ANTICIPATING THE EVOLVING SPACE TRANSITION THROUGH A HISTORICALLY GROUNDED FRAMEWORK

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tise transition, innovation and sustainability environments

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- My parents, more than an orbit away, who've provided the freedom and encouragement to chart my own path through the universe

ABSTRACT

The last two decades have been largely defined by the Digital and Sutainability transitions. However, the previously overlooked but increasingly prevalent Space transition may have an even greater transformative impact that must be carefully planned using experience. This experience will be gathered and applied through a summary of historical context and developments as it relates to Global Trade and European colonialism, as well as the context of the modern socio-economic and geopolitical environment.

A comparative study in the form of a Future Scenario Analysis of both topics drew multiple parallels between european colonialism and the contemporary circumstances regrding the space transition. Key findings include:

- Deglobalization will likely continue in the next 10 years, setting up an an international environment similar to European Mercantilism during the colonial period
- The next 10 years of space development, strongly driven by mineral extraction, closely resembles Spanish colonial operations.
- This has both globalizing and deglobalizing effects, mainly the latter
- The following 10 years of space development more closely resembles the more diverse, British model of colonial operations
- Uncertain outcome of counteracting globalizing and degloblizing trends
- Major socio-economic and technological transitions likely to follow, particularly after the first 10 years of future space development

There are many broader policy concerns and questions regarding responsible space transition which would be prudent to research further

Keywords:

Comparative Study, Mercantilism, De/Globalization, Space Transition, Scenario Analysis

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ABBREVIATIONS AND DEFINITIONS

Industry - “a group of companies that operate in a similar business sphere, and its categorization is narrow.” (Investopedia, 2024)

Sector- “refers to a part of the economy into which various industries consisting of a great number of companies can be fit, and is larger in comparison.”

Orbit - “a regular, repeating path that one object in space takes around another one” (NASA, 2024)

Karman line - The line dividing earth from space, at roughly 100km altitude

LEO - Low Earth Orbit, at roughly 200 km altitude above sea level. Most satellites are positioned here (NASA, 2024)

MEO - Medium Earth Orbit, at roughly 2,000-35,870 km above sea level

HEO - High Earth Orbit, beyond 35,870 km

GTO/GSO - Geostationary/Geosynchronous orbit. Satellites are positioned that they orbit at the same speed as Earths rotation, remaining in place over a certain point.

Light Launch Vehicle - Can carry a payload of up to 2,000kg into orbit (NSF, 2024)

Medium Launch Vehicle - Can launch between 2,000kg to 20,000 kg into space

Heavy Launch Vehicle - Can launch beyond 20,000kg into space

“Green” Minerals - many metals like Lithium and Rare Earth Elements (REEs) that are vital for green and digital technologies

Solar neighborhood - celestial bodies extending between the sun and the inner asteroid belt

MAD - Mutually Assured Destruction

1.3 Introduction

This thesis is the final deliverable of the Erasmus Mundus Joint Masters in Transition, Innovation and Sustainability Environments (TISE). Over the course of this masters, which emphasizes system complexity, and innovation and transition systems, two primary transitions, the Digital transition and Sustainability transitions, were studied closely. This was done through numerous classes and workshops in a number of transdisciplinary fields, providing a holistic picture of the history of the technologies and their pioneers, the context of the important points along the timeline of these innovations, as well as the social impacts that they have had on communities at all scales and dispositions.

In 2024, it is easy to see why these particular transitions were chosen as the focus of this masters: the Internet and digital technologies have permeated nearly every aspect of our lives on a social and individual scale, and the actors who have facilitated such innovations have become political and economic juggernauts the world over. Digital technologies have changed how we think and feel, interact with each other and with institutions, formal and informal. Popular media, such as *The Social Network* have highlighted the stakes, history and impact that this transition has had, all of which have only become more noteworthy since the film's release in 2010.

The sustainability transition, in response to environmental and climate degradation, arrived on the scene at least a decade after the widespread adoption of digital technologies, is not just becoming increasingly important to the wellbeing of our communities, but crucial to the very survival of the human species and our modern way of life. As we’ve discussed with our colleagues and professors, there are many ways that the sustainable transition manifests, from renewable, emission-less energy generation, to better city design, regulatory and governance overhaul, responsible businesses, more responsible consumption and production, etc.

Both transitions, and broader socioeconomic context that determine their impact on communities everywhere, have justly received considerable investment and attention outside of academia for the reasons mentioned above and more. Decisions, conscious or unconscious, made at the beginning of a transition have an exponential impact further down the road. Innovations and their subsequent effects are frequently compounding, building upon each other in often unpredictable ways, often acting to the benefit of some and the detriment of others. Repeatedly short-sighted choices or individually focused motivations and intentions have created extremely difficult obstacles to surmount as the consequences of such inputs become clearer. Here then is among the chief lessons taught by the TISE masters, simple as it may sound: new technologies, innovations and transitions must be carefully evaluated, and designed and implemented with a multifaceted, long term and transdisciplinary approach to provide sustainable and equitable social, political and economic benefits.

In accordance with this principle, we considered additional innovations and transitions which have reached the forefront discourse only in the last few years, such as Artificial Intelligence (AI), Internet of Things and economic degrowth and deglobalization. However, I personally think that an important transition, with the potential to impact our lives on a scale similar too or even greater than the transitions we've discussed over the course of the masters, has been overlooked in both our academic studies and discussion, as well as, until recently, the public eye: the Space transition.

The Space transition has already begun, much earlier than many of us might think. While Sputnik and the Apollo missions may still be recalled clearly by hundreds of millions around the world, the generations of Galileo and Copernicus have long since passed. The technological gap and wealth of knowledge of these eras may be quite different, however both eras fall under the banner of space exploration. It has been only over the last 50 or so years that the space transition has begun to move outside the realm of exploration and toward practical implementation in the complex systems of the modern world, and impact our daily lives on a scale similar to the digital and sustainability transitions, a trend which will only accelerate. Much like with current transitions, this velocity must be managed with foresight and prudent experience. As new actors, including states of various geopolitical and economic orientations, as well as individuals, and corporations and other organizations, seek to discover and exploit new opportunities in space, national and international regulations and their enforcement have failed to keep up with the current circumstances of the early stages of the space transition. Yet a critical mass necessary to permeate many aspects of our existence, like the digital transition has, is rapidly approaching, and with it bears a credible threat not only to vital *existing* space infrastructure, but to the potential of all *future* opportunities in extraterrestrial environments.

While certain agreements already exist between many spacefaring actors, efforts to follow and enforce them have not been sufficient since their inception at the beginning of the space exploration era in the 1960's. This failure to follow prudent guidelines for stakeholders and decision makers through the present moment, let alone anticipate and adapt for potential future scenarios, must be remedied.

1.4 Research Question

Establishing and following prudent guidelines for the present and future relies on essentially trying to predict the future consequences of our decisions in the present day. Doing so requires a reference, a reference which is often drawn from the consequences of *past* decisions: history, aka experience, always has been, and will continue to be, such a principal reference.

This is what this thesis will begin to do: find relevant historical examples that are relevant to the space transition, evaluate their context and outcome, draw comparisons to the current socio-economic context of the space sector, and finally extrapolate the insights gained forward into the future. The final product of the comparative study of past colonization on earth and current space colonization efforts will be a scenario analysis of the next 20 years should the status quo of socio-economic and geopolitical conditions continue to hold steady. This will be done to explore the answer to the question "What are some potential geopolitical and socioeconomic outcomes of the next 20+ years of the Space Transition, based on historical colonial precedent?"

1.5 Methodology

The literature review will first discuss relevant historical precedents surrounding global trade and European colonialism and mercantilism. The second part of the literature review will evaluate the status quo of the contemporary space sector and the global economic and geopolitical context in which it exists, isolating and presenting specific, key characteristics

The main synthesis and analysis of these two core concepts defined and outlined in the literature review will be a comparative study in the form of a Scenario Analysis, using a 20-year time frame, broken down into a pair of 10-year increments, beginning in 2025 and observing a number of broader contemporary geopolitical and socioeconomic effects

2.1 Literature Review Part 1: Trade, Colonization and Globalization

A brief historical summary of global trade, economic and geopolitical developments, and their interactions relating to European Colonialism

2.1.1 Origins of Global Trade

When one finds that they are wanting for something, there are three things that they could do: produce it themselves, forcefully take it from someone else, or instead *trade* for it, giving one, or multiple, of their own possession in exchange. Evidence of such exchange can be found from fairly early in our history as a species, when two different communities exchanged primitive stone tools (Renfrew, Bahn, 1991). While present throughout much of our early history, local, and later international, trade has only become more and more important in our societies and everyday lives. As populations grew and civilizations continued to expand and develop in their own unique geopolitical and social contexts, greater and greater specialization produced unique and increasingly complex and valuable products (Simmons 2011). While this process occurred in all major civilizations, its interaction with the unique geopolitical and social context of each further differentiated the resources and goods produced in each locality (Mankiw 1997)

As civilizations established contact with each either via land and sea, goods and ideas were exchanged, creating demand for goods in regions that had never produced them before (Krugman and Obstefeld, 2018). If possible, with local resources, knowledge and skills, civilizations would produce these novel products themselves: if not possible, then that product would need to be sourced from outside of their own sphere of influence. Thus, all other things being equal, we would expect the establishment of trade routes between groups and geographies, both potentially creating new demand, and/or fulfilling the existing demand of others.

Even if a society had the proper circumstances to utilize specific resources or produce newly discovered goods themselves, it may not be most efficient and utilitarian deployment of the limited resources available for development. If they have a *comparative advantage* in the production of a certain good, that advantage should be pressed to secure trade for another good of interest (Ricardo, 1817). If demand for certain resources and goods is not being met, standards of living for the broader population may decline, potentially leading to social instability and change in leadership/governance (Pugel and Lindert, 2000)

2.1.2 Origins of Colonialism

The historical record most relevant to this thesis is an example of this: the often cold and damp fields of much of Europe cannot grow the pepper, cumin, cinnamon, nutmeg, and many other spices that are harvested in more tropical climates, characteristic of regions like modern day Indonesia, India and Vietnam (Turner 2005). These spices were highly sought after alongside other products such as silk, porcelain and tea, which were only produced on a meaningful scale in places like China and, once again, India, which they sold in exchange primarily for Gold, Silver and other precious minerals (Pomeranz and Topik 2017). Thus, some of the first truly global trade routes were established between these two regions as early as the 1st century BCE (UNESCO 2024)

Figure 1. Map of the trade routes primarily between Europe and Asia which constituted the "Silk Road UNESCO. (2024). *About the Silk Roads*. About the Silk Roads | Silk Roads Programme. https://en.unesco.org/silkroad/about-silk-roads

This trade between the two regions followed a path commonly known as the Silk Road, a pair of land and sea trade lanes which originated in southern and eastern Asia, spanned the central Asian steppes and Indian ocean, and reached their terminus across the Mediterranean Sea. Both of these paths present a physically arduous journey, with the sheer distances involved making such imported goods expensive and thus only realistic for wealthy Europeans to purchase (O'Rourke and Williamson, 1999). However, the exclusivity of these products only deepened when new geopolitical factors arose in modern day Turkey, taking the form of the Ottoman Empire. The supremely positioned Ottomans, at the intersection of Europe, Asia and Africa, as well as major maritime trade areas like the Black, Red and Mediterranean seas, used this positioning to effectively take control of the western end of the Silk Road (Robinson, 2010). They placed heavy taxes and religious restrictions on those trading with them, mainly Christian Europeans, constricting access to Asian goods and leaving a massive demand unfilled.

Seeking to bypass the Ottomans and supply this unfulfilled demand, the monarchs of Spain, and shortly after Portugal, commissioned voyages to investigate new routes to Asia (Nowell, 1964) The Portuguese, sailing south and east, around Africa and along the Indian ocean, established a series of trade outposts along the African and South Asian coastlines, at which ships could reprovision and load local goods for sale back in Portugal. Later, the Dutch would emanate parts of this colonial model, directly harnessing the trade of the unique and valuable goods produced near such outposts and establishing themselves alongside the Portuguese as the new middlemen of European-Asian trade, generating immense profits, much as it had for the Ottomans shortly before them (Rich and Wilson, 1967)

The Spanish followed a different approach: sailing west across the Atlantic, rather than south as the Portuguese had, Spanish sponsored expeditions discovered the two previously unknown American continents (Mann 2011). After initially establishing small missionary outposts, the discovery of gold, and large native populations which could be enslaved to provide free labor, enticed numerous settlers and *conquistadores (*conquerors) to the "New World", conquering and exploiting the lands and native populations of Central and South America.

2.1.3 The Economics of European Colonization

Extraction of minerals became the defining industry of the Spanish colonial empire, as vast mining operations were established by hand chosen governors to generate wealth for the state or by individuals seeking fortune and glory, known as the *Encomienda* system (Carrasco, 2001)). This set the precedent for the development of many European colonies in the Americas: expeditions, sanctioned and funded by European monarchs and crewed by individuals acting in their service, claim and begin exerting control over large territories. These territories would then be granted to individual stakeholders who had proven loyal and effective to the given monarchy, who would continue to conduct profitable farming or mining operations, generating wealth for themselves and their royal patrons through taxes. (Jackson, 1962) The provided financial and status incentives for more individuals to migrate to colonies in the Americas, assisting in their development.

The mines especially proved incredibly productive under the inhumane methods employed by the individual Spanish on the enslaved natives, and the Spanish Crown soon found itself as the wealthiest, and most powerful, state in Europe, with a GDP roughly 40% higher than other European states by 1600 (Charotti et al, 2022)

This wealth, held in gold and silver, not only allowed for direct purchases and investments within the Spanish empire, but also facilitated trade with China, then world's largest economy and, as established previously, a major producer of sought after goods such as Tea, Porcelain and Silk (Pomeranz and Topic 2017). Previously, there had been few European goods that were demanded in China: Silver proved to be the only good that Europeans could offer in exchange for Chinese goods. Spain, holding silver resources dwarfing other European powers, became a main European broker of trade with China (Lach 1942)

2.1.4 Expansion of Colonial Actors

Hearing of a new continent ripe with great riches and territory unclaimed by other nation states, other European monarchs, chiefly the English and French, also set out colonial expeditions to the Americas, their primary claims encompassing large swaths of the eastern coast of North America and multiple islands in the Caribbean (Canny 1998). While the geographic reach of the English and French empires spanned to an extent comparable to the Spanish empire, the economic and political organization of the other European Empires were radically different, not only to the Spanish but to each other. The French presence, in what is now southeast Canada, was predominantly reliant on the trapping of furs and trade with local native Americans (Eccles 1990). The British presence in what is now the east coast of the United States, was further differentiated. The southern colonies of British North America, also settled by individuals seeking wealth, developed as large-scale agricultural operations to harvest high revenue crops, also known as *cash crops*, such as tobacco, cotton, sugar and rice (Dunn 1972), while the northern colonies, settled by Puritan religious refugees, developed around maritime trade and resources, such as shipbuilding and trade with England, whaling and fishing (O Grada 2018). These cultural factors would prove important in the later development of these two subregions of British North America. Ship building and timber harvesting, significant industries in New England, may have proven to be among the most important elements in this context. The construction of maritime infrastructure, such as ports, as well as the improved supply of inputs, primarily timber, required for shipbuilding and maritime trade enabled further exploration, development and trade in colonial territories *(*Dunn 1981*)*. Indeed, it was advancements in shipbuilding, such as the Portuguese *caravel* design, in navigational tools such as the magnetic compass, astrolabe and cross/back-staff instruments, and other maritime developments that enabled European colonization in the first place (Elliot 2006).

While the colonial systems of each European power were unique in their primary methods of wealth generation, they were alike in that the vast majority of the wealth and resources gathered in the colonies did not remain there, and were instead exported back to their respective European capitals (Rich and WIlson, 1967). Colonizing states would in turn ship finished products back to the colonies, which locals were forced to purchase exclusively from their imperial state at a fixed price, ensuring that all profits from the production and sale of a product remained within the closed economy of their respective empire. This system is known as *mercantilism*, which remained in place till the beginning of the end of the imperialist system in the 20th century (Mathias and Postan, 1978). Mercantilism was immensely profitable, growing to be an increasingly significant part of imperial European economies: in the 16th century, trade accounted for only 5-10% of European GDP. By the 19th, this would be at least 20-30% for the main imperial actors like Britain, France and Germany (Guillaume et al, 2021). This was further expedited by rapid population growth as young families and European immigrants took advantage of the abundance of productive land and opportunity in the new world. (Taylor 2001). The larger, more robust workforce would assist in the further development of colonial economies and industries. These outcomes are most applicable to more diversified colonial economies, like Britain's, rather than the trade/extractivist dominated mercantilist systems of the Spanish, Portuguese and Dutch.

2.1.5 Allocation of Colonial Incomes

The immense wealth of the mercantilist system was spent in a number of ways, chief among them in defense: vast new colonial holdings in the Americas and later in Africa and Asia require not just investment in land-based security assets to exert imperial influence over locals, but also (potentially) even more expensive naval assets to patrol and protect the maritime connections that connect these holdings to their European capitals (Ferguson 2004). While piracy was a very real concern, these investments were made primarily to deter interference from *other* European states, seeking to enhance their own influence both on the continent and beyond by disrupting their rival's lucrative trade with their colonies. Security spending rose to constitute a steady 5-10% of GDP for major European empires, much higher than the current global average of 2.2% (Kennedy, 1987; SPRI, 2023)

Such spending was not without warrant, as the 7 Years War would exhibit. This conflict originated in Europe, as France and Austria signed an alliance, which disrupted the balance of power on the continent and left Britain isolated from the mainland. To maintain its influence, Britain in turn allied with Prussia, a young but rising power, yet did little of the fighting on the actual European continent (Anderson, 2001). Instead, almost all conflict Britain engaged in was with France in overseas territories they both had interest in, such as:

- North America, where the conflict was known as the "French and Indian War"
- India, where the East India companies of both empires vied for favor with local groups and tried to muscle each other out of important markets
- and on the seas themselves, as the global naval leaders at the time

Britain emerged victorious in all theatres as the worlds leading naval power, allowing it to project influence and control important economic assets around the world, as well as consolidate control in important regions such as India, but not unscathed. The war had considerably expanded Britain's Debt, inducing Parliament to place greater taxes on some of their American colonial subjects, beginning the chain of events that would spark the American Revolution (Land and Eloranta, 2011)

Although defense constituted a major portion of new investment, even a smaller proportion of such a huge sum of money was a massive increase in available funds for other purposes. Generally, reinvestment in other colonial ventures was prioritized and would grow this wealth further, which would be facilitated by new financial instruments and institutions that were created to manage and administer the expanding and increasingly complex trade between European states, their colonies and other actors (Ferguson 2008). Such institutions directed other investments in an array of economic and social development projects like infrastructure. Finally, a significant portion of imperial wealth was spent directly by the elite class of rulers and settlers, on either luxury goods, or prestige projects such as sponsorship of the arts and culture, as well as scientific advancements (Landes 1998).

While only a small portion of the total wealth was diverted toward investment in scientific advancement, in conjunction with the financial capacity created to prudently manage wealth and investments, would bring about the next stage of global socio-economic and technological transition, The Industrial Revolution, which will be covered in the second to next section.

2.1.5.1 Mismanagement of Wealth: The Spanish Example

The key in this cliffhanger is “prudently”. Just as physical forces like earthquakes and floods can be strong enough to damage many anthropological systems, economic forces may prove equally impactful, if not more so (Skidmore and Toya, 2002). This may be more evident in modern societies more strongly influenced by more abstract factors like economics and politics, but still rang true even during a time before capitalism and digitalization. This was certainly the case with how the Spanish crown mismanaged the incredible wealth it was acquiring from its American colonies.

Spain during the late 16th and early 17th century was pulling in incredible quantities of gold and silver from its mines in the Americas. While atleast 1/3 was being used in trade in China, the rest was converted into currency within the Spanish and wider European market (Maltby, 2009). This dramatically increased the supply of currency in circulation, while the amount of consumer goods available or produced within its own economy remained constant. Thus, a greater quantity of currency was distributed among a lower supply of goods, increasing the per unit cost of many of said consumer goods, driving inflation. Wages were not high enough to adjust for this, and thus standards of living declined among the Spanish working class.

This was a result of poor monetary policy (control of the currency), but was only exacerbated by poor fiscal policy (the spending of financial resources): instead of investing in domestic industry to produce more consumer goods, additional wealth was spent on financing wars, further straining domestic industry, and importing luxury goods from abroad, again neglecting domestic industry and tilting positive trade balance away from Spain. This combed to disrupt the success of their mercantile system and gradually eroding Spain’s dominant position in Europe and the world (Hamilton, 1934)

2.1.6 The Industrial Revolution

The Industrial Revolution (IR) ignited with the invention of the steam engine, which allowed for the application of powered, mechanical force to greatly increase the output of many production processes by an average of 5% *a year* between 1810 and 1860 (Bouscasse et al, 2024). Initially beginning in England, the steam engine burned coal to power the pumps keeping coal mines dry and operational (Hobsbawm 1962). This drove down the cost of mining coal, and thus made operating the steam engine itself cheaper, creating a positive, reinforcing feedback loop. Soon, the engine was adapted to other industries, such as textiles, where steam engines were used to power massive mechanical looms, the first example of the employment of industrial machinery not just to make resource extraction more efficient, but also manufacturing more efficient as well (Strandh 2000). Even as the mechanical technologies matured, they were still an expensive, specialized investment, able to be financed in large part by capital and financial institutions created by the colonial system (Allen 2009).

Mechanized production of finished goods such as textiles resulted in far greater quantities of goods being produced, which in turn drove down the per unit cost of production orders of magnitude lower than the previous small scale, largely artisanal production that had defined local economies for most of human history (Floud and Johnson 2004). This is a broader economic concept called *economies of scale*, which dictates that the per unit cost of production falls as production capacity increases (Mankiw 2018). This incentivized the further mechanization of other industries, such as which also increased the demand, and thus production capacity, for the machinery itself, introducing economies of scale to this sector as well, driving down the cost of further mechanization, creating yet another positive feedback loop.

Employing so many machines that required fossil fuels introduced an entirely new global commodity, energy (Broadberru and O'Rourke, 2010). Like some foodstuffs such as grain or ore, fossil fuels provided a mobile and dense energy source which could be sourced and transported to and from the wider world. This helped diversify the global commodity market and expanded opportunities for capital generation for geographies that may have lacked the agricultural or mineral resources for sustainable, self-driven development (Acemoglu and Robinson, 2012). Additionally, industrialization provided both the necessity and capital required for the construction of expansive, modern infrastructure (Hobsbawm 1975). With industrial production demanding vast amounts of raw materials to be shipped in from potentially hundreds of kilometers away, rail lines, ports and roads were constructed and expanded, leading to greater connectivity and economic growth through lower transportation costs (Floud and McCloskey 1981). This same infrastructure, used to ship in raw materials, would also be employed to ship *out* the finished products and goods back to consumers, improving the overall efficiency and return on investment of transport infrastructure projects. This effect would later be amplified by the international standardization of some trade tools, such as cargo containers.

2.1.6.1 Socioeconomic Impacts of the Industrial Revolution

Since machines were doing most of the work required to create a finished product, 1. The productivity of an individual worker skyrocketed and 2. The skill required by the workers to achieve this productivity plummeted (Floud and Johnson 2004).The widespread adoption of industrial, mechanized production effectively destroyed the previous, more rural, individual focused artisanal economic system which was in place the world over with a more urban, unskilled and unequal socioeconomic structure.

Hastened urbanization would lead to further social effects including to public health. Densely populated and more confined living spaces became vectors for disease, many of which, such as Tuberculosis, were made even more contagious as the air choked with soot degraded respiratory health and immune systems (Hobsbawm 1975). Healthcare and public infrastructure adapted to be able to accommodate this rapid rise of people and patients: healthcare by becoming more centralized and reliant on public sanitation systems, and the public infrastructure by expanding said sanitation facilities. In fact, just as investments in transportation infrastructure has excellent economic and social returns, investment in other public infrastructure and services such as water, power, healthcare, transportation, education and housing had even high social impact and economic benefits (Pomeranz 2001). This would lead to the first social welfare systems.

2.1.6.2 Industrialization Accelerating Colonization

Since mechanized production was ramping up across almost every industry, iterative improvements were being made to the designs of machinery and methods of production as well, providing new technological improvements, which reduced costs yet again and would continue to be built upon in the future (Floud and Johnson 2004). This process would be applied to transportation as well, not just production itself: month-long journeys across the vast oceans on ships harnessing the wind were replaced by steam powered voyages that only took weeks (Stearns 2019). Multi-month overland journeys with horse and wagon would eventually be replaced by train, and later automobiles, which, while requiring expensive and difficult to construct infrastructure like rails and roads, also greatly increase the cargo capacity of these methods, which also applies to maritime transportation. With mechanized transportation, cargo capacity and speed increased and cost per unit/distance decreased dramatically, allowing for the much more effective application of capital over long distances, greatly increasing the reach of industrialized European influence around the world, further accelerating colonization (Ferguson 2004).

Not only did industrialization provide tools useful in accelerating imperialism, it further directly incentivized it as well. The accelerated rate of technological advancement spurred new inventions and products, many of which would garner significant market demand both at home and abroad. Much like how access to trade was a driving force behind European states embarking on colonial expeditions in the 15th century, the technological and market evolutions brought about by the IR created both demand for new resources like rubber and cotton, as well as new markets to sell finished products to (Broadberry and O'Rourke 2010). The markets of continental European states were only so large, and to avoid "wasting" the capital invested in and the operating costs of industrial production, new markets needed to be secured (Hobson 1902). This was done either through direct conquest, as in further forceful integration of many African and Asian regions like Kenya and India by the British, or more indirect interference in large markets like China by all western/industrialized states.

2.1.7 Emerging Globalization

Imperial European states came to be among the most belligerent actors in the world during the imperial periods, with the United States and Japan proving to be notable exceptions. As global trade became increasingly important, the likelihood of serious competition between now industrialized states became more likely and more dangerous, as conflicts such as the Crimean war and World War One would show. It was still the norm to deploy force to gain access to or outright annex the resources and markets required to maintain consistent economic growth and political stability among industrialized societies.

This would culminate in the Second World War, focused around two main theatres: the European and Mediterranean, and the Pacific. In the west, European democracies such as Britain, France, and the Netherlands, supported by their colonial empires, alongside the United States and Soviet Union, were locked in savage combat against Germany and Italy, which claimed tens of millions of lives (primarily Soviet and German) and left the European continent in ruins In the east, the United States and Chinese groups such as the Communists and the Nationalists (Kuomintang) were the primary combatants opposing the rapid, brutal Japanese expansion, which produced results much like in the European theatre

2.1.7.1 The End of Classical Imperialism

With much of the world reduced to rubble, two superpowers, the United States (US) and Russian-dominated Soviet Union (USSR) emerged, champions of diametrically opposed world views, the former advancing a democratic, capitalist model and the latter a authoritarian, socialist one. The “Cold War” as it would come to be known, featured extreme geopolitical tensions and frequent hybrid warfare (unarmed interstate conflict) between the US and USSR, with both superpowers investing heavily in military and technological capabilities to defend themselves and their allies and undermine the others influence. Both, however, supported the end of imperialism, which occurred over the next half century, aided by hollowing out of imperial navies and economies following the war, and political pressure from the aforementioned superpowers (Lapping, 1985). This led to the creation of many modern nation states, primarily in Africa and Asia, which had declared independence from their previous colonial rulers.

The end of the imperial, mercantilist system, in combination with the safety guarantee of international transport provided by the now monolithic US navy, led to the reopening of global trade, swiftly recovering to and even surpassing pre-war levels (IMF, 2023). There were still some limitations, primarily political ones as these now independent states aligned themselves with either the American and Soviet Spheres, or completely refrained from doing so. However, global trade was no longer largely confined within the military and political boundaries of western empires. It didn't need to be: the resources required for industrialized development could simply be purchased on a single, commodified global market (Ravenhill, 2005). This market would only expand and become more active following the end of the Cold War in the 1990's with the collapse of the Soviet Union, along with its economy and geopolitical influence. At last, this brings us to the modern day.

Figure 2. Global trade during various periods of the 19th, 20th and 21th century (IMF, 2023)

2.2 The Modern Geopolitical and Economic Context

2.2.1 Modern Globalization

No longer were the Americans and Russians, up till then the world's two largest economies, at each other's throats, at least for a time after 1991. With the threat of an armed military confrontation with a peer adversary gone, states the world over jumped on the opportunity to divert the huge sums of funding that had previously been dedicated to defense towards socio-economic development, a phenomenon known as the *peace dividend* (Kegley 1992). Many states, if not entire regions, previously off limits due to the geopolitical contention of the Cold War, were now open for Foreign Direct Investment (FDI) in a number of economic sectors, such as resource extraction, agriculture, manufacturing and the service economy. Combine new, largely untapped and relatively undeveloped markets and resource with a glut of additional capital seeking returns and the world stage was set for the transition to a truly globalized economy.

Just as population growth in earlier human history allowed for specialization, this new wave of globalization has done the same: the large, low cost workforces of many still developing regions such as Latin America, African and Asia were much more competitive in labor intensive, low-mid skilled sectors, such as manufacturing and services: to capture this operational edge, many western companies initially invested heavily in establishing production and further operations in these regions in a trend known as *outsourcing* (Milberg and Winkler 2013). The entire economies of some states, such as China, India and Mexico became almost completely reliant on global trade of manufactured goods (Stiglitz 2002). Others states became reliant on global trade to acquire or export important commodities: much of the European Union, poor in local energy supplies, became reliant on fossil fuels piped in from Russia, and many developing countries saw a considerable portion of their food supply originate overseas (Baylis et al, 2017). However, while such industries grew in these low-cost labor markets, they would shrink in markets that were now less competitive, like manufacturing in the high-cost labor market of the United States, leading to the loss of once reliable and certain jobs and the decline of the communities that had come to rely on them.

In theory, the socioeconomic benefits of foreign investment would spread even further than the investment itself, such as

- Wages and tax revenues generated by these new operations
- Additional support services and infrastructure generally developed around rapidly growing industries based on trade
- Consumption led growth, sparked by the initial capital generated by trade and maintained by the increased income of the general populations
    - This would help diversify economies and spurn greater domestic and economic growth (Stiglitz 2002). However, if states, through fiscal and monetary policy, as well as regulations, failed to adequately promote their own domestic industries, a large portion of the revenues generated through FDI would not be distributed equally, typically at the detriment of the receiving actor, capping socioeconomic growth and development (Galbraith 2012). This would leave more homogenous economies more vulnerable to potential instability in these outsized industries, increasing the risks of socioeconomic and political damage in turn.

Some industries, however, are incredibly difficult to outsource due to either their strategic significance, such as communications and energy, the sheer time, skills and capital required to build them, such heavy machinery and finance, or both, as is the case with many high tech industries such as defense and information technology (Hitch and McKean 1960). Unless a state or entrepreneur has the resources and motivation to make such investments, these industries have largely been and will likely continue to be dominated at the global level by entrenched players, many of which are largely owned, operated or supported for many decades by western actors (Baylis et al, 2017) This gives them an edge over potential new competitors on the global geopolitical and economic stage, since they are likely better financed and have an edge in built and technological capacity. Many major economic actors, such as states and corporations alike, will increasingly seek to take advantage of this edge over the next decade, as policies such as the CHIPS Act in the United States, and Western technology sanctions against potential belligerents (CNBC 2024). This is part of a broader global trend over the last decade, towards regionalization and deglobalization.

2.2.2 Enter, Deglobalization

While economics is defined by competition between actors as large as states and as small as the individual, fierce competition and increasing international wariness over closer integration has become much more palpable over the last 20 years, triggered by the financial crisis of 2008 (Philippon 2019). Much like the Great Depression of 1929, this financial crisis originated in the United States, and due to its highly connected financial system and economy, rapidly spread to other parts of the world, which were even more poorly equipped to handle an economic crisis of this magnitude (Reinhart and Rogoff 2009). Trillions of dollars were erased in the span of months, and the recovery, while varied by each fiscal department in its effectiveness, took years. The widespread unemployment, poverty, state fiscal distress and political instability that followed the world over eroded public trust in institutions at all levels, the most central of which being the one that enabled the crisis in the first place, globalization itself (Stiglitz, 2010). The seeds of doubt were sown into the free trade experiment much of the world had invested in since the end of the cold war.

The transformation of globalization as we have become familiar with over the last 3 decades following the end of the Cold War has not been entirely due to the 2008 financial crisis, at least not directly. Fears of economic instability spreading beyond national borders and affecting the broader global economy are not one sided either: many western actors and decision makers have concerns Geopolitical factors once again play a major role in this broad transition:

- A byproduct of American efforts to undermine Soviet influence during the cold war, The September 11th, 2001 attacks on the United States marked a fracture of western political stability
    - In response to the attacks was the misguided and poorly executed American invasion of Iraq in 2003, marking a decline of international trust in the US as the guarantor of global peace (Wilson Center, 2021)
- The 2008 and 2014 Russian invasions of Georgia and Ukraine, respectively brought instability and armed conflict to Europe, a region that had come to be recognized as one of the most stable and peaceful of the 21st century (Hyde-Price 2006)

- The People's Republic of China (PRC) rapid economic growth and integration with the global economy (WTO, 2021). Stemming from some of the methods employed in service of rapid short term economic growth, built upon a foundation of questionable volumes of credit and real estate investment. These problems became pronounced with the collapse of *Evergrande*, China's second largest real estate firm.

2.2.3 A New Cold War

The renewal of "peer" interstate competition marks an uncertain transition back to historical trends of exerting influence on the world stage. The policy of mutually assured destruction still remains in place and has prevented direct military conflict between major powers. The Cold War style of interstate competition has reemerged, again defined by ideological differences, diplomatic and economic competition and military buildup (Koenig 2020). The world is once again dividing into competing spheres of influence, oriented around similar structures as they had been during the cold war of the second half of the 20th century: the democratic Western, American and European centric bloc, the authoritarian Russian and Chinese centric bloc, and more independent states, once again including India? And others such as the Association of Southeast Asian Nations (ASEAN) (Allison, 2017). Under the renewed intensity of hybrid warfare, every major economic sector, as well as social dynamics of different states, are all in play.

2.2.3.1 Broader Economic costs of Global Instability

The diversity and scale of resources and markets for goods has only grown with the complexity of modern, industrialized societies. The rapid growth of the world's population has further increased demand for everything from food, water, energy, housing and consumer goods of all stripes (Population Media Center, 2024). This increased demand needs to be secured, however if it is sourced from a potentially unreliable trade partner, then important domestic industries may be disrupted following external instabilities. Such followed in the wake of the continuation of the Russian invasion of Ukraine: in response to renewed Russian aggression against Ukraine in 2022, European states supported Ukraine and placed stiff economic and political sanctions on Russia (CSIS, 2022). In retaliation, Russia cut off fossil fuel supplies to much of Europe, driving up energy prices and leading to political pressure to either acquire new energy supplies or ease support for Ukraine. Market effects on energy prices and economic activity in Europe did not remain confined to the continent, either: new energy supplies were secured, diverted from other markets, which suffered in turn. Exports of grain, another major commodity affected by the conflict, were greatly reduced as well, which drove up global grain prices and most adversely affected lower income states (UN Press, 2022).

Spillover effects from regional instability are not limited to the production of strategically important resources, however: the routes of trade themselves are vulnerable as well, which can have similar, if not greater widespread effects. Activities of Houthi rebels in Yemen, in response to the 2023 Israel-Hamas war have threatened global trade routes running through the Red Sea and later Suez Canal, the main trade conduit between Europe and Asia. This has redirected maritime trade back to the historical route which connects these two regions, around the horn of Africa, adding thousands of kilometers of additional travel and increasing costs by up to 50% on some particular routes (Arab Center Washington DC, 2024). This, at a time when consumer demand has exploded following the end of the Covid-19 pandemic, which had already frayed supply chains.

Additionally, the recent and continued acceleration of the renewable energy and digital transitions have exploded previously restrained demand for materials such as lithium and rare earth metals, which are concentrated in specific, potentially unstable and unreliable locations, such as China and the Democratic Republic of the Congo (DRC). (Vekasi, 2023). To maintain and increase flows of these vital materials, while reducing risk of external instability impact domestic socio-economic health, mainly Western states that may have uncertain relationships with either China or the DRC are seeking to expand their own supplies, by both investing in their own production, or establishing new relationships and agreements with other countries that may have these resources (European Commission, 2024).

This exposes the supply chains of these commodities to both local and international geopolitical risks, therefore increasing the risk associated with a rapidly growing strategically important industry. Total violence around the world, not including other forms of socio-economic and geopolitical instability, now spans across 92 countries, $19.1 trillion of lost economic activity, and “poses a significant supply chain risk for governments and businesses” according to the 2024 Global Peace Index (visionofhumanity.org, 2024)

All of these factors and events, of increased demand for strategically important resources, combined with increased interstate competition and geopolitical tensions that have incentivized isolating one's own economic and political system from increasingly global risks, have driven a trend of deglobalization, a reversal of the "process of international integration arising from the interchange of world views, products, ideas, and other aspects of culture" (Steger & James, 2009, p. 2).

3.1 Literature Review Part 2: The History and Development of the Space Sector

The section of the literature review pertaining to the space sector will begin with a brief history of space exploration. This is relevant and important, as it puts into context the socioeconomic and geopolitical conditions that accompanied specific advances in space exploration and potentially space utilization. Along this vein, the contemporary space sector will also be evaluated and summarized. At the end, common trends will be identified and reviewed alongside common themes from the other sections of the literature review in the Scenario analysis section.

This part of the literature review will include a brief timeline of major astronomical developments and practical applications of space exploration, framed by a summary of the defining actors, and socioeconomic and geopolitical context of each advance.

3.1.1 Early Mankind and the Night Sky

Our species and others like it gazed upon the star millennia ago, seeing a sparkly tapestry of softly glowing lights scattered across the night sky. The history of space, albeit but a minute part of it, is also our own. Records of ancient astronomy, believed to be an ancient star chart on a cave wall in France, range back to at least 17,000 BCE (Rappengluck, 2004)

3.1.2 Early Civilizations

After the neolithic revolution, agriculture let to urbanization, organization and specialization, further developing scientific and observational capacity. Some of the earliest civilizations used more detailed observations of the earth and other cosmic bodies to better understand their own world such as the Babylonians and Ancient Greeks (Tymienecka, 2011). However, practical applications of this knowledge was limited, mainly used in navigation and with partial reliability. The exchange of information and trade was also largely limited, confined to the shores of the Mediterranean sea. Finally, technological limitations prevented the taking of more precise observations. Further astronomic discovery would be marginal until later periods

3.1.3 Pre-Renaissance Contributions:

3.1.3.1 Rome

The Roman state lasted centuries as one of, if not the most influential states of its time. Taking advantage of innovations in military tactics and weaponry, logistical and engineering prowess and an effective, stable government, Rome consolidated direct control of much of southern and central Europe, as well as the African and Asian coastlines along the Mediterranean Sea (Garnsey and Saller, 1987). Roman additions to the astronomic base of knowledge were limited, with the most notable being reform to the more consistent Julian Calendar and further refinement of the astrolabe (Suetonius, 121).

Yet, despite the staggering concentration of wealth and power than had been accrued in Rome, few major astronomical discoveries were made.

3.1.3.2 Arabic Contributions

Many Arabic civilizations have had a greater recorded impact on the development of astronomy than their Roman contemporaries, exhibiting their strength and/or priorities given many Arabic caliphates-controlled wealth and territory comparable to Rome. Various regions within the Middle East have historically epitomized scientific knowledge and discovery, such as the House of Wisdom in Baghdad and Maragheh Observatory in Persia (modern day Iran) were invaluable tools for observing celestial bodies and their orbits. (Saliba, 1994)) Other such centers of discovery hosted the had also calculated the observed trajectories using pioneering mathematical techniques (King, 1999). While the resources and results associated with these discoveries is impressive in their own right, the most relevant advancement to this thesis were now well familiar navigational tools, the Astrolabe and Backstaff (MMA, 2011)

3.1.4 Renaissance and Early Colonialism

Much like how European colonialism was triggered by the rise of the Ottomans in Anatolia and the Balkans, the Renaissance was birthed of the same event, which sent a large repository of Greek texts and observations westward to Italy (Burckhardt, 1990). In this period, the Italian city states rose to prominence as the major trade and finance centers of Europe, largely as a result of the inflated prices of many imported goods like spices.

Banking, an industry that would naturally arise in major ports and centers of trade even before inflated profits filled its coffers, would also act as an important measure of securing wealth and projecting influence through loans and other means (Strathem, 2003). With an abundance of raw financial resources, and instruments in place to prudently manage it, these merchant families sought to build prestige through patronage of the arts and sciences. Many of the most famous classic painters, architects and thinkers in history, Galileo, Da Vinci, and Michelangelo, were all sponsored by merchant families, along with development in other fields such as chemistry, biology and astronomy which would usher in the Scientific Revolution (Kuhn, 1962). This would set the roots of the scientific process taught in classrooms and practiced in research and daily applications the world over today.

Navigational tools like the Astrolabe and Backstaff further evolved, and along with the seafaring expertise of many Italian traders, would become vital inputs in the first efforts of European colonization. Other game changing technologies, such as more advanced optics and time keeping would be vital in expanding our ability to study our solar system and our place in it with greater precision and accuracy (Landes, 1983). Promising new thinkers like Galileo, Copernicus, and Kepler, the latter two hailing from beyond the Italian city states, would apply these clearer observations in novel perceptions of the solar system that more accurately reflected reality.

- The Heliocentric model of the solar system, advocated for by Copernicus:
- Further refined to include elliptical rather than perfectly round orbits of celestial bodies like planets and moons described by Kepler’s Law of Planetary Motion
- And the visual discovery of distant planetary bodies, such as Jupiter's Moons and Saturn's rings, by Galileo.

3.1.5 Early Colonialism

The broader geopolitical and economic context of this period has already been discussed in prior sections, so focus will instead go to the relevant circumstance of major advances in astronomy and space exploration.

- The scale of the solar system became easier to measure and define as a new standard unit, the astronomical unit (au), which is the distance of the earth from the sun, began to be adopted by the astronomical community. This was achieved following multiple observations of Venus’ transit across the sun in the 17th and 18th century (Encranz, 1992)
- John Hadley’s refinement and practicality of tools such as reflecting telescopes and the octant the precursor to the widely employed sextant, a navigational aid (Howse, 1973)
- Most famously, Isaac Newton proposed the laws of gravity and the laws of motion which would become the foundation of physics and classical mechanics

3.1.6 Industrial Imperialism:

The immense wealth generated by European imperialism in the Americas and elsewhere in the world also provided the other precursor of the Industrial Revolution, a capital-intensive transition which had major socio-economic and geopolitical impacts on all regions and peoples around the world.

The Scientific Revolution, sparked near the end of the Renaissance and fanned by the initial influx of capital from the first wave of European colonialism, would roar to life, doused by the unprecedented generation of capital and\ from late stage colonialism and the Industrial Revolution, rapidly building on the strong foundation of scientific thought provided by earlier eras (Henry, 2002).

While geopolitical tensions were high during this period, with multiple military conflicts fought on the European continent alone, there was a considerable degree of scientific cooperation as both physics and astronomy exploded with new discoveries and theories throughout the 19th and early 20th centuries. German-born Albert Einstein's theory of relativity was proposed at this time, and validated in 1919 by astronomical observations taken by an Englishman, Arthur Eddington (BBC 2019). Other notable scientists like Niels Bohr, Micheal Faraday, and James Clark Maxwell would all make significant discoveries in fields such as electromagnetism, atomic and astronomical physics, setting up later innovations, as well as generate more interest in research. Heightened interest in these fields, manifested as both cooperation and competition, spread quickly in a world now highly connected by self-powered transportation and instantaneous communication like telegraph, telephone and radio.

Alongside instances of cooperation between scientists from sometimes mutually distrustful states also came competition. This would be the prevailing sentiment of much of the first half of the 20th century, when science was primarily employed to achieve a military and strategic edge over rivals (Brown, 2002). The same scientists, who had respected and collaborated with each other, often found themselves forced to take sides, most clearly exhibited by the race to the Atomic Bomb. Major innovations that began in this period such as electricity, powered flight, rudimentary computing and a plethora of other technologies, would be the first steps in a more active space presence, igniting the Space Race of the Cold War only a few decades after these innovations first appeared.

3.1.7 Cold War and the Extraterrestrial Presence, 1944-1991:

On June 20, 1944, a German V2 rocket, initially designed and utilized as a guided combat munition for use against Allied cities, became the first ever object to reach sufficient velocity to pass the Karman Line, the demarcation between earth and space at 100 km above sea level (USAF, 1990). While technically occurring before the beginning of the “Cold War”, a period of extreme geopolitical and socioeconomic tensions between the United States (U.S) and Soviet Union (U.S.S.R), this launch marked a vital step towards the start of the Space Race, a key sub-theater of this new geopolitical reality. Much like the launch itself, the Allies efforts to build their own orbit rocket and missile capacities also started before the end of active combat in Europe. British, French and American intelligence and scientific agencies sought to bring as many former Nazi aerospace scientists and engineers under their banner before the Soviets could do the same, thus initiating Operation Paperclip (NASM, 2023). Both Western and Soviet efforts were successful, with each rapidly developing their own rocketry capabilities shortly after.

These capabilities initially followed a strictly security-oriented utility. Rapid, iterative design produced ever more capable ballistic missiles, each with greater range and payload, as well as more difficult to intercept, than the last. The first non-defense related use of a space-capable missiles to achieve orbit, the launch of the *Sputnik* satellite in 1957, mounted atop an intercontinental ballistic missile (ICBM) primarily designed to counter potential western aggression (Harford, 1997). Initially bearing only conventional explosive warheads, the same missiles and later iterations would be adapted to carry nuclear payloads, thus establishing a key component of the *Nuclear Triad*, a military strategy consisting of three main strategic nuclear delivery systems: strategic bombers and, nuclear submarines, and ICBM’s (USDoD, 2010). This military capability is itself part of a wider global geopolitical doctrine that had developed between nuclear armed states. In this doctrine, any state that had developed the capability to reliably pose an unacceptable nuclear risk to any potential aggressor, even if it were itself to be attacked, would have an effective nuclear deterrent (Kaplan, 1993), establishing an outcome of the total, Mutually Assured Destruction (MAD) of the belligerent parties. This policy would carry over into outer space, as treaties prohibiting the deployment of nuclear weapons in space were signed between the main spacefaring actors at the time (UN Office for Disarmament Affairs)

While the bulk of space related budgets was allocated towards defense and prestige projects, considerable efforts and investments were made toward scientific discovery, even if also in service of interstate competition: probes on Mars, the Voyager missions, telescopes. Indeed, the Soviet Space Station "Mir", culminating in the International Space Station (ISS), post-cold war decades long, multibillion dollar and multinational collaboration of space infrastructure and research (Launius, 2003). More advanced telescopes like Hubble and James Webb gave us a broader and clearer picture of the universe and its history. Humanity's collective knowledge of the cosmos and our solar system expanded swiftly, generating new questions and limits to test.

As the tensions between the United States and Soviet Union receded following the collapse of the latter, and many of the confines of the political spheres which had divided the world for nearly 50 years dissolved as well. While demand for space launches wanned in the years immediately following the end of the Cold War due to fewer defense related missions and budget cuts (NASA, 2024), the built launch capacity of multiple actors still largely remained in place. There was a large workforce of highly skilled and trained technicians, engineers, physicists, programmers, etc, many of whom would find work in other public projects, or, most likely, the private sector (UNOOSA, 2023)

The shift towards cooperation in space, rather than competition, would also prove vital for the continued and healthy operations of remaining space actors, chiefly western government space agencies and Russia's *Roscosmos*. Joint programs such as the International Space Station (ISS) would put this built capacity to use once again, establishing a permanent human presence in space, and generating countless benefits for humanity as a result of the research being conducted in orbit (NASA, 2024). A peaceful and steady space environment also allowed a myriad of new actors, both public and private, to establish assets in space, with a nearly tenfold increase in the number of nationalities in space since 1991. (UNOOSA Online Index of Objects Launched into Outer Space).

3.2 Modern Space Sector, Status Quo

This section will observe the status quo of the broader contemporary geopolitical and socioeconomic context of the space sector. Also included will be a brief summary of major developments in a number of industries that have been involved in the space sector, or are likely to become (further) involved.

3.2.1 Launchers

Most launchers, just as they were at the beginning of our forays into space, are requisitioned ICBMs. Such systems were in high demand during the cold war, and thus there was sufficient political will and industrial capital on either side of the Iron Curtain to manufacture them on an economically feasible scale, with both the US and USSR making thousands (USAF, 2024). However, launch costs were still high relative to their modern launch counterparts: launch costs of the Soviet R7 series, and many of the rocket families used by the United States over the last 75 years have averaged around 17,900$(FY21) and 30,000$(FY21) per kilogram (Aerospace Security, CSIS 2022). Fuel for the launcher, itself a component of the first stage of a launcher make up the majority of these costs: it is this first stage of the launch vehicle that SpaceX targeted specifically to drastically reduce launch costs to around $2,000/kg in orbit (SpaceX, 2024) The entire launcher industry is estimated at nearly $15 billion in 2023, according to Grand View Research and is expected to double by 2032 (Grand View Research 2023).

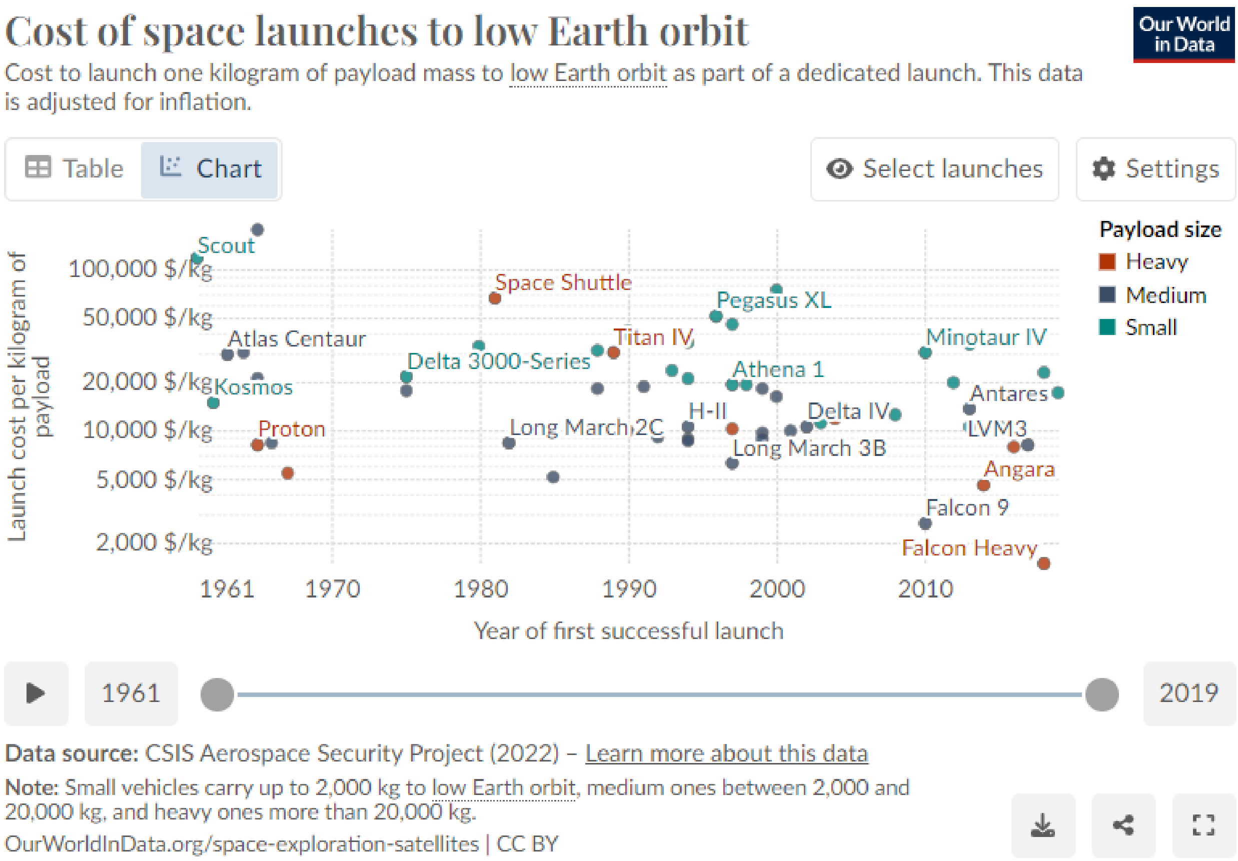

Figure 3. Launch cost per kg to LEO by launch system

Cost of space launches to low Earth Orbit. Our World in Data. (2022). https://ourworldindata.org/grapher/cost-space-launches-low-earth-orbit

3.2.2 A Moment in History

At 8:29pm on December 21st, 2015, a Falcon 9 v1.2 rocket launched from Cape Canaveral, Florida, the space complex that has been the home base of United State space launches for over half a century (SpaceNews, 2015; NASA, 2024). What was remarkable about this flight, however, was made evident when the 1st stage of the rocket set itself gently back down at the same launch complex it had lifted off from not even 15 minutes earlier. For the first time in the history of rocketry, the first stage of a rocket had safely landed back on earth after deploying a payload into earth orbit, marking a literal turning point in the space transition.

While the launch and successful recovery of the Falcon 9's first stage was a technological marvel, the socioeconomic impact it has had in the time since, and will continue to have well into the future, will likely dwarf memory of this event as a merely a feat of engineering. This launch and recovery demonstrated that it was indeed possible to *reuse* the first stage of a rocket, a feat many had hitherto viewed with scepticism, particularly after two failures of the Space Shuttle program resulted in the loss of 14 crew members in total (NASA Columbia, Challenger, 2024).

Other parts of the entire system of a launch vehicle had been refused before, as in the 5 Space Shuttles, yet these are not the most expensive components of the launch system: while different launch systems may have varying expenses, the first stage alone is usually around half the of the cost of the launch, if not a majority of the costs (SpaceNews, 2016). Thus, being able to recover and reuse the 1st stage considerably reduces the cost of each launch, becoming cheaper each time the 1st stage is successfully reused. This has led to the Falcon 9 eventually cutting the cost to launch one kilogram of payload mass to low Earth orbit to half of the next cheapest non-SpaceX system, and atleast 5x-10x cheaper than many other launch systems throughout the history of aeronautics, according to Our World in Data (Our World in Data 2024). The fall of the cost of launching into orbit is expected to continue as SpaceX, still commanding a staggering share of the launch market, and other emerging reusable rocketry firms achieve greater economies of scale

3.2.3 The SpaceX Edge

The prolific rise of SpaceX to domination of the space launch sector cannot be overstated. Founded in 2002 by Elon Musk, this disruptive aerospace firm angled to decrease the incredibly high launch costs of conventional space launch systems by making them reusable. They moved quickly in the RnD process, with their first, albeit unsuccessful, launch in 2006, followed by their first successful orbital flight in 2008 and the 2015 launch and recovery (nasaspaceflight.com, 2008). Commercial success was built on a number of factors and innovations:

a. SpaceX captured over 80% of the entire commercial launch market in 2024, almost completely displacing established market players like the United Launch Alliance (ULA), a joint venture between Lockheed Martin and Boeing, and Ariane space, a collaboration of a number of states in the European Union. Not only did the novel technology of rocket reusability make SpaceX more competitive, but as did its business model of producing nearly all components and services of each launch in house, which reduced costs by removing the subcontractors which had often inflated the final costs of previous privately operated space launch missions (Sharma, 2018).

b. Additionally, since the first stage of the Falcon 9 could be reused, and the procedure to do so was streamlined with repetition and scale, SpaceX was able to increase launch capacity while maintaining a smaller number of rockets (Spaceflight Now, 2024).

This additional launch supply would at times be unmatched by demand, so to increase the down time of the rockets, SpaceX itself created additional demand, by becoming a broadband satellite internet provider (ISP). Offering extensive coverage of the earth at an economic scale enabled by yet another novel approach in the space sector, the launch of hundreds of smaller satellites in a constellation providing broadband internet service for earth, Starlink (SpaceX, 2021).

Constellations themselves are not new ideas: the Americans and Soviets had employed them in navigation and communications systems as early as 1964, which would eventually evolve into the modern Global Positioning System (GPS) makes instant position and accurate navigation possible (US Space Force, 2022). Previous navigation, imaging and communications constellations, however, are tiny in comparison to the projected total of satellites in the completed Starlink constellation. While the median size of prior constellations geared around geopositioning and communications is 24 satellites, they will be dwarfed by the thousands, if not tens of thousands, of much smaller satellites that are expected to comprise many next generation constellations, all of which will be broadband internet service providers (OneWeb, 2023).

c. Finally, these business and design decisions are augmented by a degree of flexibility other established launch service providers largely lack, yielded by the reliable operation of multiple launch capabilities. Firms such as ULA and Ariane space, previously servicing two of the largest markets in the United States and Europe, provided relatively rigid launch capabilities catered to the medium-heavy launch market (2000kg-20,000kg for medium, 20,000+ kg for heavy launches) This range of launch weights accounts for at least 70% of all of their launches collectively (NSF, 2024). However, in a broader launch market that is becoming increasingly reliant on smaller launches, with a total mass less than 2,000 kg, a lack of a cost effective and reliable launch vehicle has been a driving factor behind the market decline of established launch platforms such as those provided by ULA, ArianeSpace and Roscosmos, Russia's state-owned corporation for space activities (Grandview Research, 2023). Additional firms such as Rocket Lab and Blue origin have been founded to further target niches in the small lift launch market, the latter of which “appears” to emulate the hybrid launch system and ISP model pioneered by SpaceX by providing its own broadband internet service via LEO small constellation.

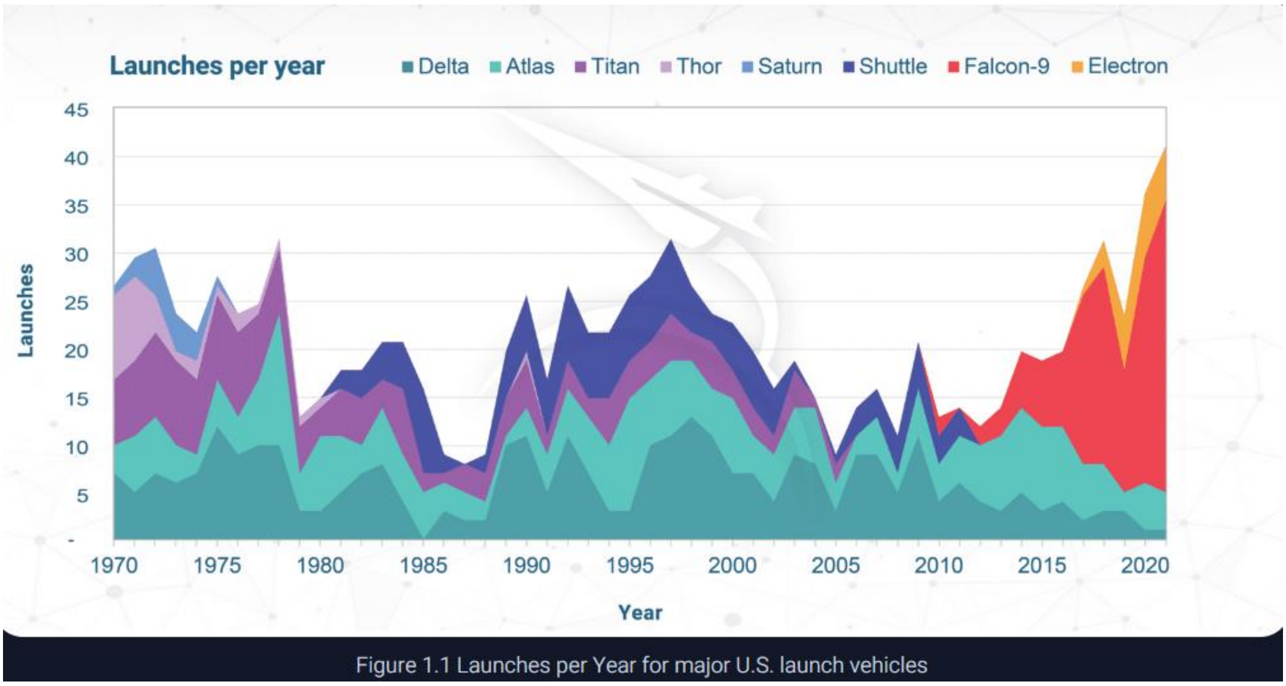

Figure 4. Launches per year for major U.S launch systems. Mackey, A. (2024, April 24). *Survival of the fittest: Saturation in the space launch industry*. SpaceWorks Enterprises, Inc. https://www.spaceworks.aero/survival-of-the-fittest_launch_industry/

While the Falcon 9 is classified as a medium, rather than small, lift launcher, the ability to add unfulfilled demand in the form of the Starlink satellites allows each launch to full meet its optimal launch specifications regarding payload (SpaceX, 2024). This effectively makes the Falcon 9 a hybrid of small-medium launch capabilities, perfect for deployment and maintenance of future constellations. SpaceX has done so while still maintaining, and even expanding the capabilities of heavy and even super-heavy launchers, through their existing Falcon Heavy and currently under development Starship launchers, which will also be reusable and are expected to once again send per kg launch cost plummeting (American Enterprise Institute, 2022). The Falcon Heavy is already the most powerful existing launch vehicle, and the Starship is expected to completely dwarf the capacity of all previous launch vehicles at between 100-150 tons, surpassing even the Saturn V (SpaceX 2024). This allows much more flexibility in the design of satellites and modules, which was previously made much more difficult, complex and expensive due to stringent weight and volume constraints (Perun, 2024).

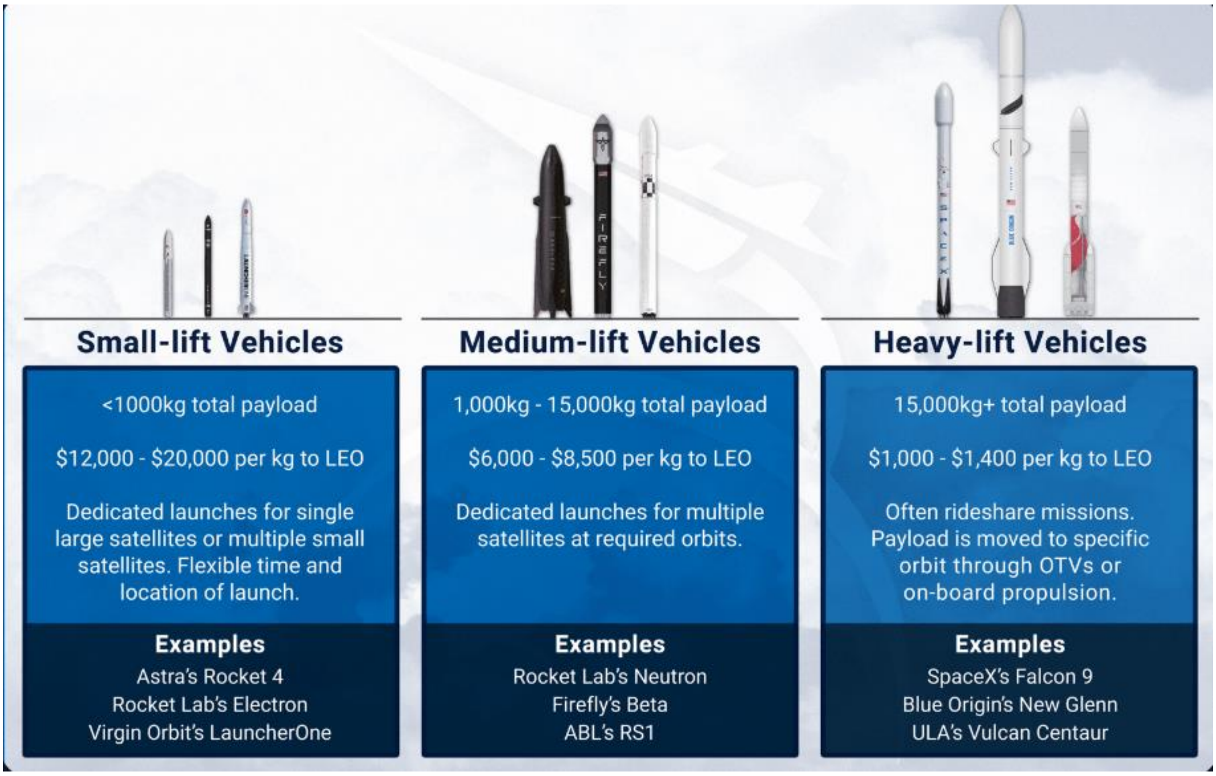

Figure 5 "Vehicle classification, price per kg, & primary application" Mackey, A. (2024, April 24). *Survival of the fittest: Saturation in the space launch industry*. SpaceWorks Enterprises, Inc. https://www.spaceworks.aero/survival-of-the-fittest_launch_industry/

Either through impressive technological feats that can be viewed in high def, real time: or the attention a personality like Elon Musk commands, SpaceX was largely responsible for generating huge public and private interest and discussion in the space sector (GAO, 2020). It is *the* industry leader by a landslide, currently commanding a staggering 87% of the commercial launch market by launches (Spaceworks.aero, 2022).

Declining launch costs have already led to a massive reshuffling of not only the space launch market itself, but have also begun a colossal shift of the entire space sector. Much as the end of the Cold War in the 1990's sparked the internationalisation of space and the rise of commercial actors in the field, modern market conditions have led to private actors becoming increasingly influential as investors in the space sector (Space Foundation, 2023

3.3 Development of International Actors and their Impacts:

During the Cold War, the American National Aeronautic and Space Administration, (NASA) and the Soviet Space Program, which lacked a central space agency and instead operated with a more distributed structure, were by far the most activate players in space: both superpowers accounted for over 90% of all space launches (IAF, 2924). Many of the most notable missions, discoveries and accomplishments were conducted by these two states. While the US American based actors have entrenched themselves in dominant positions in the space sector, it has recently been increasingly challenged by the PRC (China) which has emanated many previous achievements in space: the China National Space Agency (CNSA) have successfully launched rovers to the Moon, have a permanent space station, and are rapidly expanding the capabilities of their launchers, the next generation of which are expected to be reusable as well (CNSA, 2022).

The world is increasingly taking notice of historically smaller actors, such as the Indian Space Research Organization (ISRO) or hitherto non-existent actors such as the United Arab Emirates' (UAE), each having launched a successful mission to Mars orbit in 2013 and 2020, respectfully, and the former also successfully landing a Moon rover in 2023 to widespread press coverage (ISRO, 2023).

3.4 Industry Specific Evaluations

This section will briefly describe each major industry that has been or potentially may be active in the space sector. For each industry, if necessary, will be a summary of the market, and the key developments that have influenced them.

As the space launch industry as a whole has already been covered in the context of SpaceX swift ascension to industry dominance, the payload iis the very reason, and thus the most valuable component, of the launch system from an operational standpoint. These payloads carry out a number of valuable functions in service of a diverse clientele, which will be discussed below.

3.4.1 Satellite Manufacturing

Most payloads consisted of incredibly expensive satellites or probes which have and will continue to provide valuable data and services in a number of important fields. The main players in this market are familiar aerospace and defense firms, most of which are also American: Boeing, Airbus, Lockheed Martin and Northrup Grumman control roughly 50% of the market for satellite manufacture (Euroconsult, 2023). Public agencies such as NASA, ISRO and JAXA also have their own satellite manufacture capabilities, which have yielded many of the successful missions mentioned previously, and account for an estimated 30% of the market (SIA, 2022). Designing and producing these complex, specialized devices has grown into a $13.2 billion industry as of 2022, growing at an estimated 5-8% compounded annual growth rate (CAGR), served by both public and private actors (Polaris Market Research 2023). This growth is currently driven in part by rising demand for satellite services, like imaging and broadband internet, and new technical and market innovations like constellations. This demand will only expand as many private actors begin deploying private space stations for independent missions or leasing modules on the commercial market (Space News, 2023).

3.4.2 Research and Emerging Space Industries

As summarized in the literature review, research in astronomy has been a centuries long undertaking, evolving with the technological and socioeconomic limitations of its time. Many earlier discoveries regarding the cosmos and our position in it proved most practical in relation to navigation, helping sailors keep track of their position on the surface of the earth by referencing celestial bodies like the Sun and stars. Other improvements, like in optics, would be instrumental in learning more about our immediate extraterrestrial neighborhood, such as Galileo’s discovery of Jupiter’s moons, but the full practical utility of such findings is not likely to be achieved until well beyond the scope outlined in this thesis.

The impact of the research of space grew broadly and rapidly when research happened *in* space: initially, observations and data were gathered by rudimentary satellites with restricted movement, precision, accuracy and transmission capability (NASA, 2005). Even with the limitations posed by early satellites, useful data about nearby celestial bodies such as the Moon, Mars, Venus and others would provide an important starting point for future missions, which would be much quicker in harvesting practical results than previous generations of space exploration.

3.4.2.1 Limits of Earthbound Observations

These observations were made possible not despite technological limitations, but *because* of certain physical ones: Earth's atmosphere is dense, polluted and largely unpredictable, making observations of the cosmos from the earth less accurate and more difficult to obtain. Electromagnetic pollution, such as light and radio waves, and air pollution like smog, compel many astro-physical observatories to be built in locations remote enough to escape human interference (Australia Telescope National Facility, 2024). Natural atmospheric interference like differential pressure systems, humidity and weather also interfere with incoming cosmic particles, prompting observatories to be built not only remote relative to other human activities but also at sufficiently high altitude to lower the impact of the atmosphere on observations.

For other observations, even building on the peak of Mt. Everest would not be enough to adequately negate terrestrial interferences on potentially observations. At 8,849m elevation, the atmosphere is one-third as dense as it is at sea level: gravity, on the other hand, is only 0.4% weaker. While some terrestrial observatories are among the most capable and advanced astro-physical tools we have, they are still expensive and difficult to build, maintain and operate, especially when there's better alternatives. Many of the most useful astro-physical experiments that have been conducted over the past 75 years occurred in microgravity environments, chiefly in low earth orbit (LEO).

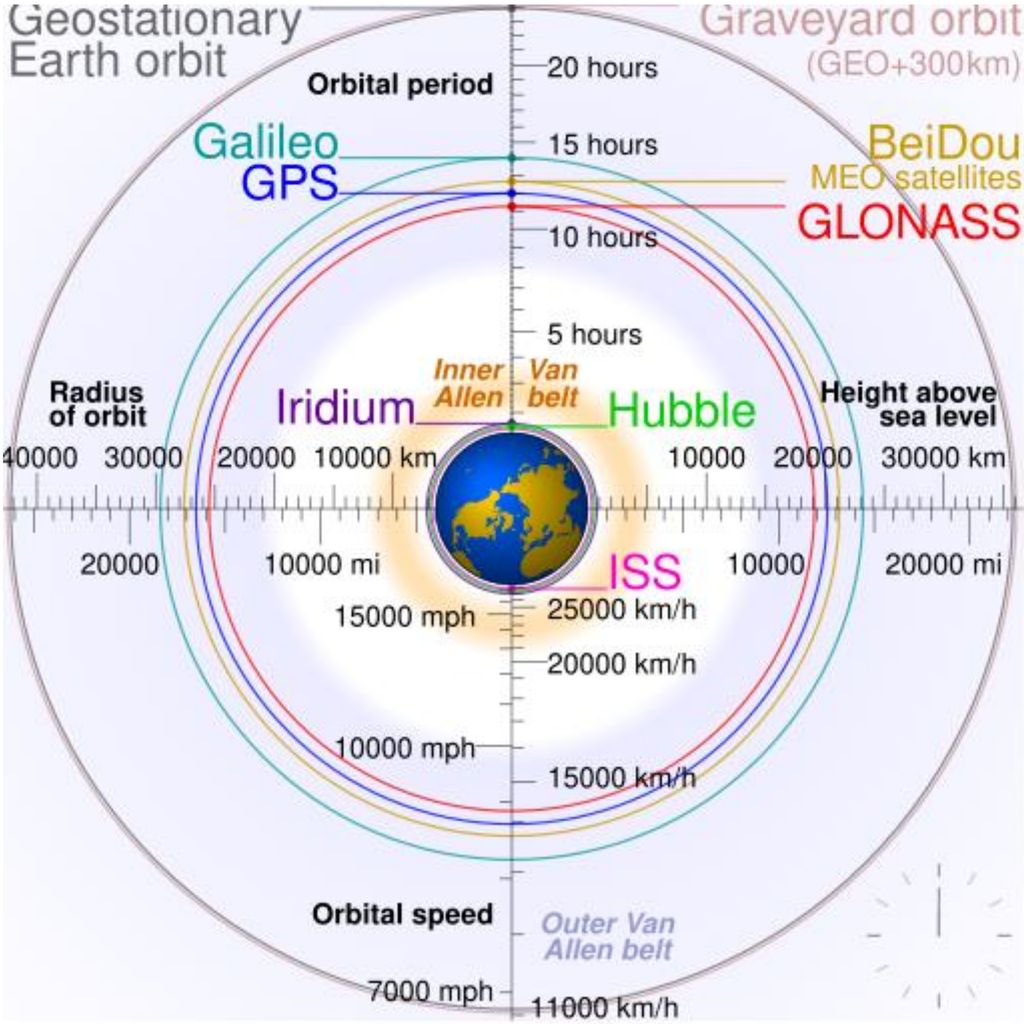

Figure 6. Comparison of several satellite navigation system orbits – (wikipedia 2024)

Putting measuring instruments in orbit, where they are only marginally affected by the atmosphere and earth's gravity, effectively eliminates both forms of interference in observations. Some of the most stunning, inspirational and impactful discoveries in astro-physics have been made with space-based telescopes like Hubble and the James Webb Space Telescope (JWST), exactly because they receive data unaltered at the point of contact (NASA Hubblesite, 2024). It is the research and work done directly by humans in space that has had the greatest practical impact on day-to-day life back on earth for many of us.

Not only do astronauts, or cosmonauts, as the Russians/Soviets have traditionally referred to trained professionals conducting space exploration and travel, help maintain and repair the automated telescopes and other satellites that have contributed to scientific discover in space, but they have also conducted thousands of experiments in a large array of disciplines, that have literally filled a book of practical impacts (NASA ISS Benefits for Humanity, 2022)

3.4.2.2 Biomedical Research

Biomedical advances have been among the most remarkable benefits that have stemmed from the collaboration of space agencies and astronauts on the ISS. A variety of common conditions many astronauts experience after prolonged stretches in microgravity allow for the natural and humane study of Bone, Muscle, Cardiovascular and Immune systems, better guiding treatment and best practices in these areas on Earth (NASA Space Station Research Explorer, 2024). Not only would healthcare on Earth benefit, the same knowledge applied off-world would better prepare future astronauts, and potentially entire generations of spacefaring humans, a possibility that has already begun to take shape.

Pharmaceuticals and Genetics: As someone who comes from a biochemistry family, I may be somewhat biassed in my optimism for the potential of 0g research in genetics. Genetic treatments, including genetic engineering, have near limitless potential for treating dangerous, currently incurable and often fatal conditions such as cancer and Alzheimers and genetic conditions like cystic fibrosis and Huntington's (National Cancer Institute, 2022). However, by directly editing our genes, humanity could also soon be capable of modifying its phenotype as well, selecting for beneficial traits. However, a technology with such potential has garnered considerable scrutiny from the public and regulators, and proceeds forward cautiously. Given the uncompromising standards required for FDA approval, pioneers of gene editing techniques strictly adhere to exhaustive standards in research, testing, and adjustments, aggregating to abnormally high RnD costs compared to other industries (DiMasi and Hansen, 2016). Only aerospace and defense might have such high RnD costs. Rendering these techniques effective in 0g may be difficult and thus expensive to affect, but, also like aerospace/defense, the pharmaceutical industry has deep pockets, commanding a $1.2 trillion dollar market with projected compound annual growth rate (CAGR) at %11.8 annually (Int’l Fed. of Pharmaceutical Manufacturers and Associations, 2022)

If developed responsibly, on an expedited timeline, safe and reliable gene editing treatments might be capable of augmenting the knowledge gained about the effects of 0g on our physiology, and provide future spacefarers with an anatomy modified to withstand the prolonged effects of reduced gravity.

Much like how genetic editing has been applied well outside of the human pharmaceutical industry in fields such as agriculture, cultivating genetically modified crops, with increased yield and resilience (agricultural GMOs are a $70 billion industry in 2024, (Research and Markets, 2024)), genetically modified organisms (GMOs) optimized for reduced gravity could prove instrumental in maintaining a source of fresh nutrition on longer term missions. Applied simultaneously with an environment that is completely within control of the farmers on the spacecraft, the phenotypic benefits of the GMO's may prove viable enough to seed the agricultural industry in space, diversifying the rapidly expanding space economy, or perhaps one day even challenge agriculture on Earth.

3.4.2.3 Computing and Robotics

The computer aboard the Apollo 11 mission, which accomplished its objective to put the first humans on the Moon, had 4 kilobytes (KB) of RAM, 7 of ROM, and 1.024 Hz processor, making it at least 2,000 times slower and with a million times less storage and memory than a modern smartphone (NASA, 2023). It conducted complex calculations to execute novel orbital maneuvers while working with only the power the Lunar mission had brought up in batteries from Earth.

The computers and electronic systems of modern spacecraft have come a long way since these early days of manned spaceflight. Computers process an unfathomable flow of information in the blink of an eye, acting with cold calculation when keeping spacecraft steady in the extreme conditions of space launch or orbital maneuver. They've become small and portable, able to fit into a pocket or the back of a glove, even visible on transparent surfaces in the form of an augmented vision, which makes them easier to work with and always accessible.

Used in conjunction with the ever-expanding fleet of small satellite broadband constellations, the computer is always connected back to early, relaying any data observers might need to keep track of the spacecraft's integrity and performance, and capable of making adjustments even before receiving instructions from a mission controller. Remote controlled robots and drones have served with great utility on earth, under a wide variety of conditions and tasks, from precise tasks such as explosives disposal or surgery, to most basic, repetitive tasks like car assembly. Space would require it all from any automatons we use in space, which will have novel propulsion and control mechanisms due to their operations in a microgravity vacuum.

Fortunately, we do have experience constructing and operating such machines: the Canadarm on the ISS and Space Shuttles enabled astronauts to more safely and effectively complete EVA's, aka space walks, as well as to far more easily assemble new modules onto the space station via remote control. Individual drones would be able to be controlled by an individual, as they are on earth, but the greatest utility would be gained if multiple drones were able to communicate and coordinate with each other autonomously and in real time to solve tasks like mining operations or deflect potential collisions with space debris. Higher numbers mean that the loss of one or even multiple drones would not be fatal to the function of the group, more capabilities can be employed, and a wider area can be serviced. This is already being studied in a number of applications on earth, but will likely require use of artificial intelligence (AI) to become viable. AI technology is still novel at the time of writing, but is already a market of at least $86.9 billion dollars and the drones it would operate are part of a robust and expanding $30 billion market (MarketsandMarkets, 2023).

3.4.3 Established Markets:

Services that have historically been the primary industries that have been enabled and benefitted from space exploration and development.

3.4.3.1 GPS:

Thus far in the literature review, we’ve seen that many practical advances in space exploration have related to maritime navigation, with incremental improvements in tools like the astrolabe, star tables and maps making it easier and safer to travel around the world via the seas. Despite these advances and the admirable skill of navigators and helmsmen everywhere, nothing could provide the accuracy, reliability and accessibility as satellite-based navigation systems.

Initially pioneered for military use during the cold war, the Global Positioning System (GPS), and its Soviet/Russian equivalent *Glonass*, employed 24 large satellites in a stable, medium earth orbit (MEO), each making 2 orbits in a 24-hour period (EOS, 2023). This allows for at least 4 satellites to establish direct communication with a ground-based receiver, the physical GPS unit installed in surface vehicles like cars, planes or ships, at any given time, from any given location on earth. Since the positions of the satellites in their orbits are known, the position of the GPS unit on earth is compared to its distance to each individual satellite, which is used to triangulate its own position on the surface of the earth. Algorithms and incredibly precise atomic clocks account for any atmospheric interference or unexpected positioning of satellites.

Satellite geolocation and positioning became available for commercial uses following the 1983 downing of a Korean Airlines flight that had accidentally crossed into Soviet airspace, leading to the development of the first civilian GPS receivers (NASA, 2023). Its full capacity in the commercial sphere would be realized in 2000, when civilian restrictions on GPS applications would be lifted and the constellation was completed a few years earlier. This technology is now applied in a number of major sectors, such as transportation, agriculture, drones, and emergency services: the GPS market by itself was valued at $37.9 billion and expected to nearly double by 2027. The real value of GPS becomes obvious when viewed from a broader perspective: it is believed to have contributed over $1.4 trillion dollars to the US economy alone since the constellation became operational (Allied Market Research, 2021; RTI International, 2019).

Potential Future Applications

Although trends of declining costs and greater launch and design versatility will lead to the development of entirely new sectors in space, and the transformation of those on the surface and beyond, the earth-based navigation market probably won't change much at its core. It will certainly expand, and more actors around the world use GPS in the aforementioned industries, and more. Strategic concerns may lead some to develop their own GPS constellations, which may be adapted to operate as larger constellations of small satellites in LEO, rather than smaller constellations of large satellites in MEO. This adds redundancy, and thus greater resilience, in the face of the orbital debris issue, while also reducing lag times between transmission and reception of position data. The next generation of cheaper and more versatile launchers allows for the cost effective replacement and modernization of existing GPS constellations, improving accuracy and potentially coverage. This all will likely provide growth and stability in the industry.

Other, non-earth markets, may emerge, however: the same fundamental principle of GPS design and function are applicable to other solar objects like the Moon and Mars: when time comes to begin establishing a greater presence on either, GPS constellations will likely be erected in orbit there as well, tracking and guiding assets on the surface.

3.4.3.2 Communications

Like GPS, communications (comms) satellites were among the first deployed in orbit: unlike GPS, these satellites served more diverse purposes, with heavy implementation in civilian applications: the first comms satellites, Telstar 1 and Syncom 3, were used to transmit television, telephone and fax signals from civilian sources from MEO and geostationary orbits, respectively (NASA, 2023). While GPS satellites were limited to only the most advanced space programs, the market for communications satellites was more inclusive, with states like Canada, Japan, India, China, France, Brazil and Australia and others participating in as early as the 1980's (ISRO, 2023)). Although initially providing mainly television and radio broadcasting, communications services have expanded to included broadband internet and satellite phone for regions that lack the physical infrastructure that enables these services in more developed areas. This has improved connectivity and disaster response, as well as provided reliable and secure communications in defense. All applications thus far have manifested a total market of $56 billion in 2020, which is also expected to almost double by 2027 (Allied Market Research, 2021)

While already a profitable and expanding service, broadband internet provided by large constellations of small satellites in LEO will likely be adapted for more conventional communications, improving speed, reliability and resilience of telecommunications infrastructure. Additional broadband capacity will also be vital as the volume of data being transferred around the world continues to accelerate and grow exponentially. This would likely be instrumental in enabling the coordination of many off world assets as well.

3.4.3.3 Remote Sensing and Intelligence

Satellite technologies revolutionized navigation and communications, but neither have had quite the impact that satellite imaging has. It is further set apart by the earlier initiation of its development process, beginning just 1 year after the launch of the first object to reach space, the German developed V2 rocket. On this mission in 1960, the United States launched a V2 it had made itself through Operation Paperclip, sending it beyond the Karman line and capturing the first images taken from space, which were recovered via re-entry capsule (NRO, 2023), marking the beginning of the satellite imaging (SI) industry. It should be noted that SI is itself a part of the broader field of Remote Sensing (RS), the science of identifying, measuring and analyzing electromagnetic radiation with sensors, often propagated from aircraft or satellites (ASPRS, 2024). The pictures taken of Soviet Military assets would be the first of many that this novel field would be largely dedicated to producing for defense agencies. Later, more advanced reconnaissance (recon) missions, now employing permanent imagers in orbit, incrementally improved the resolution and scope of images, reshaping the nature of military reconnaissance.

These advances would reach past military applications in 1972 with the successful launch of Landsat 1, the first civilian application of satellite imagery and beyond visual spectrum detection, providing environmental observations to NASA and the US Geological Survey (USGS) (USGS, 2023). The commercial market would launch with the 1999 IKONOS mission, which provided publicly available, high-resolution images of earth (Maxar, 2023). Further developments in detection of non-visible electromagnetic radiation would lead to the improvement of weather forecasts, enable more detailed environmental and urban monitoring, assist in archeological projects, and even locate mineral deposits.

The industry grew massively following its commercialization, valued at $3 billion in 2023, and expected to triple by 2032, by commercial and public/defense actors (Allied Market Research, 2023). When committed to focus on our rapidly developing, already commercialized solar neighborhood, the potential applications would be huge: Hyperspectral and LIDAR imaging, the technologies behind the archeological and mineral exploration mentioned previously, has already enabled the mapping of mineral deposits on the Moon, Mars and Asteroids on previous public space missions (KONICA MINOLTA, 2024). These technologies will be instrumental in kicking off a robust, scalable space mining industry and tracking the status of circumstances impacted by electromagnetic radiation.

3.4.3.4 Defense

Although defense may have historically been the driving force behind the development of satellite-based technologies and applications, it has largely been met, if not surpassed by commercial actors as leaders of innovation and investment. Even as defense investment in space continues to rise, novel applications are largely limited, confined to the adoption of LEO constellations to provide resilience and greater functions to their recon, navigation and communications assets (Council of the EU, 2022). While geopolitical tension on earth continues to escalate, the potential for weaponization and conflict in space also grows too, even if not quite to the extremes we might imagine, primarily due to the presence of orbital debris, which will be covered soon in a later section.

3.4.3.5 Mining

The mining sector in space is the least developed industry our of those likely to be directly affected by the pioneering of space colonization, aside from benefits provided by by some remote sensing services which helps locate mineral deposits, as well as a handful of tests conducted by NASA, JAXA and a few private actors (NASA, 2017). While piggybacking off the rising attention and interest of the space sector, the $1.1 *trillion* market for mining has still sourced a complete 100% of all its minerals from earth (Global Market Estimates, 2023)

3.4.3.6 Support services

Regarding the launcher itself as a subsystem of the broader launch industry, other inputs are required to execute a successful rocket launch and satellite/probe deployment. The rockets must be fueled and erected at a launch site designed to both withstand and direct the force of the launch of a multi-ton rocket. Once complete, launch procedures must also be directed by a number of teams under the mission control banner.

While design and production of launchers and payloads, and then their successful launch, makes up the bulk of the cost associated with a satellite launch into orbit, continual monitoring and adjustment is required to keep the satellite in safe orbit and in optimal position to receive and transmit data. This data exchange does not happen directly between computers at mission control and the satellite, but rather is often channeled through a ground relay station that acts as an intermediary between the assets and operations (NASA, 2023). Since data transfer and reliable connectivity to orbital assets are the core functions of such stations, they are positioned in the most favorable geographies to such functions: satellites positioned a high inclination orbit would best communicate with ground stations at far northern or southern stations, and free of other communications signals, justifying their construction in traditionally less economically viable locations such as Alaska and Antarctica (ESA, 1988). The construction and maintenance of these stations is vital for maintaining swift and reliable communication and coordination of space assets, and is estimated to be a $65.1 billion industry as of 2023, projected to nearly double by 2028, according to market research group MarketsandMarkets (MarketsandMarkets 2023). Local, indirect economies such as small businesses, restaurants, housing, and entertainment would also grow with this sector, just like they have during other localized development booms in the past: one is reminded of the such an instance like that followed large scale exploitation of shale formations in the American Dakotas in the 2010’s.

3.5 The Implications of Orbital Debris

An environment, as defined by the United Nations Environment Programme, is "...the external conditions, resources, stimuli, etc. with which an organism interacts. It includes both biotic (living) and abiotic (non-living) components." (UNEP 2024). Many human activities on earth often lead to environmental degradation, either through pollution of the water, soil and air, or the direct destruction of delicate ecosystems and landscapes. This has led to the extinction of many species of plants and animals, as well as the diminishment of the environmental services many environments provide, such a flood control and landslide prevention, a process which is often self-reinforcing (UNSDSN, 2019). Many environmental impacts of human activities can be felt across entire regions and even globally, however most direct environmental degradation has historically been localized to a specific area of the land, air and seas, confined by the physical factors of the environment

However, in the context of outer space, the conventional definition of an environment becomes more difficult to apply: as far as we know, there are no biotic components, nor are there many non-biotic factors in certain areas such as the space between celestial bodies: there is no atmosphere, no land or sea, practically no matter at all in these places. Despite this, much like how human activities degrade our spaces here on earth, which often leads to detrimental effects on public health and safety as well as socioeconomic development, human activity in space may have similar reinforcing, detrimental effects on our development in the extraterrestrial region.

It is because there is practically nothing else in the vacuum of space that any pollution created by human activities, be it defunct satellites and other space debris still trapped in orbit, or radiation from nuclear tests, will not be naturally contained, nor are there any natural systems and services we can employ to protect ourselves and our assets from our own harmful byproducts (NASA, 2023). The most noticeable, and pressing, of these byproducts is the aforementioned space debris, much of it concentrated in the cluttered area of LEO, just 200km above sea level, orbiting the earth multiple times a day at hypersonic speeds. Smaller objects in lower orbits can experience orbital decay, aka the gradual loss of energy and altitude due to earth's still present gravity and traces of atmospheric drag, which brings them within earth's atmosphere and the intense heat generated by the friction between them and the surrounding gases harmlessly burn them up miles away from any life. Yet many objects in orbit are at a sufficiently high enough altitude to be largely immune from the forces posed by the earth, and are thus trapped in orbit, effectively becoming a dense, spinning hail of billions of often microscopic bullets that orbit around every 90 minutes. This poses a direct and omnipresent threat to astronauts and space assets, both of which are extraordinarily delicate and complex systems. Yet the threat does not stop at individual space assets and astronauts: the entire orbital environment is at risk of becoming completely unusable, since the amount of space debris is growing, “and is growing” exponentially.

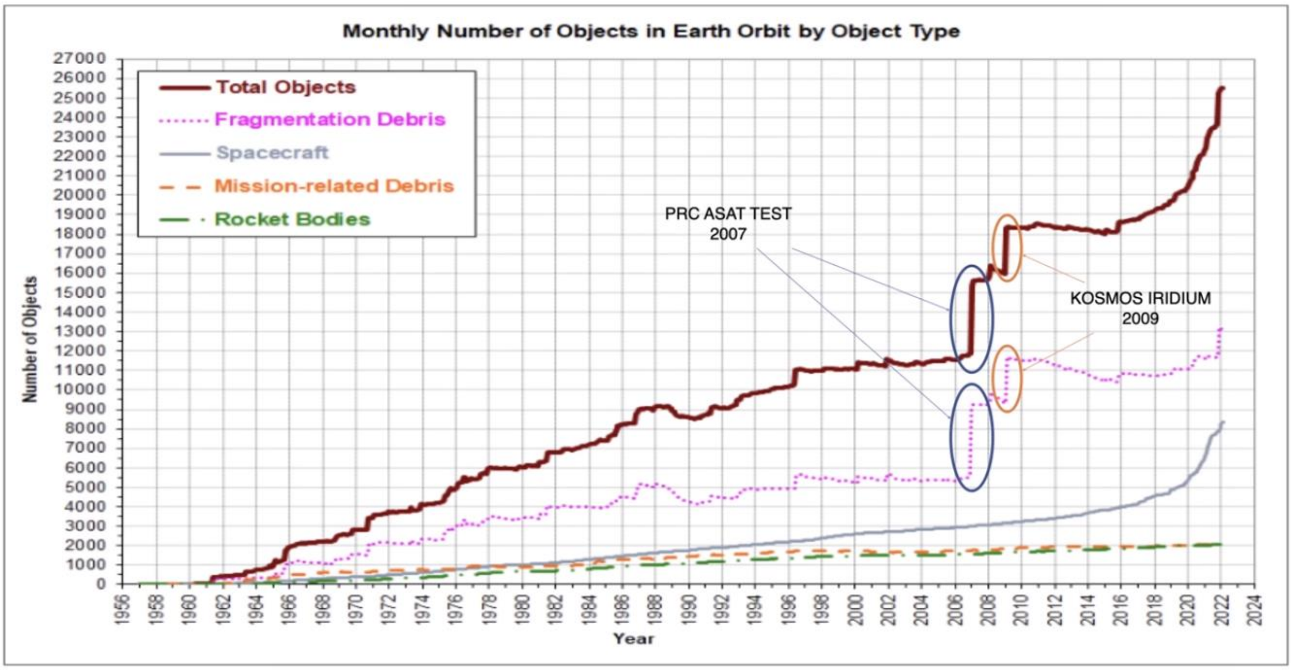

Chart showing number of objects >10 cm in LEO. Credit: NASA ODPO.

Figure 7. Chart showing number of objects >10 cm in LEO

NASA. (2023). *Ares*. NASA. https://orbitaldebris.jsc.nasa.gov/modeling/legend.html

Such exponential growth could certainly be attributed to the exponential growth of the space sector as a whole: while orbits are carefully planned and monitored, launching thousands of satellites into them makes mistakes, and the debris producing collisions, inevitable. It is rather the forces involved with these collisions that accounts for the exponential nature of generation of orbital debris: colliding at tens of thousands of “kmph” effectively vaporizes the two objects, producing thousands of new pieces of debris shooting out into all directions, which may in turn collide with other objects in orbit (NASA, 2023)

Two objects have now become thousands, with each one capable to reproducing similar results. The generation of space debris could, without warning, reach a critical point where it has completely runaway, rendering LEO inoperable, uninhabitable and inescapable, bringing all space-based research and services down with it

There are currently few defenses against this potential maelstrom of space junk: protecting satellites, astronauts and spacecraft using shielding increases weight and thus launch costs, and provides little additional protection (ESA, 2024): the immense kinetic energy of even small objects travelling at such a speed would just punch right through. Objects smaller than 10 cm in diameter cannot be tracked either, which makes it impossible to know when they might impact space assets and thus conduct an orbital adjustment (NASA 2024). Fortunately, all objects follow a predictable trajectory in orbit, yet even for larger objects that are continuously monitored, expending additional fuel for otherwise unplanned orbital adjustments accumulates additional wear and tear on the station and increases operating and maintenance costs. This isn't to say that there will not be more effective measures of protecting against or removing space debris, as many are being explored and the entire issue is met with increasingly thorough research and investment by many international space agencies and increasingly from the private sector (ESA, 2024; CNSA 2024).

This currently leaves measures to prevent/mitigate the creation of new debris as the primary way to reduce the risk of debris impacts, and stay the critical point of no return. “This can be done in a number of ways: reducing the length of time satellites remain in orbit following completion of their mission, designing new satellites to function optimally in less busy orbits, and prohibiting anti-satellite weapons tests

The last of these measures may prove to be the most important in the broader geopolitical context of the contemporary space sector. Just three anti-satellite weapons tests are responsible for creating at least a quarter of all space debris (UCSUSA 2014; Our World in Data, 2023), insert graph). Since an attack against one nations space assets may lead to the destruction of *all* nations space assets regardless of retaliation, anti-satellite weapons effectively behave in an even more mutually destructive than the actual nuclear weapons which prompted the adoption of the Mutually Assured Destruction (MAD) doctrine between all nuclear powers during the Cold War. This doctrine prevented direct conflict between these states, or the use of nuclear weapons on other states, safeguarding humanity from extinction or another conflict as destructive as World War II: a similar approach to space based weapons maybe warranted to prevent conflict in the fragile earth orbit environment.

4.1 Scenario Analysis and Discussion

In this scenario, current trends are extrapolated 20 years into the future, starting with 2025 and proceeding in 10-year intervals. This timeframe was selected both to maintain a reasonable scope, but also because this may be the most pivotal moment of the space transition, much like how the 2000's and 2010's proved pivotal in how the digital and sustainability transitions unfolded. The future will be based on the continuity of the socio-economic and geopolitical status quo. So, let's begin in 2025.

4.1.1 Years 2025-2035: Enter Chaos

The world of 2025 is a chaotic place. Persistent conflict in Ukraine and the Middle East, directly and indirectly restricting international trade in the Black and Red seas, maintains inflationary pressure worldwide as the still widely globalized economy absorbs the economic impact of increased transportation costs on commodities, particularly minerals, energy and foodstuffs (FAO, 2023). This inflation is not felt equally, however, as developed regions such as the United States and the European Union, being largely self-sufficient in food production and having secured reliable energy supplies, and continued economic growth (OECD, 2023). Even some less economically robust states may still experience growth under such conditions, should they have both large reserves of strategically important resources and a generally stable government and socio-economic structure: mineral and hydrocarbon-based economies such as Chile, Venezuela (if managed properly) and Russia, if western sanctions are defanged, would become much wealthier

Less developed regions, mainly in the Global South, with rapidly expanding populations, renewed industrialization and modernization, and limited infrastructure and social welfare proving insufficient to adequately provide many basic services for their citizens are hit hard by inflation, leading to further increased global instability (UNCTAD, 2022). This increases the likelihood of additional conflict, which, like the two aforementioned engagements, could further spill over into globally strategic areas, markets and/or resources, placing further strain on economies reliant on international trade.

Such concerns are only exacerbated as the effects of climate change become more severe, particularly in the same communities also most impacted by inflation (IPCC, 2022). Healthcare and food systems, as well as power grids, are stretched thin by more frequent and intense forest fires, heatwaves, and flooding, driving millions of rural refugees out of their homes to cities or outside of their countries entirely, reducing economic activity as well as tax revenue, and pushing many governments to the brink of failure. The exodus of millions of refugees seeking safe harbor in more stable regions like North America, Europe, the Arabian Peninsula and East Asia feeds into populist narratives against migrants continuing the growth of many extremist political groups that began in 2012 (Dervis, 2017). These groups often promote isolationist foreign policy and ethno-nationalist social structures and policies, promoting narratives against globalization.

With little help from those with the resources to do so, teetering states are likely to be consumed by instability for years to come, removing potential supplies of strategically important resources such as fossil fuels and rare earth metals from the global market, increasing their costs and as well as inflation, also slowing down the renewable energy transition. A brutal cycle of inflation, accelerated effects of climate change, and instability may have emerged in many developing countries.

4.1.1.1 Deglobalization

While not as severe, these changes will still affect the socio-economic state of many developed countries. With fewer consumers for manufactured products in developing countries, as well as high input costs for energy and other strategic resources, the Chinese economy will at the very least slowdown from its breakneck pace, potentially leading to political unrest. Seeking to boost public morale through nationalist rhetoric, the PRC, will likely intensify military posturing towards Taiwan, if not launch an outright invasion of the island (CFR, 2023). While Western, most importantly American commitment to defend Taiwan is unclear, it is likely there would be some degree of military intervention to defend their ally, which, as the Russo-Ukrainian war has demonstrated, may be enough to ensure Taiwanese sovereignty. Regardless, this would still not only disrupt trade along one of the world's busiest trade routes running through the waters around the island, spiking global transportation prices even further, but would also halt or greatly reduce the production and export of much of the world's semiconductor supply: 55% of the market is Taiwanese and even more in share of production (WSTS, 2023).

This conflict in particular would be the exemplar of the intensified deglobalization and regionalization that had come to define the decade before. Incredibly strict western sanctions, and potentially from other states that have vested interests in the Asia-Pacific region, would isolate China and its sphere of influence, which most notably includes Russia, itself also economically and diplomatically reduced and isolated following its large-scale invasion of Ukraine (Council of the EU, 2024). Symbols of deglobalization, such economic decoupling, regionalization and self-sufficiency manifest in forms such as the U.S CHIPS Act, and are proven to have been prudent investments as the US and its allies maintain some independent capacity to manufacture semiconductors at all levels despite the sharp decline of the global microchip market (Semiconductor Industry Association, 2024).

The reduced supply of microchips, vital in all digital, informational and computer related industries, is among the main threats facing Western economies, as well as India and China, all of which are much more reliant on these industries than their developing counterparts, causing social unrest that prompts even more support for populist causes promising instant change and further recluse from the global system (Funke et al, 2024) Any trade that does happen going forward in the immediate future is likely to be exclusively with close allies that share strong political, cultural and historical ties. These ties would likely be leveraged by China and Russia, now in a closer military, economic and political alliance, to deny access to rare earth elements to their perceived opponents in the West, further eroding economic growth and hitherto rapid pace of the Green and Digital transitions

4.1.1.2 Budget Implications

If current trends regarding tax policy and wealth distribution in Western states hold, wealthy individuals and corporations will not see an increased tax burden to provide additional revenue. Thus, state budgets shrink due to reduced economic activity and increased spending on unemployment benefits following any potential disruptions of globalized industries and the broader economy. Among the affected state agencies are space agencies of nations developed and developing alike: accelerating the transition from public to private funding in the space sector, and further centralizing the hold of private actors like SpaceX and

Blue Origin. Yet, this hold would likely not be as strong as it was in five years before 2025, as the reduced supply of semiconductors also hits the space sector in force, reducing demand for launches, and increasing the cost of building and launching new satellites (Apex Waves, 2024). However, potential capital that wealthy market leaders like SpaceX and Blue Origin and their ultra-wealthy sponsors in Elon Musk and Jeff Bezos may have in reserve from the golden years before the recent descent into chaos, as well as the innovative business model of partially being their own customer, may be enough to carry them through the market downturn. At the end of the chaos, they will be the only remaining space actors, with the possible exception of truly well operated small scale launch firms that may have achieved low enough operating costs to still break even while in a difficult market. However, it is unlikely that either SpaceX or Blue Origin would allow potential competition to continue to exist unmolested, and will probably attempt to acquire any such firms.

While it may not be acknowledged by the now more extremist, right wing populist governments of many countries, there is still growing recognition that maintaining the transition to renewable energy and digitalization would help take the edge off the worst effects of climate change and deglobalization. In continuing the renewable transition, while also securing a supply of microchips, states would need to secure their stocks of the necessary inputs into renewables, which will be referred to as “Green Minerals' such as Lithium and Rare Earth Elements (REEs). A significant supply of such minerals is extracted in what are now unstable regions, which could also be said for the manufacture of semiconductors (Drobniak and Mastalerz, 2022). With what little relatively stable and secure supplies of these inputs having been claimed almost instantly by any actor with a semblance of power projection capability, there’s only one place to left to go

4.1.2 Enter: Space

Mining in space has the potential to satisfy all demand for any and all minerals required for production on earth for years. It can be done fairly cheaply, safely and efficiently, but only if economies of scale are present in both the launch sector required to get the infrastructure into space, as well as the equipment itself (Calla et al, 2022). Fortunately, SpaceX already has effective economies of scale for launchers capable of the novel heavy, or super heavy, lifting required to quickly launch large scale mining operations past the Karman line and into space. The mining operations themselves had not yet reached a critical mass to be cost effective before deglobalization began, but with now irresistible incentives for development, the actors who had been studying the prospect before now lean into their head start and race ahead. The technology might become economically viable within only a few years, given that the broader space sector is already mature and has many of the tools and experience needed to scale quickly. A similar process would likely unfold for the production of semiconductors in LEO, as well as other practical applications in material science and biotechnology initiated by previous research conducted on the ISS. Technologies that would be vital in both endeavors, dually Artificial Intelligence (AI) and Automation and Robotics are would also be more mature industries that have been proven in a 0g environment like the ISS and in production processes back on earth. With greater demand for renting modules in LEO, it may also be possible that the lifespan of the ISS itself is extended past the planned decommission date of 2030, if it is still feasible from a safety perspective. The proliferation of private space stations that had begun development before 2025 would provide the additional real estate in space required by the growing number of private actors seeking to establish large-scale operations in zero-gravity.

These private space stations will continue to shape the future of the space sector, by initiating a new chapter in the democratization of space. Instead, the following the historical track of a government led megaproject, billions of dollars and decades into developing the technical and built capacity to establish its own space station, a realm once reserved exclusive for only the world's largest space industries in countries like the US, USSR or PRC, even a mid sized economy could simply rent out a module on a private space station and customize it towards their needs and interests. This does have an obvious restriction in that wealthier states and organizations might still simply outbid less financed actors, but such an innovation would greatly reduce the technical and economic barriers of entry into the space sector. This would need to be preceded by more effective and well enforced intellectual property laws that are agreed to by all actors to protect the credibility and mutual trust of all actors in space required to responsibility and efficiently develop the international space sector and other strategic industries.

Within 10 years, regardless of whether national and international governments step up additional funding to expedite the development of these technologies and industries in space, there may well be rapidly growing space mining and semiconductor manufacturing industries in LEO and beyond, if the pace of other recent major transitions is any indicator. As production reaches a level that can meet considerable market demand on Earth, prices of strategic minerals and semiconductors start to fall back to levels at the beginning of deglobalization, revitalizing many states and their economies. However, much like how more progressive and stricter tax policy largely failed as a vehicle of global fiscal stabilization during the recent past as well as present, the immense *profits* generated by the overwhelmingly private actors pioneering the large scale space transition would likely remain concentrated in the hands of a small number of stakeholders, further propagating the wealth inequality which both precipitated, and was a result of, the instability associated with deglobalization. The power associated with control over strategically important inputs like green minerals and semiconductors would likely also internationally influence in the hands of the mainly Western and Chinese stakeholders who had been at the forefront of the space transition, potentially partially closing the markets to perceived rivals, a practice used since the start of deglobalizing trends. Open markets for these goods had propelled many promising economies such as Nigeria and India to greater relevance in the era of globalization, further centralizing wealth and power in the hands of relatively few developed states, reminiscent of the mercantilist, colonial period.

4.1.2.1 Next Steps

While the energy ecosystem on earth may have eventually stabilised due to the influx of space mined minerals, also enabling the continuation of the renewable energy transition, the period of high energy prices around the world from 2022 onward also incentivized renewed development of nuclear energies (IEA, 2023) This field, alongside private space stations and heavy lift launch vehicles, had already received considerable study and investment prior to 2025: small modular reactors had been investigated by numerous private and government actors, and of course there is the ever present possibility of fusion reactors, which were expected to come online near this time frame as of time of writing. Mineral extraction and potentially refining of elements used in fission reactors, potentially done more responsibly and cost effectively in space than on earth, may have provided the financial and public safety incentives to bring nuclear energy as a more prominent fraction of the global energy supply. If fusion were to indeed be proven viable as well, there would also be demand for an entirely new commodity relevant to energy production, Helium-3 (He-3), the most promising of known fusion reactions (ESA, 2023). While already a candidate for mining and production of materials required for conventional earth markets, the successful initial deployment of fusion would reignite interest in the Moon, as eons of exposure to the solar wind had led to the accumulation of considerable deposits of He-3 on the surface (ESA, 2019). These deposits are currently known on the bright side of the Moon, which has already been thoroughly observed by multiple stakeholders and even visited by humans, but what lies on the dark side of the Moon is uncertain as of time of writing. This has already begun to change, however, as China just retrieved samples from the surface of the dark side of the Moon with the Chang'e 6 rover, and other rising space faring states such as India, Israel and the UAE have also launched successful Moon missions (Emirates Mars Mission, 2021). NASA expects to send manned missions back to lunar orbit, and later the lunar service, in 2025 and 2026, respectively (NASA, 2024)

As orbital infrastructure, such as relay satellites and transfer stations, around the Moon develops, the exploration of this dark frontier will accelerate, driven in search of other vital resources in addition to He-3, such as water and minerals (ESA, 2019). Plentiful on earth but not so common beyond our terrestrial boundaries, water ice would be mined to sustain extraterrestrial outposts and create rocket fuel for missions deeper into space, expanding the possibilities of development further beyond our immediate solar neighborhood. It is much more economical to launch a farther-reaching space mission on a lighter platform on Earth and have it refuel and relaunch from the Moon than it is to send the payload onto its planned trajectory using a heavier launcher directly from the Earth's surface. Thus, the Moon would become an important stop, a port, effectively for future missions to other major celestial bodies such as mars, the asteroid belt and the outer planets. These reasons and many more highlight the economic and strategic importance of a robust Moon presence and provide even greater incentives for extraterrestrial investment and market expansion to that frontier.

4.1.2.2 Conflict in Space

With the increased activity in space, the risk of space debris affecting the important operations of the entire sector rises substantially. This increased activity in space occurs alongside the increased geopolitical activity back on Earth: potential conflicts are difficult to predict, especially when considering rogue or highly belligerent actors. These actors, some that we may not know of yet, already have the capability to destroy a satellite: orbital trajectories are fairly predictable, and easy to track and reach with sufficiently powerful ballistic missiles, which can be built even with limited economic resources. Other such actors have been expanding their fleet of more practical space assets, such as navigation and communication; they may still be limited in regards to establishing a stronger and impactful space infrastructure. Thus, if conflict arises with an actor(s) that are a leader in space-based assets, it would be in the tactical and potential strategic interest for the party with comparatively ineffective military space capabilities to “level the playing field” so to speak, by removing *all* enemy assets and thus overwhelming capability, at the small sacrifice of their own comparatively ineffective capabilities. Simply put, such actors might not mind fighting in the shade of orbital debris.

The doctrine of Mutually Assured Destruction (MAD), as outlined in the summary of the historical literature, existed because of a triad of nuclear delivery methods: strategic carriers such as bombers, missile forces such as ballistic missiles, and strategic nuclear submarine forces (Federation of American Scientists, 2024). Even the most powerful of states, armed to the teeth with thousands of nuclear warheads, would not be able to destroy all of the opponent's nuclear assets with 100% coverage under such a configuration: this leaves them vulnerable to a counter-attack, one nuclear in nature and at far too high a cost to justify conflict or escalation. Even nuclear states with far lower warhead counts might be able to establish a nuclear triad and guarantee a reliable nuclear deterrent. The mass utilization of outer space, as well as the laws of physics themselves, lower the barrier to space-based deterrence to basically any motivated and moderately well financed actor. A LEO in danger of Kessler Syndrome, is an environment where practically everyone has the equivalent of a nuclear triad: the only thing stopping the *actual* "war to end all wars" in space is a basic trust in the other actors that share the same environment with each other.

All this to say that while actors with integrated and expansive economic and defense space capabilities may have agreed to follow a policy comparable to MAD, smaller, potentially more belligerent actors so far have not, and can pose serious, collective risk to anyone and everyone that operates any kind of space infrastructure using fairly limited resources. The militarization of space and the potential weaponization of the Kessler Syndrome, described in the summary of the contemporary extraterrestrial environment, will force the issue of collective security in space in national and international governing bodies.

4.1.2.3 Historical Comparison

As stated in the literature review regarding the broader historical context surrounding global trade, European colonialism and accompanying colonial and mercantilist system, the Spanish and British methods of colonial administration and development provide relevant examples to the expected trajectory of space colonization. Recall that the Spanish system succeeded for some time mainly because

1. They got there first

2, The chance discovery of huge deposits of silver and gold.

This basically allowed Spain to, within less than a century, directly achieve the primary goal that had driven the Europeans to the open seas in the first place: bypass the Mediterranean middleman and trade directly with China, offering them the only thing they actually demanded, silver. Pause the thought of the value of trade with China, and consider the value of the items being traded, effectively silver for luxury goods like spices, silk, porcelain and tea. The goods certainly have utility in their own way, but what utility did silver have? It is simply a perceived, high value vanity item, useful as either a status symbol, or a means of transferring wealth.

How does this relate to the immediate future of the space transition in this scenario? In this analogy, the trailblazers of space mining are essentially the Spanish stepping upon the Americas in the 16th century, relentlessly developing and exploiting an economy of mineral extraction however…

1. The explorers aren't even there: the entire operation is conducted remotely using a largely autonomous drone/probe. Any humans are likely at the safely positioned homebase of the operation, likely in orbit around a nearby celestial body, reducing the risks associated with farther reaching exploration

2. They didn't stumble upon these minerals by accident: they carefully sought after it, guided by remote sensing and tracking of asteroids using space assets, backed by a mature space sector

3. The silver being mined isn't just silver, its mostly nickel, lanthanum, lithium, cobalt, silicon, or substantial quantities of a dozen other elements that make our digital, industrial modern lives work.

The new "silver" is no longer just a way to facilitate trade and transfer wealth: it is now the core component to a functioning society. The first space miners to operate at scale wouldn't just gather wealth at a pace akin to the Spanish in the New World: they could well rise among the wealthiest people in history.

Therefore, as wealthier super powers and regional powers satisfy demand and are closer to a positive trade balance, mercantilism might proliferate faster than it has historically, given the sheer speed and number of actors exploiting this opportunity. As many actors come closer to achieving self-sufficiency in key mineral inputs, the necessity to trade with mineral producers on earth declines, and with it global economic integration: in such circumstances, regionalization is in many ways comparable to mercantilism, with colonies in space providing the positive trade balance, relevant now more than ever, and even the symbolic wealth of precious metals that had predominantly driven the earliest colonial and mercantilist systems.

While the initial wave of wealth might be concentrated in the hands of a few space launch actors like SpaceX, given the sheer scale of outer space, other such deposits would likely already be known, and easy to track. Any capable actor with even moderate financing would be able to cash in on this opportunity, especially in an environment of low-cost launches that can go, at scale, farther and faster than ever previously had been economically feasible. The already breakneck pace of these developments would likely only accelerate as these ventures are undertaken not just by rising government actors, but also predominantly by private actors, each of which has likely invested in a unique business model or technology: one of them is bound to have the figurative golden combination that gives it a competitive advantage.

There would be no 7 Years War

In the historical precedent, just like now, the frontiers of the new world and the trade that connected them to their European capitals, were immensely important to maintaining international influence, economic growth and political stability. This made them valid and valuable targets for rivals. Regional conflicts had erupted in Europe, but spilled over as far away as North America, the Caribbean, Africa and India as conventional land wars. Piracy was also an effective tool of disrupting trade, i.e. British privateers and the Spanish, especially since it provided plausible deniability for the contracting party.

This occurred in an environment where there was no overhanging umbrella deterrent like nuclear weapons or orbital debris. More modern tactics and weapons would greatly reduce the influence of piracy, but in an environment where even limited kinetic attacks on space assets could completely close off the sector due to Kessler Syndrome, piracy, i.e. boarding spacefaring vessels, is a less destructive means of disruption. This will be difficult to mask, however, meaning that other methods of hybrid warfare, such as interfering with opposing guidance, communication or support signals and systems to induce failure, i.e. electronic and cyber warfare would become increasingly prevalent. Kinetic conflict in space may still arise, but likely not between leading space actors.

4.1.3 Years 2035-2045. Enter, Ambiguity

4.1.3.1 Environmental Benefits of the Space Transition

After 10 years, the space-based mining and manufacturing industries reached scale and maturity over the previous and began exporting minerals and semiconductors in quantity back to earth. The renewable energy transition, disrupted by high material costs and lack of support from many now populist governments which followed disruption of trade, restarted and then continued at a moderate pace, propelled by reduced input costs and high energy prices, but still limited by decreased public investment and inflation. This balance will likely swing decisively in favor of transitional acceleration as further scaling and competition, intensifying as new players enter the space mining industry, further driving down material input costs for green technologies, particularly energy storage. More economic energy storage solutions are one of, if not the most important developments in the renewable energy transition, as they would solve a fundamental weakness in the suite of technologies employed. With the most notable exception of hydroelectric power, conventional renewables like wind and solar are intermittent, meaning they're not always available: cloudy days and nighttime take solar production offline, and calm, quiet days can reduce wind energy production. Utility scale energy storage methods, usually a multi-megawatt configuration of multiple large lithium-ion batteries, allow for storage of excess renewable energy generation for use at a later time, thus providing a renewable baseline that has been predominantly provided by fossil fuels.

This enables a swifter and wider reaching green energy transition would lead to a number of positive global socio-economic impacts:

- Renewable energy systems allow for generation of energy independent of external inputs such as fossil fuels, instead harnessing local, natural resources such as water, wind and solar. This allows for off grid and microgrid energy generation, improving access to energy and the benefits it brings to areas lacking centralized energy infrastructure such as a connection to the grid, potentially connecting billions more to electrical services. Some renewable energy sources such as solar and wind, when employed at the smaller, more portable scale, could further build on these functional strengths and be widely employed in disaster or conflict areas to enable greater capabilities from humanitarian organizations and improve services to refugees.

- These benefits are magnified when renewable energy is used in conjunction with now far cheaper energy storage, allowing residences to produce free energy, and even profit from excess energy sold back into the grid. With less pressure on supply, in conjunction with overall reduced demand, the wider electrical grid would be more resilient to extreme weather and spikes in demand. Lower energy costs also help alleviate financial stress on lower-middle income families and individuals, improving quality of life.
- Economic growth in general accelerates as all processes requiring electricity, which in our modern, industrialized societies is practically all of them, are cheaper. Particularly energy intensive industries such as chemical and petrochemicals, and construction materials such as steel and cement would also see reduced operating costs leading to both direct and indirect economic growth through secondary industries like agriculture, real estate and public infrastructure.

4.1.3.2 Displacement of Traditional Industries

Not only would this likely signal an easing of climate change impacts, but likely also the death toll of two of the most environmentally destructive terrestrial industries, fossil fuels and mineral extraction and refining. The sharp decline of both industries would come with mixed results: on one hand, all people everywhere would be saved from significant exposure to the harmful chemicals released into the atmosphere and wider biosphere by these industries, living longer, healthier lives and reducing potentially underequipped healthcare systems. (i.e., respiratory diseases caused by smog in major cities would be greatly reduced) The broader biosphere itself would also be healthier as humanity's biggest effect on the biosphere, the alteration of the atmosphere, is scaled back substantially. Local ecosystems, once razed by massive, sprawling gashes carved through the landscape by mining operations, would slowly reclaim the area around the mine, and even adapt to be able to live in the mine itself, potentially creating new, unique ecosystems where there was no life before.

On the other hand, these labor-intensive industries will disappear fairly quickly, leaving many medium skilled workers unemployed. Certain states and regions that were once reliant on these industries will likely experience a sharp socioeconomic decline and become unstable, posing a problem for governments at all levels. Wealth inequality, likely to have increased over the previous 10 years, would become incredibly difficult to reverse, as the consolidation of strategic and large industries tends to do. Political instability in countries reliant on these now largely off-worded industries would follow: the question then becomes, would such instability ripple out to the waters of global affairs, or remain mostly localized and contained? Are other trends strong enough to push re-globalization despite this?

4.1.3.3 Re-Globalization?

To answer this question, we must first reassess the strength of global connections and the degree to which economies would be integrated into the global economy in 2035.

Following 10 years molded by increased global economic and geopolitical instability, we might expect that the world has become more polarized and regionalized: the spheres of influence emerging over the last 20 years have solidified, not just in political and diplomatic orientation but also economically and scientifically. While initially confined to within leading spheres of influence, the benefits of the space sector, cultivated in the 10 years after 2025, have begun to return beyond just the pioneering actors mainly in the opposing spheres of NATO-aligned states and the Russia-Sino partnership. Both parties will likely maintain a significant edge over many emerging space actors, and dictate the pace and degree of adoption of these technologies, depending on the control governments are able to exert over them. Should a government with jurisdiction over a particular space asset and/or capability seek to interfere in the development of another actor, they may be able to deny use of that capability to them or others, as has already been done regarding specific semiconductor and green mineral resources. This would raise the question; would private actors agree to such a dynamic? Probably not: we’ve already seen SpaceX refuse to provide aid to a strategic partner of its host nation, by the authority of its founder Elon Musk.

To shield themselves from such a possibility, actors reliant on this external capacity are incentivized to either develop it themselves, or change methods and operations to be able to function effectively without potentially unreliable external inputs. Less interaction between foreign markets and actors further entrenches deglobalization.

4.1.3.4 Wider Distribution of Opportunities

Independent, rising states such as Nigeria, Indonesia, and India likely have benefited greatly from the developments wrought by the first decade of the space transition, even if still to a lesser degree than their Western or Eastern aligned counterparts, and have begun to further develop their own space based economic activity and development. The main risk at the beginning of innovation is uncertainty, where the technology or service are unproven and potential paths of development are unclear.

A far more efficient, reliable and cost-effective space infrastructure has been established by pioneering actors, unlocking countless opportunities for stakeholders of medium sized economies and incomes. Initially employing existing infrastructure to facilitate development, the new, independent stakeholders in the space sector will eventually accrue the experience and expertise needed to deploy their own, homegrown space assets, securing a supply of many of the materials and services vital to modern and future economies and societies, a supply they themselves produce. While the economic pressure of the previous 10 years may have receded, which would normally encourage globalization, greater self-sufficiency in many keys areas of socioeconomic development would counterbalance this trend may further entrench *de*globalization, as the geographic differential of resources that first spurred globalization is now diminished, and supply and demand in key industries is located almost entirely within a spacefaring nation’s economic and political sphere.

In this new hybrid Imperial/Cold War-esque world, space, now a far larger and more developed and diversified sector and market, holds an even greater significance than it had in the original Cold War. While planning policy and military power projection, both of the original Cold War superpowers competed against each other in space, almost completely removed from any independent presence other than their own. This would not be the case in 2035: many medium sized economies would have recovered from the economic shock of 2025-2035 and can now have additional financing that could be allotted to establishing or further developing their space industry. As of 2024, there were over 70 countries with some kind of presence in space, compared to the mere dozen of the cold war (Union of Concerned Scientists, 2024). This is likely going to grow significantly, as design, launch and operation of space assets get cheaper and more flexible across the board. The renewed focus on outer space as a sphere of interstate competition would make it a very crowded operating environment, even before we consider new realms of space development. However, now the benefits of space-based resources and services could be distributed more broadly, building upon the benefits of more stable strategic input costs and more advanced renewable and digital transitions, potentially improving the fortunes of many living in developing countries. Some capabilities in particularly high tech and difficult to enter industries like pharmaceuticals or advanced computing may be completely unattainable for smaller economies and actors, which would still keep them reliant on other states to some degree, maintain atleast some conditions which generated a globally integrated economy

Additionally, the physical connections between earth and outer space, processing an ever-growing quantity of data and resources, will need to be expanded and improved. Existing spaceports on earth would be expanded and upgraded to handle a wide range of launch vehicles, from Air Launched orbiters and small rockets to the largest Starship variations. Ground relay centrals would also see a flurry of construction and upgrading in many remote, previously under-developed regions: small settlements in far northern or southern locations may rapidly expand around relay stations. This may contribute to the more equal distribution of wealth over geographic areas, incentivizing consumer spending, the supply for which likely comes from other earthbound economies, reintegrating, to some degree, the global economy.

4.1.3.5 The Moon and Beyond:

4.1.3.5.1 Advances in 3D Printing and Material Science

While launch costs to LEO and beyond have dramatically decreased over the last decade, and will likely continue to do so, it will still remain cost effective that any materials used to build off-world are also sourced off-world (NASA, 2023). The lower gravity and lack of atmosphere on many planets, Moons and asteroids in our immediately vicinity make harvesting materials for construction elsewhere beyond earth orbit viable. Additionally, if the techniques used to deploy these structures are based on three-dimensional (3D) printing, a technology already being employed to construct residences out of onside materials on earth, designs could be flexible and easy to modify (Wong and Hernandez, 2012). In a reduced gravity environment, structural demands are themselves reduced as well, which in turn reduces the complexity and thus cost and manufacture time of said structure. Of course, modifications would need to be made to the existing printers to account for reduced gravitation loads. However, if used in harmony with other styles of space habitat such as inflatable modules, future planners of outposts on the Moon and Plans would have greater flexibility to produce the optimal arrangement(s) of structures.

3D printing would likely be used for more than just mass-producing outpost structures: this function is rather quite recent even in 2024 on earth, with earlier applications of 3D printing showing greater use and promise in the swift production of custom, often complex parts (Gibson et al. 2015). It may be possible that many manned space crafts will carry 3D printers that can be easily programmed to create whatever any situation might require, an important capability to have in case of an emergency, as the crew of Apollo 13 could attest to.

4.1.3.6 The Extraterrestrials

Enabled with these advances, humanity had once again stepped foot on the Moon nearly 60 years after the first Moon landing, and began to establish a more permanent presence on both the lunar surface and in lunar orbit. Permanent Moon bases, varied in design and administration along the lines of national, international and private ventures, likely enabled by this advanced 3D printing technology, have begun to be erected on the surface or in lava tubes underground to protect from the intense solar radiation. Small crews of humans inhabit these cramped living spaces, and conduct Extra Habitat Activities (a potential new term, similar to EVA, to describe activities outside not a vehicle but rather the habitat) only when needed. Much of the work done on the lunar surface, such as habitat erection and mining of ice, mineral and He-3 deposits identified by remote sensing satellites constellations in orbit overhead, would be primarily executed by, or at least heavily assisted, by drones and robots. Servicing and repairing these tools would likely be among the chief reasons a human presence would be required on the Moon itself, as they would likely be self-operating and autonomous. Other crew members would likely be mainly dedicated to other important purposes, such as research, exploration, drone operation, coordination and communication.

4.1.3.6.1 Diversification of the Space Sector

Over the years, the crew would only grow in count and expertise as the functions of the Moonbase expanded and grew with increased usage. As the resource extraction industries expand their reach, the traffic passing through the orbiting space stations and the Moon has increased exponentially. They have become the first extraterrestrial spaceports, lived in and travelled by potentially hundreds of people of many nationalities, beliefs and expertise, ranging from private contractors to public administrators, mechanics, fab techs, researchers and more. Industries aside from minerals and semiconductors, while already early in their development in the 2020s and 30's, have become more solidly positioned beyond earth's confines. Pharmaceuticals, material research and manufacturing, and nutrition like agriculture/ aquaculture/hydroponics all begin to reach a point of sustained growth, occupying their own modules and habitats to support both the local extraterrestrial economy, and in the near future, the market on Earth.

Not only would their skills and work support a trans terrestrial economy, but they would also behave *as consumers*, supporting secondary services such as widespread infrastructure and public services, restaurants, housing, consumables and entertainment, generating additional revenue and opportunity. While still tethered, literally and figuratively, to the primary industries located at the Spaceports, these offerings would improve quality of life and provide a more inclusive environment for a new class of migrants, those working and living in space.

The built infrastructure and accrued experience of multiple, growing mature space industries has equipped humanity well to begin venturing beyond stations, Moons or asteroids for the sake of profit. Proceeding with the advancements of nearly half a decade of a permanent presence in space, Mars and Venus would be the likely next candidates for the colonization of space, but may actually see slower development than regions of space closer to home, despite the attention the former especially has historically garnered. Mars and Venus are not 0g environments and both have atmospheres, so many of the industries that thrived in orbit or on the Moon in the absence of these conditions may not be initially viable here. Water and mineral extraction would likely be the only large industry directly present on the surface, supported by an introductory constellation of broadband and sensing satellites, which would also allow for more complex research by the crew. Regardless, actors motivated on a truly long-term time span may seek to establish a direct human presence on these bodies early, accelerating the time frame of more widespread solar colonization and potentially even terraforming. Expect settlements to grow slowly at first, expanding as new innovations interact with these unique environments to generate new inputs, goods or services.

4.1.3.7 Historical Analysis

In the previous ten years, from 2025-2035, we would have observed the growth of strategic industries like semiconductors and resource extraction trigger a rush of space development as they became highly profitable tools of economic growth and geopolitical influence in an uncertain, deglobalizing world. Many factors in this sequence of events had a likeness to those that occurred during the early colonial period in the Spanish empire, which also featured a mineral rush sparking further exploration and investment in colonial opportunities. Other actors and colonial activities would follow in their wake, establishing their own interests in this previously pristine environment, the values and capabilities of the settlers and the nature of the geographies they found themselves in would interact to produce unique colonial administrations. As was discussed alongside the Spanish colonial system, the British system would also prove incredibly lucrative, yet for different reasons.

Diversity

While it did initially resemble an extractivist economy, British mercantilism extracted a more diverse range of resources. Its New England colonies provided timber for shipbuilding, as well as some of the drydocks themselves that helped enable British maritime expansion, as well as whale oil and cod that assisted development in rest of Britain's Atlantic peoples. A variety of cash crops and from the southern colonies, and spices and tea from India further diversified Britain's mercantile economy. These activities were also more integrated into increasingly global markets as well during the later colonial period, but were still largely exclusive within the British sphere of influence.

Britain encouraged diversification not just with resources but with the local economies of their colonies as well. Instead of simply exploiting the local population of indigenous people, or slaves brought in from Africa, the British were generally more likely to provide some degree of investment and development for the colonial population, or even just the freedom for them to try to do so themselves. Colonies would develop their own industries, providing additional revenue and opportunities not just for the crown but for themselves as well. So, by the time the British led Industrial Revolution, enabled by technological advances financed with colonial income, their mercantilist system already provided large markets to which to sell the glut of manufactured goods and further enrich London, often at the detriment of their subjects. Many port cities had developed primarily to service this exchange between London and its colonies, propelling them as centers of investment and development in their respective colony

Although not quite as regionalized as the world of the later colonial period, deglobalization has reached an uncertain position in terrestrial and extraterrestrial development. Multitudes of new actors have entered a mature space sector, each initially dependent on the services of another established actor, and eventually developing their own capabilities in space, increasing self-sufficiency and momentum towards deglobalization. Additional unforeseen but likely destabilizing events on earth may also build this momentum. However, in general the overall momentum towards deglobalization has slowed as the world generally becomes more stable and major costs of living, business and production have dropped dramatically due to space-based innovations and resources returning to earth, reducing many destabilizing pressures on international economies and political/social structures. It is difficult to isolate a specific aggregated trend to emerge from all scenarios above.

While not quite the direct parallel to the majority of colonial and mercantilist history, which included much more consolidation among fewer players, a few main players would likely still be well ahead of the fairly new actors that have entered the sector in the last 10 years. The leaders, like the European empires, would have achieved a massive economic and technological edge as a result of the extreme capital accrued by their colonial ventures. New transitions may emerge that they would have held the lead in from the start. Like the European empires and even some modern states, leading actors could potentially deny competitive resources or services that cannot be sourced with less development space assets, leading to yet more uncertainty regarding the integrity of a globally integrated economy or governance structure, if an effective one even exists.

The parallels between this future space ecosystem and the past circumstances of the Spanish and British mercantilist systems are more unclear than they were in the previous decade of rapid space development. As such, it would be difficult to draw concrete conclusions about any further potential parallels with the historical precedent.

5.1 Discussion

5.1.1 Major Findings

This thesis has explored the broader context of the histories of global trade, European colonialism, and the development of space exploration. A similar evaluation was conducted regarding contemporary circumstances, and the many parallels were drawn between the two and projected 20 years into the future of space development.

The main trends throughout history exhibited that the basic principles of trade such as comparative advantage, as well as the differential availability of important goods, resources or markets, incentivize global trade. When this trade is cut, demand goes unfulfilled and a new supply must be secured. This was exhibited both by the European response to ottoman restrictions on Asian trade, and by modern actors in response to increased risk of global trade near strategically important products or trade routes. This resulted in the start of European colonialism, which provided additional parallels to the story of the exploration and colonization of space.

Both processes featured an evolution of the nature of exploration and exploitation. Colonial exploration occurred over decades, via multiple voyages of discovery and colonization from a handful leading European states, much like the exploration and early development efforts of extraterrestrial environments, conducted primarily by just two post-imperial superpowers, the US and USSR. The exploration of space and development of necessary discoveries and innovations took even longer, building on a process spanning millennium.

As new actors enter these progressions, additional parallel dynamics are also observed. With the entry of the British in the colonial sphere, and their generally more versatile and diverse colonial system, focusing on more diverse resource use and local market development rather than the pure resource extraction of the Spanish, which had previously weakened the latter due to mismanagement. This system better enable the British to push their colonial advantage to 1. Trigger the industrial revolution, and 2. Further expand their maritime and colonial holdings and influence. In a comparable fashion, space leaders like the United States and increasingly China will be able to press their advantage in existing space capacity to initially capture much of the revenue generated by the growing space sector

There is the potential for overflow geopolitical conflict reaching space, but modern factors like the orbital debris issue prevent this.

Future development of the space sector, occurring in an increasingly deglobalizing world, will initially be driven largely by demand for minerals a strategic products like semi-conductors will follow a trajectory similar to that set by the mineral focused Spanish mercantile system. Why initially alleviating some deglobalizing pressures like energy and transport costs, the concentration of wealth and power will likely counteract this and main deglobalizing pressures.

In the following ten years, as the space sector becomes more diverse following the entry of dozens of new actors and industries, local economies on trade, production and research hubs in earth orbit and on the moon, begin to grow secondary economies, with the entire sector more closely resembling the British mercantile system. However, trends towards deglobalization reemerge as barriers to trade are lowered and consumer demand increases, resulting in an uncertain direction for an integrated economy.

Past this time frame, human efforts will likely begin to reach out to other nearly planets like the Moon and Venus, creating new economic and technical challenges in space colonization. The exact timeline and outcomes are difficult to predict this far into the future.

5.1.2 Limitations

I haven't covered the entire *breadth* of the entire space sector, nor have i gone incredibly deep with statistics about specific industries or actors, since this is both outside the realistic scope, as well as my own skills and abilities.

Some particular actors, both private or public, have not been named, as I don't want to get *too* political.

The analysis is being within a limited time frame, both in the scenario and in real life. The scenario only included two 10-year increments limits. This done to set a reasonable scope, that being the most important years of the transition based on timeframe of current transitions like Green and Digital.

I've planted a few of speculation, but I do not really look past 2045: 20 years is enough for massive geopolitical and socioeconomic shifts, as we've found out for ourselves through our own tumultuous little chapter of history.

The Portuguese and Dutch empires were not covered as these were trade empires: without people already in space to trade for desired goods prohibits the initial employment of trade-based systems of colonization and development.

5.1.3 Further research?

While this paper has covered, in moderate detail, some of the main economic and political aspects of the space transition with perspective and experience provided through historical precedent, a long list of highly relevant approaches and questions were unable to be explored in the scope of this master's thesis and should be considered for future study, or, if already covered, further consideration.

This list includes in no particular order, and is not limited to:

- A deeper dive into the potential socio-economic effects of the space transition on the greater public, more specifically focused on wealth distribution and the modes to influence it, such as well-defined and enforced regulations, taxes and subsidies

- The definition of a space environment, or lack thereof, as well as best practices to ensure an “environmentally” sustainable space transition

- The broader implications of a potentially quicker transition away from fossil fuels, accelerated by decreased prices of material inputs for the complete, renewable powered energy grid

- What is the passport of someone born on an international space base?

- Should private actors be required to answer to the authority of national or international governments? Will they ever become completely independent of national structures?

- Will entirely new cultures emerge as people from the entire world are in such close proximity?

- How much more irresponsible would the elite be if there was actually a Planet B?

5.1.3.1 Policy

Although covered very briefly throughout this thesis, policy and foresight will be *vital* for the establishment of a cooperative framework in space, would be imperative in, and committed, through binding resolutions and agreements between all space stakeholders, to ensuring the vast potential of the space transition is harnesses responsible, equitably and sustainably:

In confined and shared spaces, some research would be difficult to secure properly from potential espionage. Thus, station and orbit real estate would need to be preceded by more effective and well enforced intellectual property and property rights agreements that are agreed to by all actors to protect the credibility and mutual trust of all actors in space in order to maintain the mutual trust and accountability required to responsibility and efficiently develop the international space sector.

Space is regulated much like international waters. Thus, to tax and track revenues, international customs and tax laws would need to be more clearly defined regarding space ventures. Additionally, the adoption of global minimum income and capital gains taxes to ensure that the benefits of space development are harnessed by everyone. As earthbound industries shift or disappear entirely, political and economic instability can be mitigated by a proactively designed public structure for retraining the workforce unemployed by the transition.

This would need to be done before the wealthy get overwhelmingly so, potentially able to withstand many international consequences, as has been the case throughout history. Anti-monopoly laws would also need to be enforced to further prevent this.

As the nuclear test ban is occasionally tested, enforcement of arms control treaties must be renewed and taken seriously. Following this thread, anti-satellite weapons may need to be classified as WMD’s

Mutual assistance agreements may be the most cooperative agreement but we haven’t seen too many examples of it in practice: this has also been undermined by Russia withdrawal from the ISS. It may become a unifying arrangement again as national, international and private space stations proliferate.

6.1 Conclusion

In answer to the research question "What are some potential geopolitical and socioeconomic outcomes of the next 20+ years of the Space Transition, based on historical colonial precedent?", there are multiple conclusions that can be drawn from the historical precedent of colonialism and the status quo of the modern space sector and the broader context it operates in.

- The process of deglobalization has some similar driving factors and impacts as the development of the mercantilist system of many European colonial empires, among them external market instability, geopolitical tensions and broad socioeconomic impacts
- 2025-2035 would likely trend towards increase market and regional instability, trending towards deglobalization. This would be entrenched as Spanish-style space mining and semi-conductor manufacturing industries, and colonial structure among leading space actors, further promoting deglobalizing trends
- 2035-2045 may see some market impacts based on these shifts may also help reestablish a more integrated economy as barriers to trade are lowered and consumer demand increases. These results are made uncertain however, as barriers to entry have also lower for the space sector, allowing less capitalized actors to establish a presence in space, increasing self-suffiency and retreat from globalized structures.
    - A more diversified space sector in this period, now joined by a number of varied industries. The influx of people, and thus consumers, to space outposts promotes the creation of secondary economies
    - However, many energy and mineral based economies on earth have declined sharply, spurring greater instability and thus trends towards deglobalization.

These findings present a possibility of what might happen if things remain unchanged: it is an uncertain picture, which, if we want to live in a world made better by the space sector in the future, we must start accounting for this potential *now*. A deeper dive into specific socioeconomic aspects that were unable to be covered in this thesis is warranted.

7.1 REFERENCES

1. Dunn, R. (1972). Sugar and Slaves: The Rise of the Planter Class in the English West Indies, 1624-1713. University of North Carolina Press.

2. Eccles, W.J. (1990). France in America. Harper & Row.

3. (ACW), A. C. W. D. (2024, June 21). Houthi Red Sea attacks have global economic repercussions. https://arabcenterdc.org/resource/houthi-red-sea-attacks-have-global-economic-repercussions/

4. Robinson F, ed. The New Cambridge History of Islam. Cambridge University Press; 2010.

5. Acemoglu, D., & Robinson, J. A. (2012). Why Nations Fail: The Origins of Power, Prosperity, and Poverty. Crown Publishing Group.

6. Allen, R. C. (2009). The Industrial Revolution: A Very Short Introduction. Oxford University Press.

7. Allied Market Research. (2021). Satellite Communication Market by Component (Equipment and Services), Application (Voice Communication, Broadcasting, and Data Communication), and End-Use Industry (Maritime, Aerospace & Defense, Industrial, Government, Transportation & Logistics, Media, and Others): Global Opportunity Analysis and Industry

Forecast, 2020-2027. Retrieved from https://www.alliedmarketresearch.com/satellite-communication-market

8. Allison, G. (2017). Destined for War: Can America and China Escape Thucydides's Trap? Houghton Mifflin Harcourt.

9. American Enterprise Institute (AEI). (2022, January 23). Moore's Law Meet Musk's Law: The Underappreciated Story of SpaceX. American Enterprise Institute

10. American Society for Photogrammetry and Remote Sensing (ASPRS). (n.d.). What is Remote Sensing?. Retrieved from https://www.asprs.org/what-is-remote-sensing

11. Anderson, F. (2001). Crucible of War: The Seven Years' War and the Fate of Empire in British North America, 1754-1766. Vintage Books.

12. Baylis, J., Smith, S., & Owens, P. (Eds.). (2017). The Globalization of World Politics: An Introduction to International Relations (7th ed.). Oxford University Press.

13. Bergin, C. (2008, September 28). Space X's Falcon I launch success on fourth attempt - nasaspaceflight.com. Space X's Falcon I launch success on fourth attempt.

https://www.nasaspaceflight.com/2008/09/live-space-xs-falcon-i-to-make-fourth-attempt-for-success/

14. Broadberry, S., & O'Rourke, K. H. (Eds.). (2010). The Cambridge Economic History of Modern Europe: Volume 1, 1700-1870. Cambridge University Press.

15. Brown, K. (2002). Science and Empire: East Coast Fever in Rhodesia and the Transvaal. Cambridge University Press.

16. Burckhardt, J. (1990). The Civilization of the Renaissance in Italy. Penguin Classics.

17. Calla, P., Fries, D., Welch, C., & (2022). Mining in space could spur sustainable growth. Proceedings of the National Academy of Sciences, 119 (47), e2221345120. https://www.pnas.org/doi/10.1073/pnas.2221345120

18. Canny, N. (Ed.). (1998). The Oxford History of the British Empire: Volume I, The Origins of Empire. Oxford University Press.

19. Carlos J. Charotti & Nuno Palma & João Pereira dos Santos, 2022. "American Treasure and the Decline of Spain," Economics Discussion Paper Series 2201, Economics, The University of Manchester.

20. Carrasco, D. (2001). The Oxford encyclopedia of Mesoamerican cultures : the civilizations of Mexico and Central America. Oxford University Press.

21. Center on Budget and Policy Priorities. (2020). Tax loopholes and the federal budget deficit. https://www.cbpp.org/research/topics/federal-tax\

22. Charles E. Nowell; The Age of Reconnaissance, Discovery, Exploration, and Settlement, 1450-1650. Hispanic American Historical Review 1 August 1964; 44 (3): 402–404. doi: https://doi.org/10.1215/00182168-44.3.402

23. China National Space Administration (CNSA). (2024). Space Debris. CNSA

24. Citation: Grand View Research. (2023). Space Launch Services Market Size & Share Report, 2030 [1]. Retrieved fromhttps://www.grandviewresearch.com/industry-analysis/space-launch-services-market-report

25. Comparison of several satellite navigation system orbits - wikimedia ... (n.d.-a). https://upload.wikimedia.org/wikipedia/commons/b/b4/Comparison_satellite_navigation_orbits.svg

26. Cost of space launches to low Earth Orbit. Our World in Data. (2022). https://ourworldindata.org/grapher/cost-space-launches-low-earth-orbit

27. Council of the European Union. (2020). Space resilience: Enhancing the resilience of satellite services in the face of growing threats. Brussels: European Union.

28. Council of the European Union. (2024). EU restrictive measures in response to the war in Ukraine. https://www.consilium.europa.eu/en/policies/sanctions-against-russia/

29. Council on Foreign Relations. (2023, May 17). Why China-Taiwan relations are so tense. https://www.cfr.org/news-releases/us-must-do-more-deter-china-and-support-taiwan-urges-new-cfr-task-force-report

30. Derviş, K. (2017, February 22). The paradox of identity politics. Brookings.

31. DiMasi, J. A., Grabowski, H. G., & Hansen, R. W. (2016). Innovation in the pharmaceutical industry: New estimates of R&D costs. Journal of Health Economics, 47, 20-33. https://doi.org/10.1016/j.jhealeco.2016.01.012

32. DiPippo, G., & Reynolds, M. (n.d.-b). Sanctions in response to Russia’s invasion of Ukraine. CSIS. https://www.csis.org/analysis/sanctions-response-russias-invasion-ukraine

33. Drobniak, A., & Bloomington, M. M. I. U. B. (2022). (PDF) rare earth elements - a brief overview. Rare Earth Elements - A brief overview.

https://www.researchgate.net/publication/357602526_Rare_Earth_Elements_-_A_brief_overview

34. Dunn, R. S. (1981). New England Outpost: War and Society in Colonial Deerfield. W.W. Norton & Company.

35. Earl J. Hamilton, American Treasure and the Price Revolution in Spain, 1501-1650. Cambridge, MA: Harvard University Press, 1934. xii + 428 pp.

36. Elliott, J.H. (2006). Empires of the Atlantic World: Britain and Spain in America 1492-1830. Yale University Press.

37. Emirates Mars Mission. (2021). Emirates Mars Mission: Home. https://www.emiratesmarsmission.ae/

38. Encrenaz, T. (Ed.). (2002). Exploration of the Solar System by Infrared Remote Sensing. Cambridge University Press.

39. Environment, U. (n.d.). UN environment programme. UNEP. https://www.unep.org/

40. Euroconsult. (2023). Satellites to be Built by 2028 - World Market Survey. Retrieved from https://www.euroconsult-ec.com/

41. European Commission. (n.d.). Rare earth elements, permanent magnets, and motors. Internal Market, Industry, Entrepreneurship and SMEs. https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/rare-earth-elements-permanent-magnets-and-motors_en

42. European Space Agency (ESA). (1988). Telemetry, Tracking and Command (TT&C). ESA (.int)\United Nations Sustainable Development Solutions Network (SDSN). (2019, May 15). UN report: Nature's dangerous decline 'unprecedented'; Species extinction rates 'accelerating'.

https://www.theverge.com/2022/12/19/23516592/united-nations-biodiversity-conference-framework-protected-areas-30

43. European Space Agency (ESA). (2024) Space debris removal. ESA (.int).

44. Federation of American Scientists (FAS). (2024). Nuclear Triad. Retrieved from https://fas.org/issues/nuclear-weapons/status-world-nuclear-forces/nuclear-triad/

45. Ferguson, N. (2004). Empire: The Rise and Demise of the British World Order and the Lessons for Global Power. Basic Books.

46. Ferguson, N. (2008). The Ascent of Money: A Financial History of the World. Penguin Books.

47. Floud, R., & Johnson, P. (Eds.). (2004). The Cambridge Economic History of Modern Britain: Volume 1 - Industrialisation, 1700-1860. Cambridge University Press.

48. Floud, R., & McCloskey, D. (1981). The Economic History of Britain Since 1700: Volume 1: 1700-1860. Cambridge University Press.

49. Food and Agriculture Organization of the United Nations (FAO). (2023, June). Food Outlook: Biannual Report on Global Food Markets. https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1169716/

50. Freedom House. (2023, January 11). Fighting corruption is key to countering authoritarianism, and protecting human rights. https://freedomhouse.org/

51. From one, many: The race to develop commercial space stations and the markets for them by Jeff Foust (2023, March 1). Space News https://spacenews.com/does-nasas-support-for-commercial-space-stations-match-their-importance/

52. Funke, M., Schularick, M., & Trebesch, C. (2015). Going to extremes: Politics after financial crises, 1870-2014 (NBER Working Paper No. 21805). National Bureau of Economic Research. Retrieved from https://www.nber.org/papers/w21805

53. Gaddis, J. L. (2005). The Cold War: A New History. Penguin Books.

54. Galbraith, J. K. (2012). Inequality and Instability: A Study of the World Economy Just Before the Great Crisis. Oxford University Press.

55. Garnsey, P., & Saller, R. (1987). The Roman Empire: Economy, Society and Culture. University of California Press.

56. Gibson, I., Rosen, D. W., & Stucker, B. (2015). Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing. Springer.

57. Google. (n.d.). The Neolithic Revolution in the Near East. Google Books. https://books.google.at/books?hl=en&lr=&id=BLZbLtmEJ68C&oi=fnd&pg=PA3&dq=Simmons%2C%2BAlan%2BH.%2B2007%2BThe%2BNeolithic%2BRevolution%2Bin%2Bthe%2BNear%2BEast%3A%2BTransforming%2Bthe%2BHuman%2BLandscape.%2BUniversity%2Bof%2BArizona%2BPress%2C%2BTucson.&ots=mK8K0jUTT-&sig=6yHoWbDL_lPSqZJ9T9Xab-0n_FA&redir_esc=y#v=onepage&q&f=false

58. Grand View Research. (n.d.). Space launch services market size & share report, 2030. Space Launch Services Market Size & Share Report, 2030. https://www.grandviewresearch.com/industry-analysis/space-launch-services-market-

report#:~:text=The%20global%20space%20launch%20services,14.6%25%20from%202024%20to%202030.

59. Guillaume , D., O’Rourke, K., & Prados de La Escosura, L. (n.d.). Trade and Empire, 1700-1870. https://sciencespo.hal.science/hal-03459838/document

60. Harford, J. (1997). Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon. John Wiley & Sons.

61. Henry, J. (2008). The Scientific Revolution and the Origins of Modern Science. Palgrave Macmillan.

62. Hitch, C. J., & McKean, R. N. (1960). The Economics of Defense in the Nuclear Age. Harvard University Press.

63. Hobsbawm, E. (1962). The Age of Revolution: 1789-1848. Weidenfeld & Nicolson.

64. Hobsbawm, E. (1975). The Age of Capital: 1848-1875. Vintage Books.

65. Hobson, J. A. (1902). Imperialism: A Study. Allen and Unwin.

66. Howse, Derek. "The Sea Chart: An Historical Survey based on the Collections in the National Maritime Museum." McGraw-Hill, 1973.

67. Hyde-Price, A. (2009, January 29). European security in the twenty-first century: The challenge of multipolarity. Routledge & CRC Press. https://www.routledge.com/European-Security-in-the-Twenty-First-Century-The-Challenge-of-Multipolarity/Hyde-Price/p/book/9780415545075

68. Hyperspectral cameras. Konica Minolta Sensing. (2021, October 8). https://sensing.konicaminolta.us/us/technologies/hyperspectral-

cameras/#:~:text=A%20hyperspectral%20camera%20can%20scan,each%20material%20interacts%20with%20light.

69. ICBM timeline - air force museum. (n.d.-a). https://www.nationalmuseum.af.mil/Portals/7/documents/other/af_space_command_icbm50th.pdf

70. Indian Space Research Organisation (ISRO). (n.d.). Aryabhata and INSAT-1A. ISRO (.gov.in). [एन. एस. रा. ओ. अंतरिक्ष भवन (isro.gov.in)]

71. Intergovernmental Panel on Climate Change (IPCC). (2022). Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller (eds.)]. Cambridge University Press.

72. International Astronautical Federation (IAF). (n.d.). Space Launch Statistics: Cold War Era. Retrieved July 1, 2024, from https://www.iafastro.org/

73. International Energy Agency (IEA). (2023). World Nuclear Outlook. https://www.iea.org/energy-system/electricity/nuclear-power

74. INTERNATIONAL FEDERATION OF PHARMACEUTICAL MANUFACTURERS & ASSOCIATIONS. (2022). The pharmaceutical industry and global ... THE

PHARMACEUTICAL INDUSTRY AND GLOBAL HEALTH. https://www.ifpma.org/wp-content/uploads/2023/01/i2023_IFPMA-Facts-And-Figures-2022.pdf

75. ISRO. (2023). Chandrayaan-3. https://www.isro.gov.in/Chandrayaan3.html

76. Jackson, R.H. (1962). The Encomenderos of New Spain, 1521-1555. University of Texas Press.

77. Kagan, R.L., & Parker, G. (Eds.). (1995). Spain, Europe and the Atlantic World: Essays in Honour of John H. Elliott. Cambridge University Press.

78. Kegley, C. W., Jr. (1992). The Peace Dividend: Progress and Prospects. St. Martin's Press.

79. Kennedy, P. (1987). The Rise and Fall of the Great Powers: Economic Change and Military Conflict from 1500 to 2000. Random House.

80. Kifleswing. (2024, March 20). Intel awarded up to $8.5 billion in Chips Act grants, with billions more in loans available. CNBC. https://www.cnbc.com/2024/03/20/intel-awarded-up-to-8point5-billion-from-chips-act-with-loans-

available.html#:~:text=A%20key%20motivation%20behind%20the,Ohio%2C%20New%20Mexico%20and%20Oregon.

81. King, D. A. (1993). Astronomy in the service of Islam. Variorum.

82. Kroenig, M. (2020). The Return of Great Power Rivalry: Democracy versus Autocracy from the Ancient World to the U.S. and China. Oxford University Press.

83. Krugman, P., & Obstfeld, M. (year of publication). International Trade: Theory and Policy, Krugman, P., & Obstfeld, M. (2018). International Trade: Theory and Policy (11th ed.). Pearson.

84. Kuhn, T. S. (1962). The Structure of Scientific Revolutions. University of Chicago Press.

85. Lach, D. F. (1942). China and the Era of the Enlightenment. The Journal of Modern History, 14(2), 209–223. http://www.jstor.org/stable/1871252

86. Land, J., & Eloranta, J. (2011). Hollow Victory? Britain's Public Debt and the Seven Years' War. Essays in Economic and Business History, 29(1), 101-118. https://www.ebhsoc.org/journal/index.php/ebhs/article/view/215

87. Landes, D. S. (1983). Revolution in Time: Clocks and the Making of the Modern World. Harvard University Press. https://doi.org/10.4159/harvard.9780674283030

88. Landes, D. S. (1998). The Wealth and Poverty of Nations: Why Some Are So Rich and Some So Poor. W. W. Norton & Company.

89. Langager, C. (2023). Industry vs. sector: What's the difference? Investopedia. https://www.investopedia.com/ask/answers/05/industrysector.asp#:~:text=Industry%20refers%20to%20a%20group,and%20is%20larger%20in%20comparison.

90. Lapping, B. (1985). The end of empire: Africa in the twentieth century. Verso.

91. Launius, R. D. (2003). To Reach the High Frontier: A History of U.S. Launch Vehicles. University of Kentucky Press.

92. ltd, R. and M. (2024, May). GMO crops and seeds - global strategic business report. Research and Markets - Market Research Reports - Welcome. https://www.researchandmarkets.com/reports/5141331/gmo-crops-and-seeds-global-strategic-business

93. Mackey, A. (2024, April 24). Survival of the fittest: Saturation in the space launch industry. SpaceWorks Enterprises, Inc. https://www.spaceworks.aero/survival-of-the-fittest_launch_industry/

94. Maltby, W. S. (2009). The rise and fall of the Spanish empire / William Maltby. Palgrave Macmillan.

95. Mankiw, N. G. (2016). Principles of microeconomics (8th ed.). CENGAGE Learning Custom Publishing.

96. Mankiw, N. G. (2018). Principles of Economics. Cengage.

97. Mann, C.C. (2011). 1493: Uncovering the New World Columbus Created. Vintage Books.

98. MarketsandMarkets. (2023). Artificial intelligence market by offering (hardware, software, services), technology (machine learning, natural language processing, computer vision, context-aware computing), deployment mode, organization size, business function, vertical and region - Global forecast to 2027. Retrieved from MarketsandMarkets

99. MarketsandMarkets. (2023). Drone market by solution (platform, software, infrastructure, service), platform type (civil & commercial, military, consumer, government & law enforcement), application, operation mode, MTOW, region - Global forecast to 2026. Retrieved from MarketsandMarkets

100. MarketsandMarkets. (2023, May). Satellite Ground Station market size, share, industry report, Revenue Trends and growth drivers 2028. MarketsandMarkets.

https://www.marketsandmarkets.com/Market-Reports/satellite-ground-station-market-98562261.html

101. Mathias, P., & Postan, M.M. (Eds.). (1978). The Cambridge Economic History of Europe: Volume 7, The Industrial Economies: Capital, Labour, and Enterprise. Cambridge University Press.

102. Metropolitan Museum of Art. (n.d.). Islamic astrolabes. The Met. Retrieved July 3, 2024, from https://www.metmuseum.org/toah/hd/astro/hd_astro.htm

103. Milberg, W., & Winkler, D. (2013). Outsourcing Economics: Global Value Chains in Capitalist Development. Cambridge University Press.

104. NASA. (2023). Ares. NASA. https://orbitaldebris.jsc.nasa.gov/modeling/legend.html

105. NASA. (2023). Ares. NASA. https://orbitaldebris.jsc.nasa.gov/modeling/legend.html

106. NASA. (n.d.). Benefits for humanity. Retrieved July 1, 2024, from https://www.nasa.gov/international-space-station/space-station-research-and-technology/benefits-for-humanity/

107. NASA. (n.d.). Hubble Space Telescope - NASA Science. NASA Hubblesite. https://science.nasa.gov/mission/hubble/

108. NASA. (n.d.). Optical mining of asteroids, moons, and planets to enable sustainable human

exploration and space industrialization. Retrieved from https://www.nasa.gov/feature/optical-mining-of-asteroids-moons-and-planets

109. NASA. (n.d.). Space exploration: A new frontier for economic opportunity. Retrieved from https://www.nasa.gov/sites/default/files/atoms/files/space_exploration_2023.pdf

110. NASASpaceFlight.com. (2024). ULA's penultimate Delta IV Heavy launches NROL-68 mission. Retrieved from https://www.nasaspaceflight.com

111. National Academies of Sciences, Engineering, and Medicine. 2017. Human Genome Editing: Science, Ethics, and Governance. Washington, DC: The National Academies Press. https://doi.org/10.17226/24623.

112. National Aeronautics and Space Administration (NASA). (2023, June 15). In-Situ Resource Utilization (ISRU). NASA (.gov)

113. National Aeronautics and Space Administration (NASA). (n.d.). Challenger Disaster. Retrieved from NASA Challenger

114. National Aeronautics and Space Administration (NASA). (n.d.). Early Satellites: Challenges and Achievements. Retrieved from https://history.nasa.gov/sputnik/

115. National air and Space Museum. (2023, March 31). Project Paperclip and American rocketry after

World War II. Homepage. https://airandspace.si.edu/stories/editorial/project-paperclip-and-american-rocketry-after-world-war-ii

116. Nati
onal Reconnaissance Office. (2023). CORONA: America's First Satellite Program. Retrieved from https://www.nro.gov/About-NRO/History/Corona/

117. O'R
ourke, K. H., & Williamson, J. G. (1999). Globalization and History: The Evolution of a Nineteenth-Century Atlantic Economy. Publisher.

118. Offi
ce of the Secretary of Defense. (2010). Nuclear Posture Review Report. U.S. Department of Defense.

119. One
Web. (2023). OneWeb Constellation Expansion Plans. OneWeb News. Retrieved from https://www.oneweb.com/news

120. Org
anisation for Economic Co-operation and Development (OECD). (2023, March). Global Value Chains in a Time of Crisis

121. Pers
on. (2024, June 24). What is overpopulation? causes, effects, and solutions. Population Media Center. https://www.populationmedia.org/the-latest/overpopulation-cause-and-effect

122. Peru
n. (2024, June 9). The New Space Race, spacex & starship - satellite constellations & launcher evolution. YouTube. https://youtu.be/effFp6AnCWo?si=5IxjXcQgGEvuB-f7

123. Phil
ippon, T. (2019). The Great Reversal: How America Gave Up on Free Markets. Belknap Press.

124. Plenary Speech by IMF First Managing Deputy Director Gita Gopinath 20th World Congress of the International Economic Association Colombia. (2023, December 11). Cold War II? preserving economic cooperation amid geoeconomic fragmentation. IMF. https://www.imf.org/en/News/Articles/2023/12/11/sp121123-cold-war-ii-preserving-economic-cooperation-amid-geoeconomic-fragmentation#:~:text=This%20%E2%80%9CCold%20War%E2%80%9D%20period%2C,countries%20in%20the%20Western%20bloc.

125. Polaris Market Research, https://www. polarismarketresearch. com/. (2023, March). Space launch services market size & share global analysis report, 2022-2030. Polaris. https://www.polarismarketresearch.com/industry-analysis/space-launch-services-market

126. Pomeranz, K. (2001). The Great Divergence: China, Europe, and the Making of the Modern World Economy. Princeton University Press.

127. Pomeranz, K., & Topik, S. (2017). The World That Trade Created (4th ed.). Taylor and Francis. Retrieved from https://www.perlego.com/book/2193161/the-world-that-trade-created-

society-culture-and-the-world-economy-1400-to-the-present-pdf (Original work published 2017)

128. Pugel, Thomas A, and Peter H Lindert. International Economics / Thomas A. Pugel, Peter H. Lindert. 11th ed. Boston: McGraw-Hill, 2000. Print.

129. Ravenhill, J. (2005). Global political economy. Oxford University Press.

130. Reinhart, C. M., & Rogoff, K. S. (2009). This Time Is Different: Eight Centuries of Financial Folly. Princeton University Press.

131. Ricardo, D. (1817). On the Principles of Political Economy and Taxation. London: John Murray

132. Rich, E.E., & Wilson, C.H. (Eds.). (1967). The Cambridge Economic History of Europe: Volume 4, The Economy of Expanding Europe in the Sixteenth and Seventeenth Centuries. Cambridge University Press.

133. Rich, E.E., & Wilson, C.H. (Eds.). (1967). The Cambridge Economic History of Europe: Volume 4, The Economy of Expanding Europe in the Sixteenth and Seventeenth Centuries. Cambridge University Press.

134. Roberts, T. G. (2022, September 1). Cost for space launch to low Earth Orbit- Aerospace Security Project. Aerospace Security. https://aerospace.csis.org/data/space-launch-to-low-earth-orbit-how-much-does-it-cost/

135. Robinson-Smith, W., & Clark, S. (2024, March 30). Eutelsat Mission Marks first of Double Falcon 9 launch day for spacex. Spaceflight Now.

https://spaceflightnow.com/2024/03/30/live-coverage-spacex-to-launch-eutelsat-satellite-on-a-falcon-9-rocket-from-the-kennedy-space-center/

136. Satellite Industry Association (SIA). (2022). State of the Satellite Industry Report. Retrieved from https://www.sia.org/

137. scheme=AGLSTERMS.AglsAgent; corporateName=CSIRO Australia Telescope National Facility; address=PO Box 76 Epping NSW 1710 Australia; contact=+61 2 9372 4100 (phone),+61 2 9372 4310 (fax); jurisdiction=Commonwealth. (2024, March 6). Atmospheric effects. Atmospheric Effects. https://www.atnf.csiro.au/outreach/education/senior/astrophysics/atmosphere.html

138. Selding, P. B. de. (2023, January 23). SpaceX's reusable Falcon 9: What are the real cost savings for customers? SpaceNews. https://spacenews.com/spacexs-reusable-falcon-9-what-are-the-real-cost-savings-for-customers/

139. Semiconductor Industry Association. (2024). CHIPS for America Act & FABS Act. https://www.semiconductors.org/

140. Sharma, R. (2018). How spacex transformed space exploration. Investopedia. https://www.investopedia.com/news/how-spacex-reinvented-rocket-launch-industry/

141. Skidmore, M., & Toya, H. (2002). Do Natural Disasters Promote Long-Run Growth? Economic Inquiry, 40(4), 664-687.

142. Space Foundation. (2023). 2023 Annual Report. Retrieved from

https://www.spacefoundation.org/wp-content/uploads/2024/03/SpaceFoundation_2023-Annual-Final-Web.pdf

143. SpaceX. (2021). How Starlink Funds Our Ambitions. SpaceX News. Retrieved from https://www.spacex.com/news

144. Stanley, M. (2019, May 23). The man who made einstein world-famous. BBC News. https://www.bbc.com/news/science-environment-48369980

145. Stearns, P. N. (2019). The Industrial Revolution in World History. Westview Press.

146. Stiglitz, J. E. (2002). Globalization and Its Discontents. W. W. Norton & Company.

147. Stiglitz, J. E. (2010). Freefall: America, free markets, and the sinking of the world economy. W. W. Norton & Company.

148. Stockholm International Peace Research Institute. (2023). SIPRI Military Expenditure Database. Retrieved from https://www.sipri.org/databases/milex

149. Strandh, S. (2000). A History of the Machine. Grennwood Press.

150. Strathern, P. (2003). The Medici: Power, Money, and Ambition in the Italian Renaissance. Pegasus Books

151. Taylor, A. (2001). American Colonies: The Settling of North America. Penguin Books.

152. Tek elec Communications, Inc. (2023, May 10). Types of Satellites [Blog post]. EOS. https://eos.com/blog/types-of-satellites/

153. The genetics of cancer. NCI. (2022). https://www.cancer.gov/about-cancer/causes-prevention/genetics

154. The global impact of 9/11: Twenty Years on. Wilson Center. (n.d.). https://www.wilsoncenter.org/event/global-impact-911-twenty-years

155. Tur ner, J. (2005). Spice: The History of a Temptation. Vintage.

156. Ty mieniecka, A.-T. (Ed.). (2011). Astronomy and civilization in the new enlightenment: Passions of the skies. Springer

157. U.S. Government Accountability Office. (2020). NASA Commercial Crew Program: Significant

work remains to begin operational missions to the space station. Retrieved from https://www.gao.gov/assets/gao-20-121.pdf

158. U.S. Space Force. (2022). GPS Constellation Status. Retrieved July 1, 2024, from https://www.spaceforce.mil/

159. UNESCO. (2024). About the Silk Roads. About the Silk Roads | Silk Roads Programme. https://en.unesco.org/silkroad/about-silk-roads

160. Union of Concerned Scientists (UCS). (2024). UCS Satellite Database. Retrieved from https://www.ucsusa.org/resources/satellite-database

161. Union of Concerned Scientists. (n.d.). Anti-Satellite (ASAT) Weapons. https://www.ucsusa.org/resources/space-security

162. United Nations Conference on Trade and Development (UNCTAD). (2022, July 26). Global South pays more to service its debt than it receives in development aid.

163. United Nations Office for Outer Space Affairs (UNOOSA). (n.d.). Report on the role of the private sector in the exploration, utilization and development of space. Retrieved from https://www.unoosa.org/documents/pdf/spacelaw/treatystatus/AC105_C1_2023_CRP12E.pdf

164. United Nations. (n.d.). Lack of grain exports driving global hunger to famine levels, as war in

Ukraine continues, speakers warn Security Council | Meetings Coverage and press releases. United Nations. https://press.un.org/en/2022/sc14894.doc.htm

165. Unit
ed States Air Force. (1990). The USAF Scientific Advisory Board: Its First Twenty Years, 1944-1964. Office of Air Force History.

166. Unit
ed States Geological Survey (USGS). (2023). Landsat Missions. Retrieved from https://www.usgs.gov/landsat-missions

167. Vek
asi, K. (2023). Securing Supply Chain Resiliency for Critical Rare Earth Metals. In:

Kalantzakos, S. (eds) Critical Minerals, the Climate Crisis and the Tech Imperium. Archimedes, vol 65. Springer, Cham. https://doi.org/10.1007/978-3-031-25577-9_3

168. visi
onofhumanity.org. (2024, June 12). Global peace index map " The most & least peaceful countries. Vision of Humanity. https://www.visionofhumanity.org/maps/#/

169. Wh
en did growth begin? new estimates of productivity ... (n.d.). https://eml.berkeley.edu/~enakamura/papers/malthus.pdf

170. Whi
te, H. (2012). The China Choice: Why America Should Share Power. Oxford University Press.

171. Wo
ng, K. V., & Hernandez, A. (2012). A review of additive manufacturing. ISRN Mechanical Engineering, 2012

172. Wor
ld Semiconductor Trade Statistics (WSTS). (2023). World Semiconductor Trade Statistics. https://www.wsts.org/

173. Wor
ld Trade Organization. (2020). Trade Policy Review: China. https://www.wto.org/english/tratop_e/tpr_e/tp515_e.htm

174. Ó
Gráda, C. (2018). The Atlantic Economy: Britain, the US and Ireland. Cambridge University Press.