, like China, and also because the inclusion of both civilian and military space budget for security missions.

Table 4: B factor - Space budgets

Country	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Japan	1.67	1.59	1.68	1.6	1.76	1.56	1.33	1.32	3.06	1.34	3.32	4.14
Russia	2.4	3.8	-	5.6	4.39	2.42	3.18	-	4.17	3.58	3.58	1.92
EU	4,19	4,52	4,56	4,85	4,85	4,65	5,95	6,52	6,35	6,49	5,52	5,16
China	-	-	-	-	2.66	-	4.91	-	5.83	8.00	8.85	10.28
US	18.72	18.44	17.77	16.86	17.64	18.01	19.3	19.50	20.73	21.5	22.629	23.27

In billion U.S. dollars [Appendix B] [Appendix C]

Therefore, the data from the statistical failures presence in our equation, that mark the quality of space launch system for each country (Q) are shows in Table 5. The data are collected since the year 2010 to 2021 (the 2022 is not finished yet), show the total number of Core Stage Manufacture send in space, between overall launch log outside brackets and failures inside brackets. In the end, we shows also the total launch and failures between 2010 and 2021 and the failures percentage. The failures percentage is the Q value in our equation, evidencing the failures probability to each space launch system-country for each launch.

Table 5: Q factor - Statistical failures

Country	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**TOT**	**Failures %**
China	55(3)	39(4)	34(2)	39(1)	18(2)	22(2)	19(0)	16(0)	15(1)	19(0)	19(1)	15(0)	310 (16)	5,2
Russia	25(2)	17(0)	25(0)	20(1)	20(1)	19(1)	27(3)	35(3)	32(1)	26(2)	32(4)	31(1)	309(19)	6,1
US	43(2)	35(3)	19(0)	29(0)	28(0)	21(0)	20(2)	20(0)	17(0)	13(1)	15(1)	15(0)	275(9)	3,3
Europe	6(0)	5(1)	6(1)	8(1)	9(0)	9(0)	8(0)	7(0)	5(0)	8(0)	7(0)	6(0)	84(3)	3,6
India	2(1)	2(0)	6(0)	7(0)	5(1)	7(0)	5(0)	4(0)	3(0)	2(0)	3(0)	3(2)	49(4)	8,2
Japan	3(0)	4(0)	2(0)	6(0)	7(1)	4(0)	4(0)	4(0)	3(0)	2(0)	3(0)	2(0)	42(1)	2,4
New Zeal.	6(1)	7(1)	6(0)	3(0)	1(1)	-	-	-	-	-	-	-	23(3)	13,6
Iran	1(1)	2(1)	2(2)	-	-	-	1(0)	-	-	3(2)	1(0)	-	10(6)	60

Total launch by year (total launch failures by year) [Appendix D]

It is possible to see that the Chinese government have many more launch than the US and Europe, this is due to the low presence of space satellite (for communication and security mission) orbiting the Earth by the Chinese government. The Chinese government had invested a huge amount of money to get enough satellites to make public infrastructures work. Also, Russian launch operation have been increased since the 2011, due to the retirement of the space shuttle (last mission 21th July 2011), and as result, the US astronauts had to traveling by Russian Soyuz spacecraft to get to the international space station. We have compared the data from the equation (S, T, R and Q parameters), and in Figure 1 and Table 6 we show the score after the mission succeeded or failed.

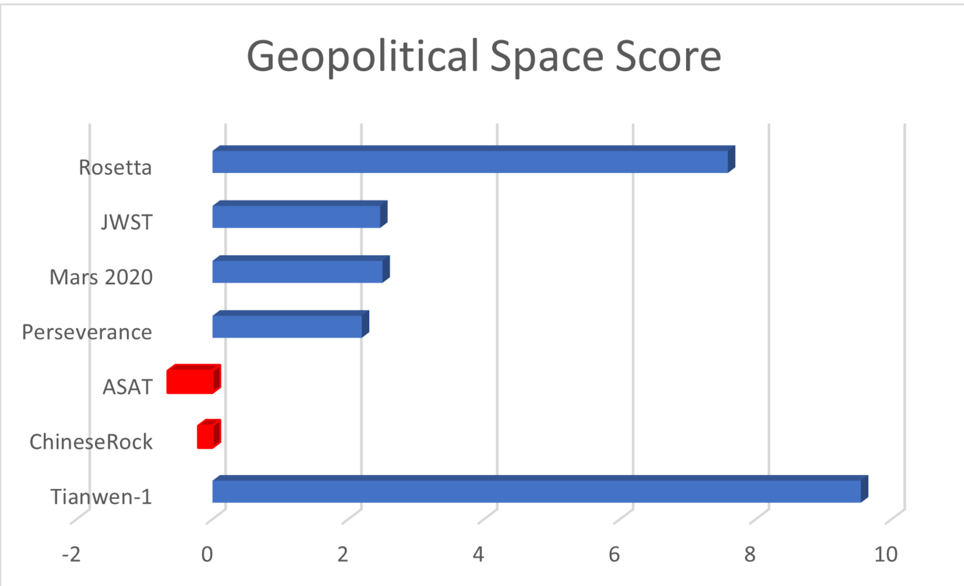

Figure 1: GSS's info-graphic of mains space mission

Table 6: Geopolitical Space Score

Mission	Geopolitical Space Score
Tianwen-1	9,547438889
ChineseRock	-0,208492857
ASAT	-0,659007937
Perseverance	2,198416733
Mars 2020	2,502628333
JWST	2,469102533
Rosetta	7,588575333

As is easiest to see, there is a negative score (we have highlight it with red on Figure 1), due to the risk of the ASAT and the space debris rocket had on population on heart and on the ISS. Tianwen-1 and Rosetta mission have a high GSS score also because it was a first huge milestone for the respectively space agency (ESA and CNSA). These data evidence the difference between a successful mission, achieving its goal; wile a successful mission, still achieving is goal but with side effect.

3.1 GSS trend in time

We have tried to quantify a GSS value for space Research Mission only between 2010 and 2021, for each country, due the fact that ASAT is a military space mission. So we have gather data from all factor for the equation, but unfortunately we did not get all the Sentiment Factor (S), because usually unknown space mission does not have much reaction on social network; As said before to evaluate the sentiment for each missions, those missions should be very important for the Humankind, or at least ”virality” for the space community, and many mission unfortunately become known to major society only from newspaper and occasionally from TV news. To solve this problem, we estimate a medium 0,425 S factor from successful mission, and a medium -0,125 for failed missions. For the other well know mission (Table 1) we have used the original sentiment. Regarding the economical resources invested (B) toward the data accumulated, we did not get the full budget planning over years for China and Russia, so we estimate a progressive linear regression between the missing data on table 4.

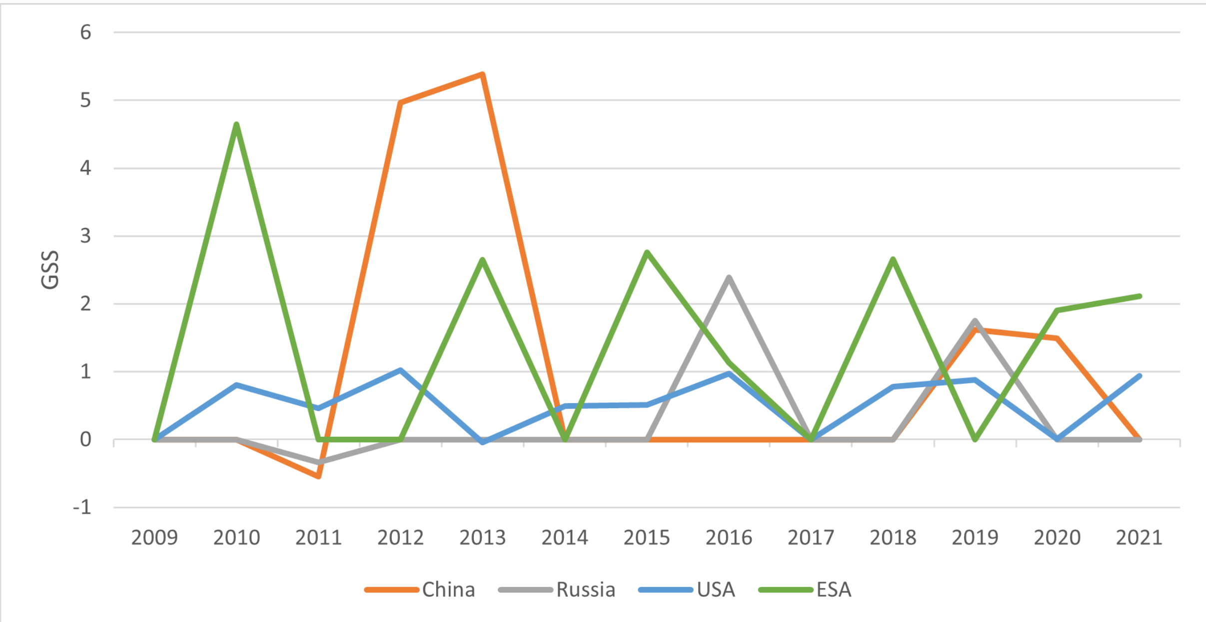

Figure 2: GSS - Research missions

Appendix E - F

As Figure 2 shows, it is possible to see the fluctuations characterised by the missions. In addition, it is also possible to see the type of strategy and activity for each country/agencies.

For example, ESA, which is characterised by the limitation of not having a launch station on the east coast, has specialised in international collaboration, and it is possible to see how ESA manages missions with fluctuations of about one year (given the many collaborations, especially with NASA). Moreover, it should be noted that the Rosetta mission, like the Tianwen-1 mission, could be designed as a "baptism of independence", derived from "not because they are easy, but because they are hard" philosophy; Thy was indeed, the first to do that, showing his competence and skill upon the others superpowers space country like US and Russia. China, on the other hand, is concentrating on a few space research missions, since it is a new superpower and has yet to stabilise its infrastructure and network telecommunication on space. Instead, the US have/had many active missions for a long time, in fact the score is relatively lower than the others precisely because of their resilience. People expect them to fail less than the others, so the astonishing/sensational felling can only be found in very difficult missions, or when they failed badly.

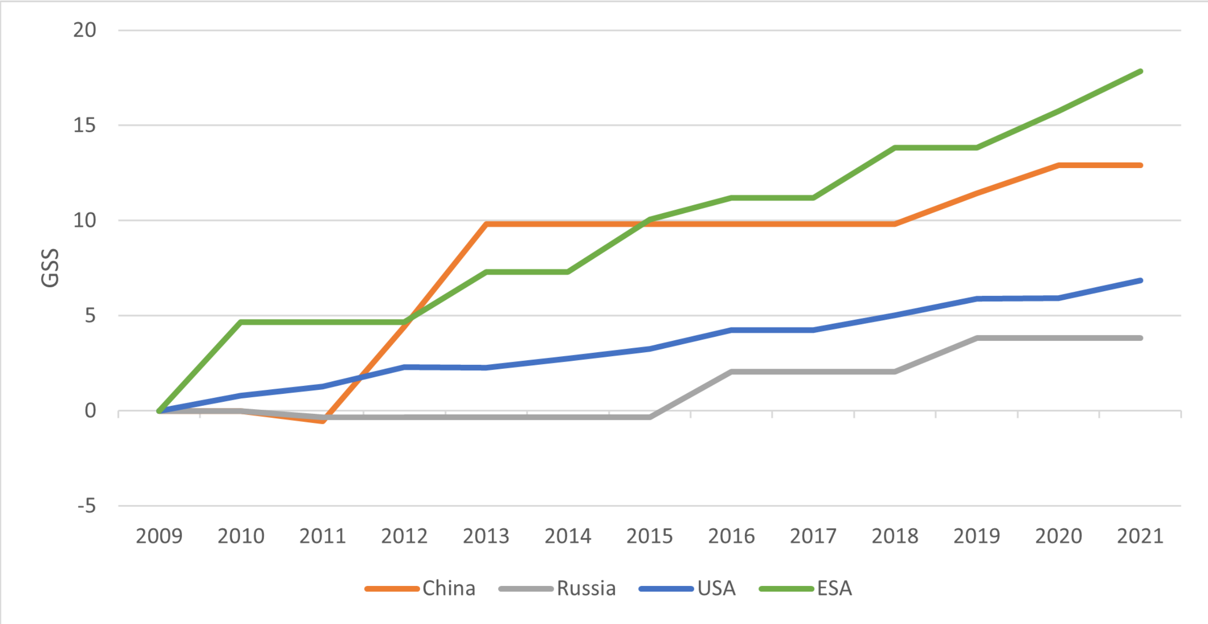

Figure 3: GSS - Research missions cumulative

Appendix E - F

4 Analysis

The Geopolitical Space Score (GSS) trends over time, as illustrated in Figures **??** and 3, display key insights into the evolving geopolitical dynamics of space exploration among the major spacefaring nations. The first figure (Figure 1) underscores the fluctuation of GSS for various space missions, emphasizing the importance of both success and public perception. While China's Tianwen-1 mission and ESA's Rosetta mission marked significant milestones, evidenced by their high GSS scores, missions such as ASAT and ChineseRock experienced negative sentiment largely due to the side effects and risks, including space debris impacting Earth and international security concerns.

The second figure (Figure 2) delves into the temporal progression of GSS for research missions between 2010 and 2021. ESA, for example, is characterized by its collaborative strategy, leading to periodic fluctuations in its GSS, as it often partners with NASA and other space agencies. China's GSS shows sporadic spikes, reflecting its concentrated efforts on fewer, high-impact research missions as it stabilizes its space infrastructure. Meanwhile, the U.S., with its long-standing history in space exploration, shows a more steady and resilient GSS progression. This consistency is partly because U.S. space missions have long been expected to succeed, making only the most challenging or high-stakes missions capable of generating high GSS values. In fact, they are not first on the geopolitical level despite having a high number of missions both quantitatively and qualitatively, in indeed, this score is given by the fact that they rarely miss, thus showing a high quality work, making the event of their possible failure so stupefying or entropic.

Finally, the cumulative GSS graph (Figure 3) highlights the aggregate impact of research missions over time, reflecting the consistent growth of space capabilities in different regions. China and ESA's cumulative GSS are notably high, indicating that their major milestone missions contributed significantly to their overall standing in the global space race. The United States' steady but lower relative cumulative GSS shows that, while they remain a dominant force, their achievements have become less surprising to the public and space community, thus lowering the GSS in comparison to newer, more groundbreaking missions from other countries.

In conclusion, the GSS scores reflect not only the technical success of space missions but also the public and geopolitical perceptions, which are crucial to understanding the dynamics of global space power competition. The different trajectories seen for China, ESA, and the U.S. underscore varying strategic priorities and public reactions to space exploration efforts.

5 Conclusions

Our study shows that can be possible using computational social method to quantify geopolitical dynamics for every country (and/or organization). In our case we have shown how space mission influence geopolitical dynamics, supported by data-driven and sociological approach. In a more specific way, we have demonstrated (1) A method for assessing the geopolitical level of any country, based on its goal and its system-organization; (2) That space missions, even if successful, can bring negative sentiment, which goes to reflect on the geopolitical value to the state itself; (3) That the investment in the space mission has a spillover effect on geopolitical value. From a sociological point of view, the GSS equation can be used to evaluate the geopolitical level not only in the spatial domain, but also in other "competitions", such as sports competitions (Olympics, world sports championships) or music competitions or international wars, where there are enough social reactions (S Factor) and enough statistical data (Q - B Factor) to evaluate both the event and the organization/country participating in the event.

6 Declaration of interest statement

The authors declare no conflict of interest.

7 Acknowledgement

We thank Taha Yasseri for for his crucial help in the equation.

References

[1] Brian Bozzo. Not because It Is Easy: Exploring National Incentives for Commercial Space Exploration through a Geopolitical Lens Notes. *Drexel Law Review*, 11(2):597–650, 2018.

[2] ASI. Documento di visione strategica per lo spazio (dvss). *ASI Archive*, 1, 2020.

[3] Marcello Spagnulo. Ecco lo spazioplano del pentagono, tra misteri e tecnologie futuribili. *formiche.net*, 1(1):2, 2020.

[4] Boris Benedikter, Alessandro Zavoli, Guido Colasurdo, Simone Pizzurro, and Enrico Cavallini. Convex approach to three-dimensional launch vehicle ascent trajectory optimization. *Journal of Guidance, Control, and Dynamics*, 44(6):1116–1131, 2021.

[5] Boris Benedikter, Alessandro Zavoli, Guido Colasurdo, Simone Pizzurro, and Enrico Cavallini. Convex optimization of launch vehicle ascent trajectory with heat-flux and splash-down constraints. *Journal of Spacecraft and Rockets*, 59(3):900–915, 2022.

[6] Jason Dittmer. Geopolitical assemblages and complexity. *Progress in Human Geography*, 38(3):385–401, 2014.

[7] Andrey Dmitriev, Victor Dmitriev, and Stepan Balybin. Self-organized criticality on twitter: phenomenological theory and empirical investigation based on data analysis results. *Complexity*, 2019, 2019.

[8] Stefano Pioppi. Ipersonica e cyber, russia e cina sfidano la nato. parla l'ammiraglio bauer. *formiche.net*, 1(1):1, 2021.

[9] Marco Giannangeli. Global tensions grow as chinese rocket scientist defects to the west. *Express.co.uk*, 1(1):1, 2022.

[10] Claudio Cioffi-Revilla. Introduction to computational social science. *London and Heidelberg: Springer*, 2014.

[11] Andrea Russo, Vincenzo Miracula, and Antonio Picone. Network analysis on political election; populist vs social emergent behaviour. *arXiv preprint arXiv:2301.05668*, 2023.

[12] Giovanni Gambino and Andrea Russo. Profilazione sociale e sicurezza nazionale. *Società Italiana di Intelligence: Arcavacata di Rende, Italy*, 2021.

[13] Andrea Russo. Organised firestorm as strategy for business cyber-attacks. *arXiv preprint arXiv:2301.01518*, 2023.

[14] Joseph Downing and Richard Dron. Theorising the 'security influencer': Speaking security, terror and muslims on social media during the manchester bombings. *new media & society*, page 1461444820971786, 2020.

[15] Jie Yin, Sarvnaz Karimi, Andrew Lampert, Mark Cameron, Bella Robinson, and Robert Power. Using social media to enhance emergency situation awareness. In *Twenty-fourth international joint conference on artificial intelligence*, 2015.

[16] Sancheng Peng, Aimin Yang, Lihong Cao, Shui Yu, and Dongqing Xie. Social influence modeling using information theory in mobile social networks. *Information Sciences*, 379:146–159, 2017.

[17] Naimisha Kolli, N Balakrishnan, and KR Ramakrishnan. On quantifying predictability in online social media cascades using entropy. In *Proceedings of the 2017 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining 2017*, pages 109–114, 2017.

[18] Peter Cihon and Taha Yasseri. A biased review of biases in twitter studies on political collective action. *Frontiers in Physics*, 4:34, 2016.

[19] CNSA.gov. China successfully launches probe in first mars mission. *http://www.cnsa.gov.cn*, 2020.

[20] CNSA. China's tianwen-1 probe sends back mars landing visuals. *http://www.cnsa.gov.cn*, 2021.

[21] Site CNSA. China launches first section of its massive space station. *http://www.cnsa.gov.cn*, 2021.

[22] News BBC. Russian anti-satellite missile test draws condemnation. *bbc.com*, 2021.

[23] NASA.gov. Mars 2020 perseverance rover. *nasa.gov*, 2021.

[24] Wikipedia. Curiosity (rover. 2022.

[25] JWST. NASA. James webb space telescope. *nasa.gov*, 2020.

[26] ESA. Rosetta operation. *esa.int*, 2014.

[27] NASA. Apollo reliability and quality assurance program quarterly status report, second quarter 1965. *NasaArchive*, 1:83, 1965.

[28] Andrew Jones. China acknowledges long march 5b situation as rocket heads for weekend reentry. *spacenews.com*, 2021.

[29] Erick Burgueño Salas. Government space program spending of the leading countries in the world 2014-2020. *statista.com*, 2021.

8 Appendix

A Equivalence of the 1962 USD to 2022 USD

More specifically: 231 408 697 113.64 USD $.
Inflation over the period: 825.63 %
Index used: USCPI31011913 (Bureau of Labor Statistics).
Initial Index: 309.12, Final Index: 2 861.33
Source Link

B Space annual budget (∼ approximately) over years and percentage of the national budget

It is very hard to collect data for the most important Space Agency, this is due to the different money value (Yen - EURO - USD), and also the difficulty to obtain data from non-democratic states, like China, due to information security and the inclusion of both civilian and military space spending under global security.

Source [29]:

1. https://www.statista.com/statistics/745717/global-governmental-spending-on-space-programs-leading-countries/
2. https://www.euroconsult-ec.com/press-release/government-space-budgets-driven-by-space-exploration-and-militarization-hit-record-92-billion-investment-in-2021-despite-covid-with-1-trillion-forecast-over-the-decade/
3. https://spacenews.com/op-ed-global-government-space-budgets-continues-multiyear-rebound/
4. https://stacker.com/stories/2524/countries-spend-most-space-exploration
5. https://www.oecd.org/sti/inno/space-forum/space-economy-for-people-planet-and-prosperity.pdf
6. https://global.jaxa.jp/about/transition/index.html
7. esa.int
8. https://en.wikipedia.org/wiki/Budget_of_NASA
9. https://global.jaxa.jp/

Military budget:

1. https://databank.worldbank.org/reports.aspx?source=2&type=metadata&series=MS.MIL.XPND.GD.ZS#
2. https://www.defensenews.com/global/2021/04/26/the-world-spent-almost-2-trillion-on-defense-in-2020/

C Billion U.S. dollars

Exchange rate 1.1269 at 27/02/2022 02:50 28 Feb 2020 - 25 Feb 2022

D Statistical failures

Annual space reports:
From 2010 to 2021 Launch Log
Source Link

E GSS - Research Missions

Table 7: GSS related to space research missions

Country	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
China	-	-	-0,541666667	4,969230769	5,383333333	-	-	-	-	-	1,615	1,490577956	-
Russia	-	-	-0,334429825	-	-	-	-	2,389937107	-	-	1,75719055	-	-
USA	-	0,808621288	0,464438894	1,026104163	-0,040508492	0,492783694	0,512710274	0,976252159	-	0,776134433	0,876356589	0,011896792	0,942333613
ESA	-	4,647391567	-	-	2,648339061	-	2,762246117	1,128012708	-	2,654855643	-	1,903820817	2,11289354
Japan	-	4,542027057	-	-2,976190476	-	4,277597403	-	-	-	5,740740741	-7,462686567	-	-
TOT	-	3,332679971	-0,137219199	1,006381485	2,663721301	2,385190548	1,637478196	1,498067325	-	3,057243606	-0,803534857	1,135431855	1,527613577

GSS - Research missions

F Country Succeeded and Failed Space Research Mission

Table 8: Country Succeeded(Failed) Space Research Mission

Year	**China**	**Russia**	**USA**	**ESA**	**Japan**	**India**
2010	-	-	Deep Impact	Rosetta	Akatsuki	-
	-	-	Stardust	-	IKAROS (Shin'en)	-
2011	(Yinghuo-1)	(Fobos-Grunt)	Dawn	-	-	-
2012	Chang'e 2	-	MSL Curiosity	-	(PROCYON)	-
2013	Chang'e 3	-	(Deep Impact)	Gaia	-	-
2014	-	-	MAVEN	-	Shin'en 2	Mangalyaan
2015	-	-	DSCOVR	LISA Pathfinder	-	-
	-	-	New Horizons	-	-	-
	-	-	Dawn	-	-	-
2016	-	ExoMars 2016 (Schiaparelli EDM lander)	Juno	ExoMars 2016 (Schiaparelli EDM lander)	-	-
2017	-	-	-	-	-	-
2018	-	-	Parker Solar Probe	MASCOT	Hayabusa2	-
	-	-	MarCO A "WALL-E"	BepiColombo	BepiColombo	-
	-	-	MarCO B "EVE"	-	-	-
	-	-	OSIRIS-REx	-	-	-
	-	-	InSight	-	-	-
2019	Chang'e 4	Spektr-RG	New Horizons	-	(Minerva II-2)	-
	-	-	Spektr-RG	-	-	-
2020	Chang'e 5	-	Mars 2020	Solar Orbiter	-	-
	Tianwen-1	-	-	-	-	-
	Beidou	-	-	-	-	-
2021	-	-	James Webb	James Webb	-	-

GSS - Research missions